# Appendix ES-1 Spelling of Hawaiian Names

| Place name | Hawaiian spelling |
|---|---|
| | |
| Aiea | ‘Aiea |
| Aihualama | ‘Aihualama |
| Aimuu | Aimuu |
| Alaiheihe | Alaiheihe |
| Alau | Alau |
| Ekahanui | ‘Ēkahanui |
| Halawa | Hālawa |
| Haleauau | Hale‘au‘au |
| Halona | Hālona |
| Hawaii | Hawai‘i |
| Hawaii loa | Hawai‘iloa |
| Helemano/Halemano | Helemano/Halemano |
| Honolulu | Honolulu |
| Honouliuli | Honouliuli |
| Huliwai | Huliwai |
| Kaaikukai | Ka‘aikūka‘i |
| Kaala | Ka‘ala |
| Kaawa | Ka‘awa |
| Kaena | Ka‘ena |
| Kahaluu | Kahalu‘u |
| Kahana | Kahana |
| Kahanahaiki | Kahanahāiki |
| Kaimuhole | Kaimuhole |
| Kaipapau | Kaipāpa‘u |
| Kaiwikoele | Kaiwikō‘ele |
| Kalauao | Kalauao |
| Kaleleliki | Kaleleiki |
| Kalena | Kalena |
| Kaluaa | Kalua‘ā |
| Kaluakauila | Kaluakauila |
| Kaluanui | Kaluanui |
| Kamaileunu | Kamaile‘unu |
| Kamaili | Kamā‘ili |
| Kamananui | Kamananui |
| Kapakahi | Kapakahi |
| Kapuna | Kapuna |
| Kauai | Kaua‘i |
| Kauhiuhi | Kauhiuhi |
| Kaukonahua | Kaukonahua |
| Kaumoku Nui | Kaumoku Nui |
| Kaunala | Kaunala |
| Kawaihapai | Kawaihāpai |
| Kawaiiki | Kawaiiki |
| Kawailoa | Kawailoa |
| Kawainui | Kawainui |
| Kawaipapa | Kawaipapa |
| Kawaiu | Kawaiū |

| | |
|---|---|
| Keaau | Kea‘au |
| Kealia | Keālia |
| Keawapilau | Keawapilau |
| Keawaula | Keawa‘ula |
| Kihakapu | Kihakapu |
| Kipapa | Kīpapa |
| Koiahi | Ko‘iahi |
| Koloa | Koloa |
| Konahuanui | Kōnāhuanui |
| Koolau | Ko‘olau |
| Kuaokala | Kuaokalā |
| Laie | Lā‘ie |
| Lanai | Lāna‘i |
| Lualualei | Lualualei |
| Lulumahu | Lulumahu |
| Maakua | Ma‘akua |
| Makaha | Mākaha |
| Makaleha | Makaleha |
| Makaua | Makaua |
| Makua | Mākua |
| Malaekahana | Mālaekahana |
| Manana | Mānana |
| Manini | Manini |
| Manoa | Mānoa |
| Manuka | Manukā |
| Manuwai | Manuwai |
| Maui | Maui |
| Maunauna | Maunauna |
| Maunawili | Maunawili |
| Mikilua | Mikilua |
| Moanalua | Moanalua |
| Mohiakea | Mohiākea |
| Mokuleia | Mokulei‘a |
| Molokai | Moloka‘i |
| Nanakuli | Nānākuli |
| Niu | Niu |
| Nuuanu | Nu‘uanu |
| Oahu | O‘ahu |
| Ohiaai | ‘Ōhi‘a‘ai |
| Ohikilolo | ‘Ōhikilolo |
| Oio | ‘Ō‘io |
| Opaeula | ‘Ōpae‘ula |
| Paalaa Uka | Pa‘ala‘a Uka |
| Pahipahialua | Pahipahi‘ālua |
| Pahoa | Pāhoa |
| Pahole | Pahole |
| Palawai | Pālāwai |
| Palehua | Pālehua |
| Palikea | Palikea |
| Papali | Papali |
| Peahinaia | Pe‘ahināi‘a |
| Pohakea | Pōhākea |
| Puaakanoa | Puaakanoa* |
| Pualii | Puali‘i |

| | |
|---|---|
| Puhawai | Pūhāwai |
| Pukele | Pūkele |
| Pulee | Pule‘ē |
| Punapohaku | Punapōhaku |
| Puu Hapapa | Pu‘u Hāpapa |
| Puu Kailio | Pu‘u Ka‘īlio |
| Puu Kanehoa | Pu‘u Kānehoa |
| Puu Kaua | Pu‘u Kaua |
| Puu Kawiwi | Pu‘u Kawiwi |
| Puu Kumakalii | Pu‘u Kūmakali‘i |
| Puu Pane | Pu‘u Pane |
| Puuhapapa | Pu‘u Hāpapa |
| Puukaaumakua | Pu‘u Ka‘aumakua |
| Puukailio | Pu‘u Ka‘īlio |
| Puukainapuaa | Pu‘u Ka‘inapua‘a |
| Puukanehoa | Pu‘u Kānehoa |
| Puukaua | Pu‘u Kaua |
| Puukawiwi | Pu‘u Kawiwi |
| Puukeahiakahoe | Pu‘u Keahiakahoe |
| Puukumakalii | Pu‘u Kūmakali‘i |
| Puulu | Pū‘ulu |
| Puuokona | Pu‘u o Kona |
| Puupane | Pu‘u Pane |
| Waahila | Wa‘ahila |
| Wahiawa | Wahiawā |
| Waialae Nui | Wai‘alae Nui |
| Waialua | Waialua |
| Waianae Kai | Wai‘anae Kai |
| Waiawa | Waiawa |
| Waieli | Wai‘eli |
| Waihee | Waihe‘e |
| Waikane | Waikāne |
| Wailupe | Wailupe |
| Waimalu | Waimalu |
| Waimano | Waimano |
| Waimea | Waimea |
| Waimea | Waimea |
| Wiliwilinui | Wiliwilinui |

*Diacriticals unknown

# Tutorial: Operating the OANRP Database

## Overview

The Oahu Army Natural Resources Program Database (OANRP Database) is a multi-level database, coordinating diverse data from rare plant observations, reintroductions, rare snail monitoring, plant nursery propagation, and weed/ungulate management. The database files are developed with Microsoft Access. It is recommended that Access software versions 2007-2016 be used.

The database allows the Army staff to know which plant individual has been collected, matured, or died thus providing a better understanding of the genetic diversity that remains for any given rare species that the Army must manage. Using this database, the Army maintains consistent tracking and reporting for its managed rare species.

The OANRP Database is based upon the criteria established by the Hawaii Rare Plant Restoration Group (HRPRG). As part of the Makua and Oahu Implementation Plans, the Army Propagation database has been an 19 year effort in developing and coordinating the collection, propagation, management, and tracking of rare species.

The following appendix will briefly cover the database requirements and database procedures. Only important search criteria will be discussed. Most data fields are self-explanatory. This tutorial will be a guide to the database reports presented in previous OANRP status updates.

Several database reports may take a several minutes to compile within the database, thus pdf versions of the three major database reports (Population Unit Status, Threat Control Summary, and Genetic Storage Summary) have been created and may be found in the database reports subdirectory. Therefore, running the database may not be necessary unless more information is needed beyond the pdf version of the reports provided. Data provided is as of June 30, 2018.

Modification to the data and/or structure of the database is prohibited. The database version provided is read-only. It is intended for Implementation Team and collaborating agencies only. Distribution of the database structure and/or data is prohibited without the consent by the Oahu Army Natural Resources Program.

Questions may be directed to:
Roy Kam
Natural Resources Database Programmer Specialist
Oahu Army Natural Resources Program
Email: rkam@hawaii.edu

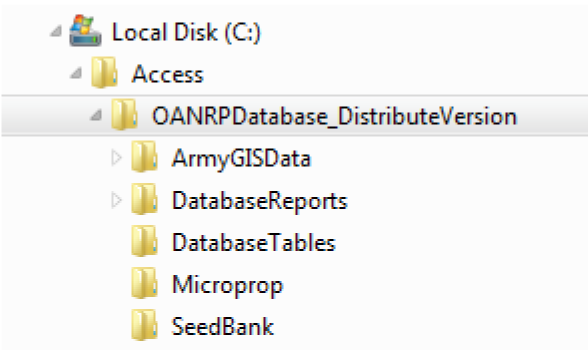
Linda Koch
Natural Resources GIS Specialist
Oahu Army Natural Resources Program
Email: lkoch@hawaii.edu

# I. <u>Database Settings</u>

## Setting Database Directories and Security Warning

### Database directories

The database must be placed under the following directories. Copy the following directories and data files from the data disc to the C: drive. Database path and GIS files must be within the following directories. All subdirectories should be under **C:**




Descriptions of the files within each subdirectory are as follows under C:\Access\OANRPDatabase_DistributeVersion:

OANRPDatabase_DV.accdb

> Front-End database file what most database users see, the database file manages the data forms, queries and reports. Data used in the OANRP Database is kept in the back-end data file (OANRPDataTables_DV.accdb) located in the database tables subdirectory. Forms are locked and may only be used for viewing purposes.

C:\Access\OANRPDatabase_DistributeVersion\ArmyGISData\

> GIS shapefiles depicting the rare plant sites, managed areas, and fence lines.

C:\Access\OANRPDatabase_DistributeVersion\DatabaseTables\OANRPDataTables_DV.accdb

> Back-End database file containing data for the Front-End database file.

C:\Access\OANRPDatabase_DistributeVersion \Microprop\Microprop.accdb

> Lyon Arboretum Micropropagation Database. Contact Nellie Sugii for more information.

C:\Access\OANRPDatabase_DistributeVersion \SeedBank\SeedBankDataTables\SeedBankDataTables.accdb

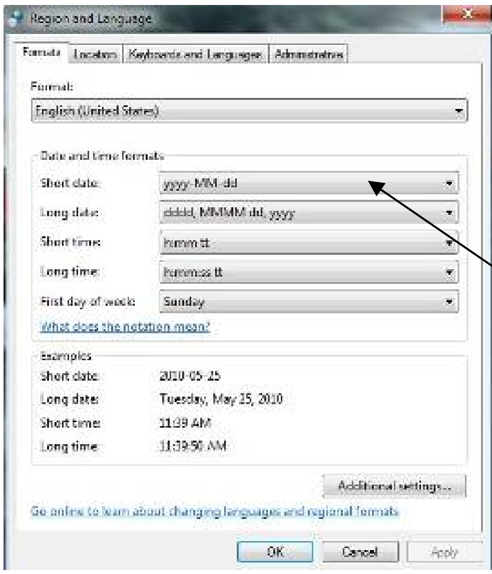
> Army SeedLab Database data. Contact Tim Chambers for more information.

C:\Access\ OANRPDatabase_DistributeVersion \DatabaseReports

> Population Unit Status, Threat Control Summary, and Genetic Storage Summary PDF reports for each IP taxa.

## Setting Default Date Format

The default date format for most computers is normally set to mm/dd/yy. The format can be confusing and not sort properly for Access database records. Although, not required, the date format for computers using this Access database should be changed to yyyy-mm-dd. Examples assume you are using Windows 10.



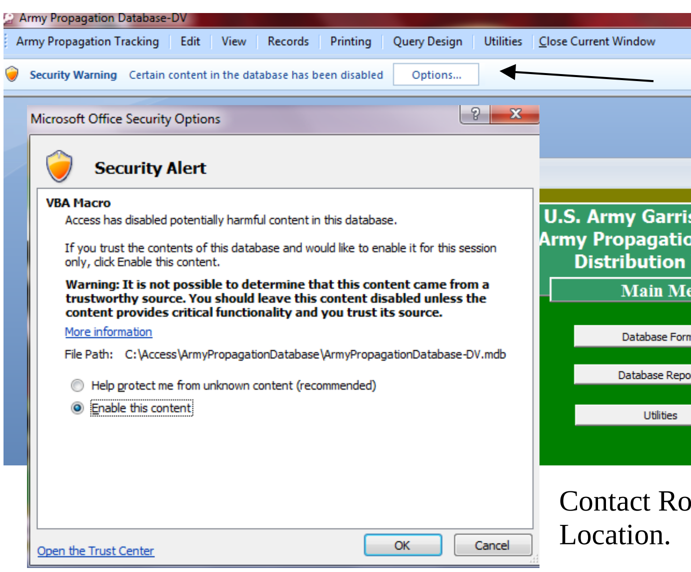

- Open Regional and Language Options by RIGHT clicking the **Start** button, clicking **Control Panel**, clicking **Clock, Language, and Region**, and then clicking **Region.** Under the Formats, change the **Short Date** to **yyyy-MM-dd.**

Change to yyyy-MM-dd

## Security Warning

Security features in Microsoft Access 2007, 2010, 2013, and 2016 automatically disables any executable content. The Access database with customized, buttons, commands, etc. will have a warning and not work unless the following is set within your computer.

To help you manage how executable content behaves on your computer, Office Access 2007-2016 database content must be enabled when the Security Warning appears.




After opening the OANRPDatabase_DV.accdb file in Microsoft Access, click on Options when it appears at the top of your screen.

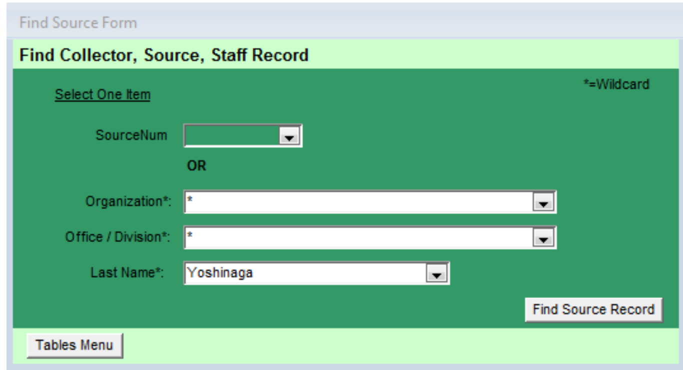
A window stating Security Alert will appear. Click on the button to select Enable this content, and click OK. Enabling the content will allow the database functions to operate.

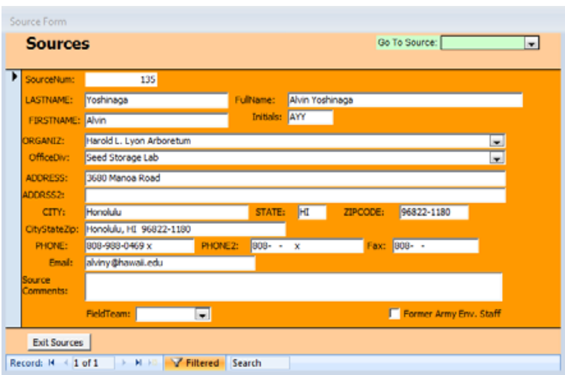
Enabling content will have to be done every time the database file is opened. You may avoid having this Security Warning appear if the Access subdirectory is added to the Trust Center Locations. Contact Roy Kam if you need to establish a Trust Center Location.

## Data Search Methods

Most data form and report sections start with a Find Form. These Find Forms have drop downs that allow you to find an existing record. In the adjacent example, locating the Sources record for Alvin Yoshinaga.

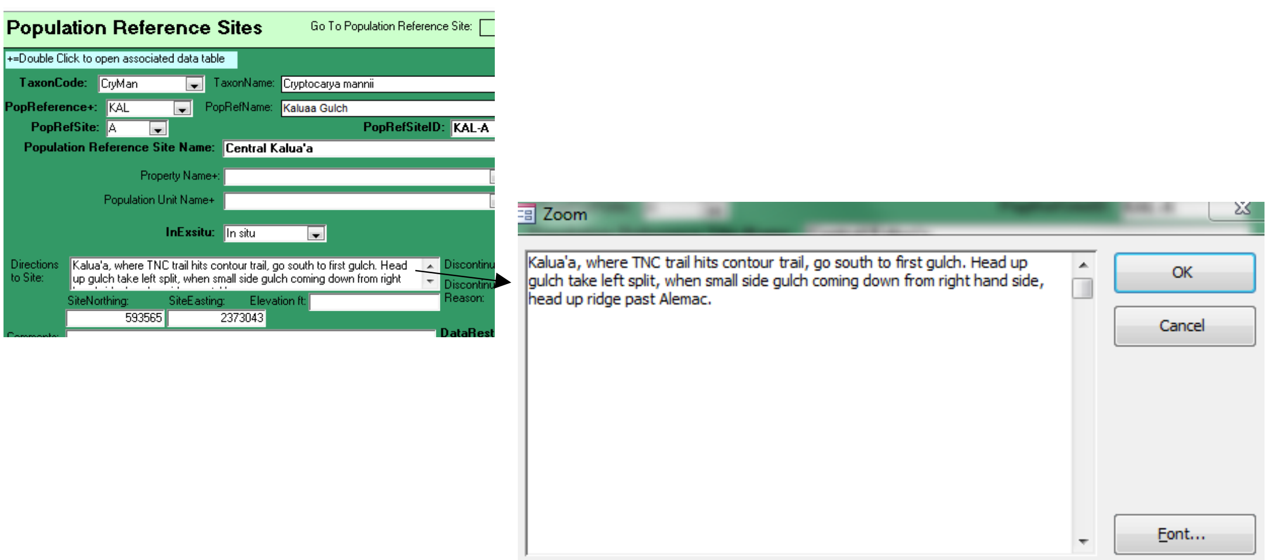
Using the * (asterisk), in a Find Form represents a wild card. Such as Organization *= Search for all Sources with any Organization. In this case, we will just search for the Last Name = Yoshinaga.




On the bottom of each Data entry form (such as the Sources Form), there are a set of Navigation buttons. These buttons allow you to go to the previous or next record. Pressing the tab or enter keys moves from one data field to another.

**Short cuts**: *Shift + F2* in any text field (within a data entry form or datasheet) will bring up the Zoom window. The Zoom window will allow you to view the complete text entered in that data field. See example below.



## II. Main Menu


Open the **OARNPDatabase_DV.accdb** either by double clicking the file, creating a shortcut on your desktop, or by opening MS Access and opening the file. The database will open to the Main Menu.

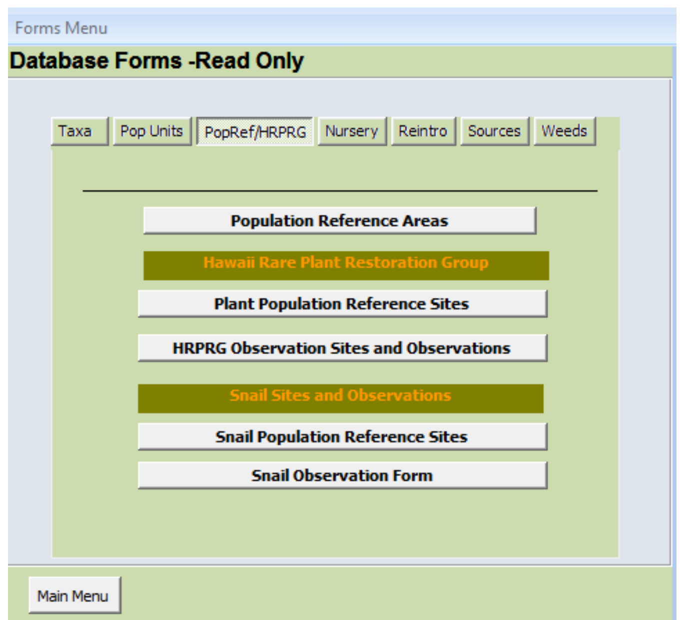
The database is broken up into 2 parts, Database Forms and Database Reports. We will primarily cover the Database reports. Database Forms are self-explanatory and is only for viewing purposes. The forms are provided for detailed review of individual observations. Only pertinent data fields will be discussed in detail.

## III. Database Forms

The **Database Forms menu** is broken up into several sections. They are Taxa, Pop Units, PopRef/HRPRG, Reintro, Sources, and Weeds.

Most buttons under each tab will open a "Find" form that will allow you to find an existing database record.

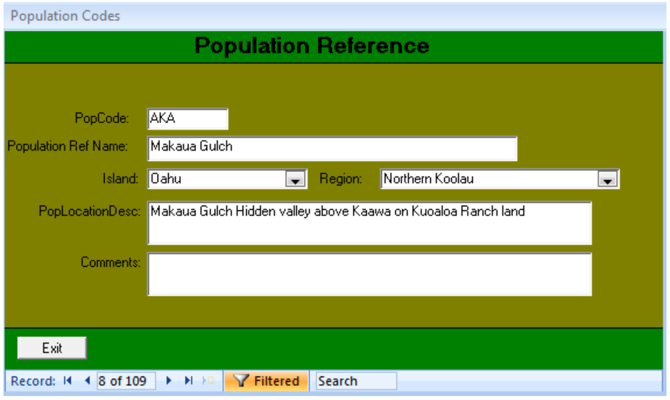
For the purpose of this tutorial, we will discuss forms of the PopRef/HRPRG tab with comprise of the Population Reference and Population Reference Sites. All other sections are supplemental and self-explanatory.



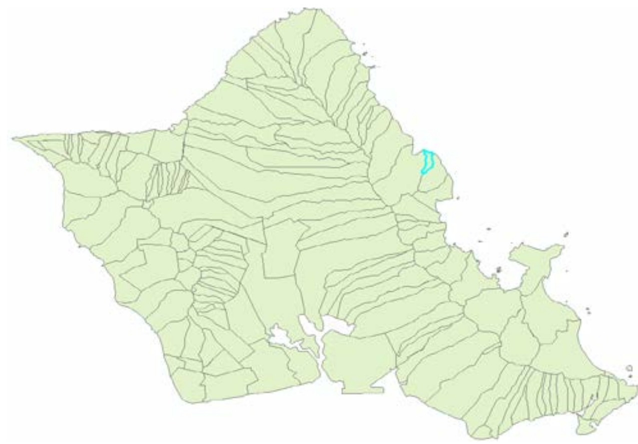

### PopRef, Sites, and Observations

Population information is broken up into three sections, Population Reference Areas (PopRef), Population Reference Sites (PopRefSite) and Observations. Both In situ and Reintro observations will be covered in this section.

## Population Reference Areas (PopRef)




Population Reference, also known as PopRef for short, is a boundary system that allows a consistent identification of plant or animal populations. The PopRef is normally valleys, summits, ahupuaa, bogs, or areas that biologists have continuously acknowledged within observations from past decades.

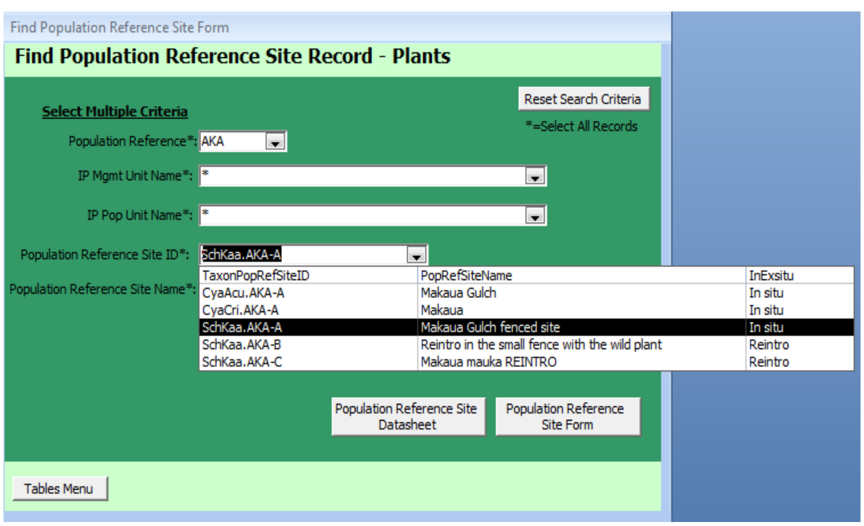


It should be noted that the Population Reference is not necessarily the name for any given population. It is only used as an identifier to compile different plant or animal populations within a given area. For example: Makaua on the Windward Koolau of Oahu (highlighted in blue). The GIS boundary is based upon Makaua's ahupuaa as AKA's PopRef. But a plant population within Makaua PopRef, its population name may be named something different like a puu, or other landmark within Makaua.

## Population Reference Site (PopRefSite)

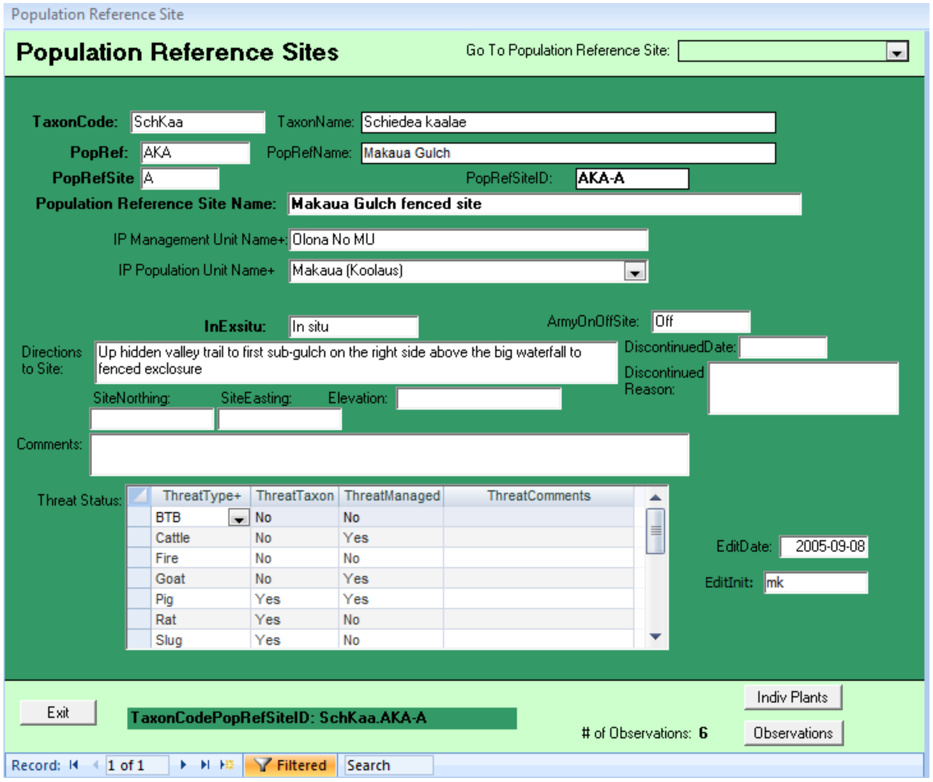
The Population Reference Site (PopRefSite) is the primary data table in establishing plant or animal population sites. The PopRefSite identifies the Population Name, whether it is In situ, Ex situ or Reintro, and provides directions to the site, etc. The PopRefSite is only site information; observation information from various surveys is kept in the observation section discussed later.

Determining what is a population or Population Reference Site is always very difficult and can vary by taxon. Normally populations are determined by the botanist in the field. Population determination criteria normally used is topography, distance from one population to another (Army normally uses 1000 ft. buffer distance), genetic dispersal, geographic features (streams, veg. type changes), etc.




To view an existing PopRefSite record, from the menu click on the Population Reference Sites button, a Find Population Reference Site Record form will appear and select AKA under the PopRef drop down as in the example. From that, you could also see all of the AKA Populations under the Population Reference Site ID Drop down. Select SchKaa.AKA-A.

Within the PopRefSite record, **TaxonCode, PopRef, and PopRefSite (Site Letter)** are kept. All three data fields build the TaxonCodePopRefSiteID (aka PopRefSiteID or PopRef Code). The PopRefSiteID is found on the bottom of the form in this case SchKaa.AKA-A. The PopRefSiteID is the unique key field that provides consistent population identification. The format of the PopRefSiteID is always TaxonCode**.**PopRef**-**<u>SiteLetter</u>.




**Population Reference Site Name** (PopRefSiteName) is the name used to identify the population. It is normally be a brief descriptive name. Detailed directions or descriptions are entered in the Directions to Site field.

**IP Management Unit Name**: Management Unit commonly known from.

**IP Population Unit Name (PopUnit):** The PopUnit is used when several PopRefSites need to be tracked together. Such as a taxon with several sites throughout the Northern Waianae Mountains, Northern Waianae could be used as a PopUnit Name.

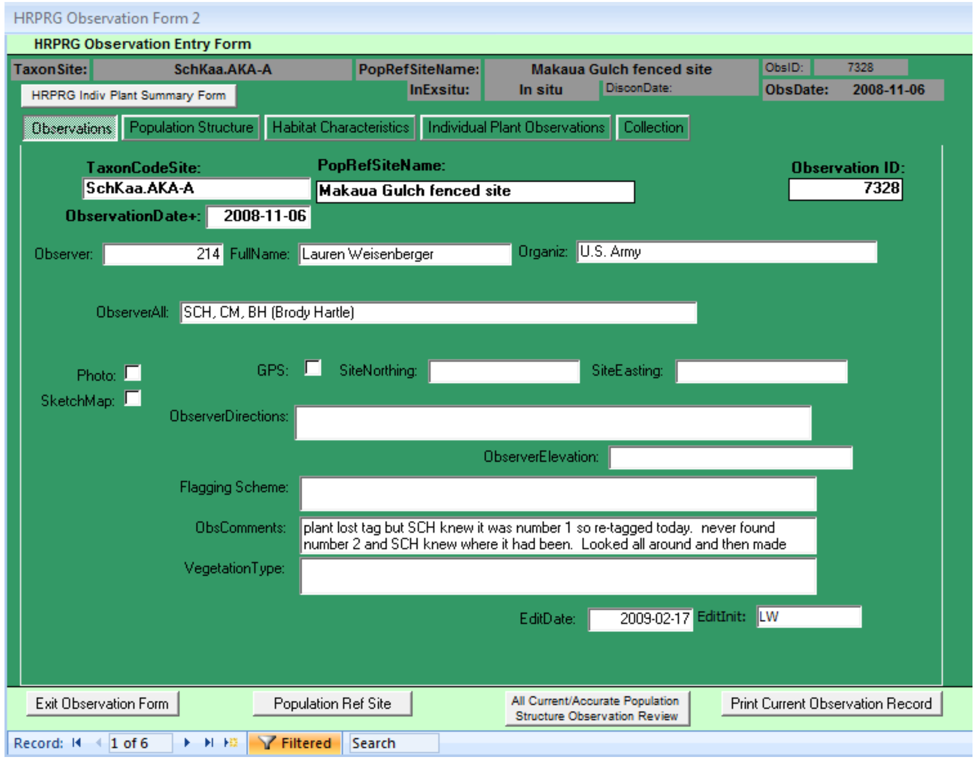
**InExsitu**: Identifies whether the PopRefSite is a naturally occurring wild (In situ), or Reintroduction (Reintro), etc.

**Directions to Site**: Detailed directions to locate the population.

**Threat Control Status**: What the threat control is being conducted (Yes, No, Partial)

## Observations

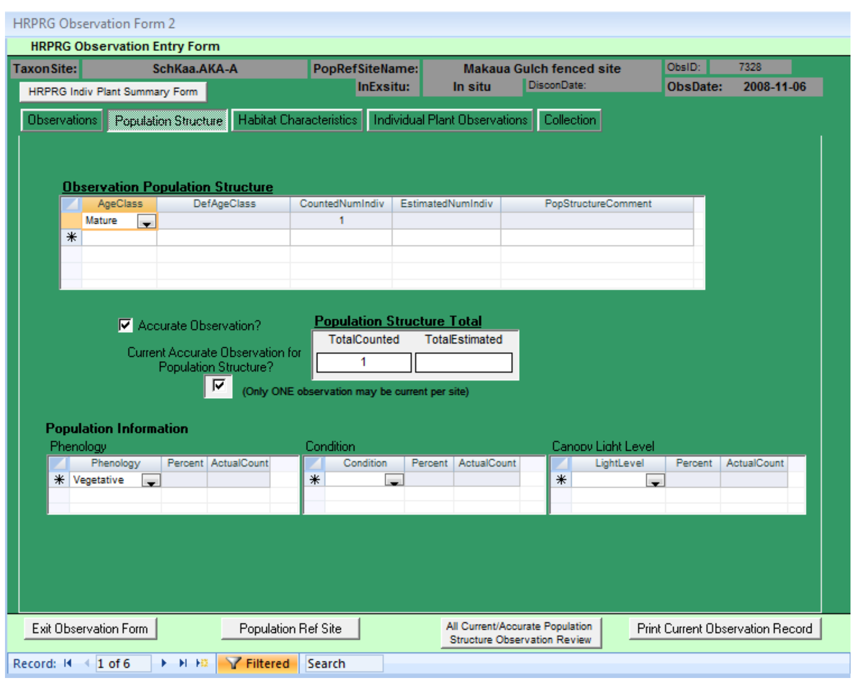
Clicking the Observations button on the bottom of the PopRefSite Form will open up the corresponding Observations.




**ObservationDate**: Observations of the Population Reference Site are entered by the ObservationDate. Observation Date is normally the day that the Population Site was surveyed. If the individual(s) were not found during the survey, the observation date and record is still be filled out. If the survey took several observation days, then the start date is entered in the ObservationDate.

**Observer Directions** may be entered if it is different from the PopRefSite Directions. Observer Directions may be a different route or situation that would represent the directions for that survey day.

**Population Structure**
The Population Structure should are always entered for any observations, even if the number of plants observed are incomplete (not all plants observed).

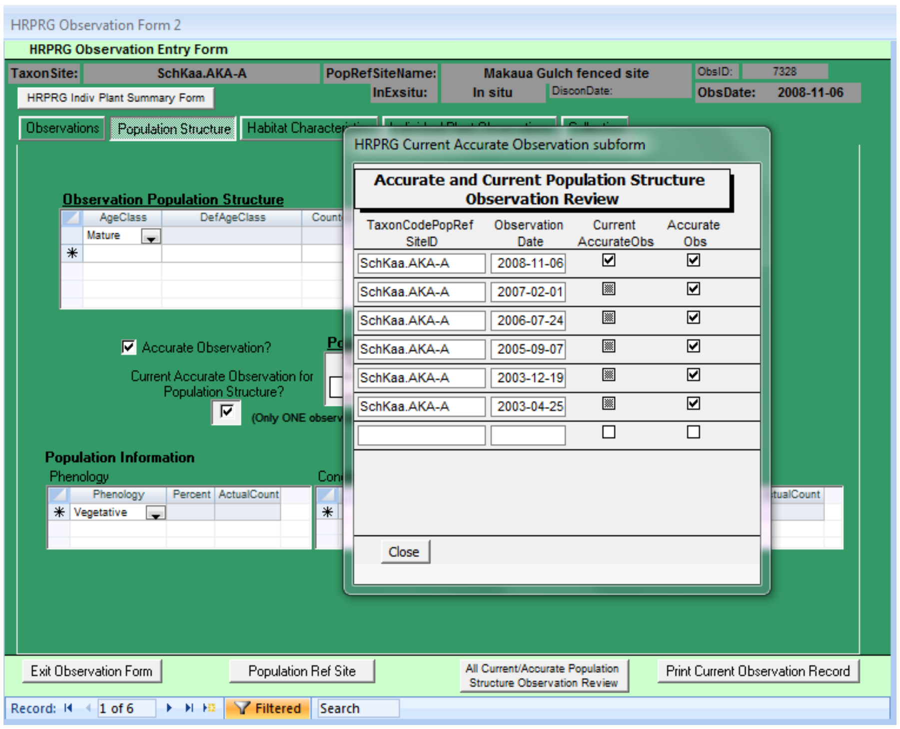



**Age Class** always is required, where **CountedNumIndiv** (Counted Number of Individuals) is considered a more accurate count of the number of plants. **EstimatedNumIndiv** (Estimated Number of Individuals) may be entered only when the CountedNumIndiv is not entered. EstimatedNumIndiv is used when the number of plants is numerous. EstimatedNumIndiv should not be entered when the number of plants can be counted.

EstimatedNumIndiv may not be a number range, if a range such as 100-200 is provided, the conservative number 100 is entered, and 100-200 may be entered in the PopStructureComment.

**Accurate Observation** is checked off when the Population Structure's Age Classes and CountedNumIndiv/ EstimateNumIndiv contain an accurate and representative count of the PopRefSite population. Many observations over different survey dates may have the Accurate Observation checked off.

As opposed to the Accurate Observation check box, the **<u>Current Accurate Observation</u>** <u>check off box may only have one observation checked</u>. The Current Accurate represents the population structure that is considered both current and accurate. The most recent observation may not always be the Current Accurate observation, thus the Current Accurate is used to identify the proper Population Structure numbers that currently represents the population in reports and queries.




Clicking on the button on the bottom "All Current/Accurate PopStruc Obs Review" will pull up a review form to show all observations for the site and which ones were Accurate, and which one is tagged as the Current/Accurate.

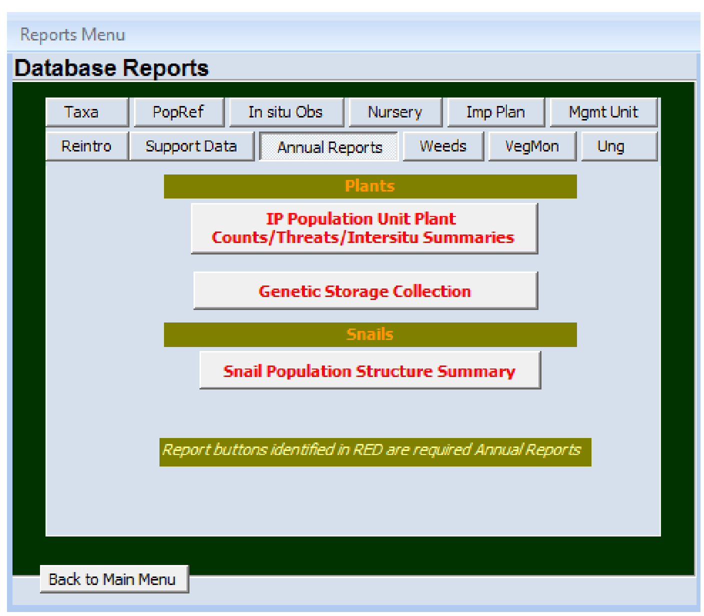
## IV. <u>Database Reports</u>

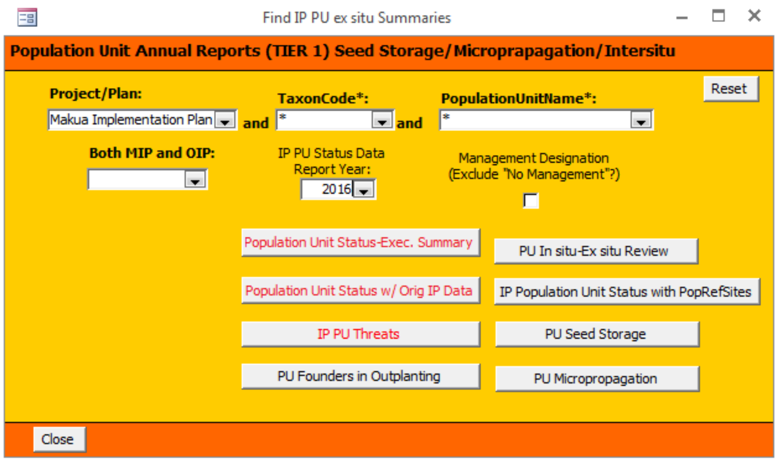
Starting from the Main Menu, click on the Database Reports button. The Database Reports menu provides reports for various sections of the database.

Similar to the Database Entries, clicking on a button within the Database Reports will open a Find Form that will assist in selecting data records for the report.

For the purpose of this document, we will cover the reports normally generated for the Year-End Annual report.

There are three sections consisting of four reports that are normally printed annually. The sections are IP Populations, Genetic Storage, and Snail Population as shown in the figure to the right.






## Taxon Status and Threat Summaries

Under the IP Population Unit button, the menu has threat reports (in red) Exec. Summary, Taxon Status (Population Unit Status) and the Threat Summary (IP PU Threats). Buttons with red text will signify it is a report used in the year-end annual report. Project/Plan and Report Year must be selected for the reports to run. In the Report Year Field, select 2016. Report Year is defined below under Total Mature, Immature and Seedling 2016.

## Executive Summary

The Executive Summary database report combines data derived from the Taxon Status Summary Report, Genetic Summary Report and Threat Summary. See below for further details.

**Makua Implementation Plan - Executive Summary - Plants**

\# of Stable IP Population Units: 46 of 101

[shaded] = Ungulate Threat to Taxon within Population Unit

No Shading = Absence of Ungulate threat to Taxon within Population Unit

| Plant Taxon | Target # Matures | Population Unit Name | Total Current Mat.+Imm. | Total Current Mature | Total Current Immature | Total Current Seedling | # Plants In 2016 | # Plant In Original Report | % Completed Genetic Storage Requirement | % of Plants Protected from Ungulates | PU Met Goal? | # PU Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neraudia angulata | 100 | | | | | | | | | | | |
| | | Kaluakauila | 124 | 100 | 24 | 1 | 124 | 0 | N/A | 100% | Yes | |
| | | Makua | 78 | 67 | 11 | 0 | 75 | 29 | 46% | 100% | No | |
| | | Manuwai | 161 | 97 | 64 | 10 | 207 | 12 | 67% | 100% | No | |
| | | Waianae Kai Mauka | 13 | 11 | 2 | 0 | 13 | 46 | 56% | 100% | No | |
| | | Neraudia angulata Total: | 376 | 275 | 101 | 11 | 419 | 87 | | | | 1 of 4 |

## Population Unit Status Summary

**Population Unit Status - Makua Implementation Plan**

**Action Area: In**

**TaxonName: Cyanea grimesiana subsp. obatae** — Target # of Matures: 100 — # MFS PU Met Goal: 2 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2016 | Total Immature 2016 | Total Seedling 2016 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pahole to West Makaleha | Manage for stability | 22 | 24 | 0 | 75 | 36 | 0 | 70 | 36 | 0 | 6 | 11 | 0 | 64 | 25 | 0 | 2017-05-09 | Small changes were noted during monitoring in the last year |
| | In Total: | 22 | 24 | 0 | 75 | 36 | 0 | 70 | 36 | 0 | 6 | 11 | 0 | 64 | 25 | 0 | | |

**Action Area: Out**

**TaxonName: Cyanea grimesiana subsp. obatae** — Target # of Matures: 100 — # MFS PU Met Goal: 2 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2016 | Total Immature 2016 | Total Seedling 2016 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kaluaa | Manage for stability | 0 | 0 | 0 | 124 | 17 | 0 | 124 | 17 | 0 | 2 | 1 | 0 | 122 | 16 | 0 | 2016-04-07 | A new census was initiated but not yet completed |
| Makaha | Genetic Storage | | | | 13 | 56 | 0 | 13 | 56 | 0 | 0 | 0 | 0 | 13 | 56 | 0 | 2016-02-09 | A new census was initiated but not yet completed |
| North branch of South Ekahanui | Manage reintroduction for stability | 5 | 0 | 0 | 82 | 65 | 0 | 82 | 65 | 0 | 0 | 0 | 0 | 82 | 65 | 0 | 2016-05-11 | A new census was initiated but not yet completed |
| Palikea (South Palawai) | Manage for stability | 3 | 60 | 0 | 120 | 19 | 1 | 911 | 10 | 0 | 8 | 4 | 0 | 903 | 6 | 0 | 2017-04-25 | Additional plants were reintroduced last year |
| | Out Total: | 8 | 60 | 0 | 339 | 157 | 1 | 1130 | 148 | 0 | 10 | 5 | 0 | 1120 | 143 | 0 | | |
| | Total for Taxon: | 30 | 84 | 0 | 414 | 193 | 1 | 1200 | 184 | 0 | 16 | 16 | 0 | 1184 | 168 | 0 | | |

The Population Unit Status Summary, shown above, displays the current status of the wild and outplanted plants for each PU next to the totals from the previous year for comparison. The report also depicts the original IP Totals for the different age classes. The PUs are grouped into those with plants that are located inside the MIP or OIP AA (In) and PUs where all plants are outside of both AAs (Out).

**Population Unit Name:** Groupings of Population Reference Sites. Only PUs designated to be 'Manage for Stability' (MFS), 'Manage Reintroduction for Stability/Storage,' or 'Genetic Storage' (GS) are shown in the table. Other PUs with 'No Management' designations are not managed and will not be reported. "No Management" PUs may be shown by not checking the "Exclude No Management" box on the report menu.

**Management Designation:** For PUs with naturally occurring (*in situ*) plants remaining, the designation is either 'Manage for Stability' or 'Genetic Storage'. Some MFS PUs will be augmented with outplantings to reach stability goals. When reintroductions alone will be used to reach stability, the designation is 'Manage Reintroduction for Stability.' When a reintroduction will be used for producing propagules for genetic storage, the designation is 'Manage Reintroduction for Storage'.

**Total Original IP Mature, Immature, Seedling:** These first three columns display the original population numbers as noted in the first Implementation Plan reports of MIP (2005) and OIP (2008). When no numbers are displayed, the PU was not known at the time of the IPs

**Total Mature, Immature and Seedling (Year):** This displays the **SUM** of the number of *wild and outplanted* mature, immature plants and seedlings from the previous year's report. These numbers should be compared to those in the next three columns to see the change observed over the last year.

**Total Current Mature, Immature, Seedling:** The **SUM** of the *current* numbers of *wild and outplanted* individuals in each PU. This number will be used to determine if each PU has reached stability goals. These three columns can be compared with the previous columns to see the change observed over the last year.

**Wild Current Mature, Immature, Seedling:** These set of three columns display the most up to date population estimates of the wild (in situ) plants in each PU. These numbers are generated from OANRP monitoring data, data from the Oahu Plant Extinction Prevention Program (OPEP) and Oahu NARS staff. The estimates may have changed from last year if estimates were revised after new monitoring data was taken or if the PUs have been split or merged since the last reporting period. The most recent estimate is used for all PUs, but some have not been monitored in several years. Several PU have not been visited yet by OANRP and no plants are listed in the population estimates. As these sites are monitored, estimates will be revised.

**Outplanted Current Mature, Immature, Seedling:** The last set of three columns display the numbers of individuals OANRP and partner agencies have outplanted into each PU. This includes augmentations of in situ sites, reintroductions into nearby sites and introductions into new areas.

**PU LastObs Date:** Last Observation Date of the most recent Population Reference Site observed within a PU. Where thorough monitoring was done, the estimates were updated. Although, there are sites that may have been observed more recently, but a complete monitoring was not done.

**Population Trend Notes:** Comments on the general population trend of each PU is given here. This may include notes on whether the PU was monitored in the last year, a brief discussion of the changes in population numbers from the previous estimates, and some explanation of whether the change is due to new plants being discovered in the same site, a new site being found, reintroductions or augmentations that increased the numbers or fluctuations in the numbers of wild plants. In some cases where the numbers have not changed, NRS has monitored the PU and observed no change. When the PU has not been monitored, the same estimate from the previous year is repeated.

## Threat Control Summary

**Threat Control Summary** Makua Implementation Plan

**Action Area: In**

**TaxonName: Alectryon macrococcus var. macrococcus**

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| Kahanahaiki to Keawapilau | Manage for stability | 1 | Yes | Partial 100% | Partial 0% | No | No |
| Makua | Manage for stability | 4 | Partial 100% | Partial 25% | No | No | No |
| South Mohiakea | Genetic Storage | 2 | Yes | No | No | No | No |
| West Makaleha | Genetic Storage | 13 | No | No | No | No | No |

**Action Area: Out**

**TaxonName: Alectryon macrococcus var. macrococcus**

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| Central Kaluaa to Central Waieli | Manage for stability | 3 | Partial 0% | Partial 0% | No | No | No |
| Makaha | Manage for stability | 29 | Yes | Partial 100% | Partial 100% | No | No |
| Waianae Kai | Genetic Storage | 0 | No | No | No | No | No |

[shaded box] = Threat to Taxon within Population Unit
No Shading = Absence of threat to Taxon within Population Unit
Ungulate Managed = Culmination of Cattle, Goats, and Pig threats
Yes=All PopRefSites within Population Unit have threat controlled
No=All PopRefSites within Population Unit have no threat control
Partial%=Percent of mature plants in Population Unit that have threat controlled
Partial 100% = All PopRefSites within Population Unit have threat partially controlled
Partial 0% = Threat partially controlled, but no mature plants

The Threat Control Summary summarizes the threat status for each Taxon Population Unit. Yes, No or Partial is used to indicate the level of threat management. Partial management has additional percentage based upon the number of mature plants being protected.

**Population Unit Name:** Groupings of Population Reference Sites. Only PUs designated to be 'Manage for Stability' (MFS), 'Manage Reintroduction for Stability/Storage,' or 'Genetic Storage' (GS) are shown in the table.

**Management Designation:** Designations for PUs with ongoing management are listed. Population Units that are MFS are the first priority for complete threat control. PUs that are managed in order to secure genetic storage collections receive the management needed for collection (ungulate and rodent control) as a priority but may be a lower priority for other threat control.

**# Mature Plants:** Number of Mature Plants within the Population Unit.

**Threat Columns:** The six most common threats are listed in the next columns. To indicate if the threat is noted at each PU, a shaded box is used. If the threat is not present at that PU, it is not shaded.

Threat control is defined as:
Yes = All sites within the PU have the threat controlled
No = All sites within the PU have no threat control
Partial %= Percent of mature plants in Population Unit that have threat controlled
Partial 100%= All PopRefSites within Population Unit have threat partially controlled
Partial (with no %) = All PopRefSites within Population Unit have threat partially controlled and only immature plants have been observed.

**Ungulates:** This threat is indicated if pigs, goats or cattle have been observed at any sites within the PU. This threat is controlled (Yes) if a fence has been completed and all ungulates removed from the site. Most PUs are threatened by pigs, but others are threatened by goats and cattle as well. The same type of fence is used to control for all three types of ungulates on Oahu. Partial indicates that the threat is controlled for some but not all plants in the PU.

**Weeds:** This threat is indicated at all PUs for all IP taxa. This threat is controlled if weed control has been conducted in the vicinity of the sites for each PU. If only some of the sites have had weed control, 'Partial' is used.

**Rats:** This threat is indicated for any PUs where damage from rodents has been confirmed by OANRP staff. This includes fruit predation and damage to stems or any part of the plant. The threat is controlled if the PU is protected by snap traps and bait stations. For some taxa, rats are not known to be a threat, but the sites are within rat control areas for other taxa so the threat is considered controlled. In these cases, the box is not shaded but control is 'Yes' or 'Partial.' Partial indicates that the threat is fully controlled over part of the PU.

**Slugs:** This threat is indicated for several IP taxa as confirmed by OANRP staff. Currently, slug control is conducted under an Experimental Use Permit from Hawaii State Department of Agriculture, which permits the use of Sluggo® around the recruiting seedlings of *Cyanea superba* subsp. *superba* in Kahanahaiki Gulch on Makua Military Reservation. Until the label is changed to allow for application in a forest setting, all applications must be conducted under this permit. Partial indicates that the threat is fully controlled over part of the PU.

**Fire:** This threat is indicated for PUs that occur on Army lands within the high fire threat area of the Makua AA, and some PUs within the Schofield West Range AA and Kahuku Training Area that have been threatened by fire within the last ten years. Similarly, PUs that are not on Army land were included if there is a history of fires in that area. This includes the PUs below the Honouliuli Contour Trail, the gulches above Waialua where the 2007 fire burned including Puulu, Kihakapu, Palikea, Kaimuhole, Alaiheihe, Manuwai, Kaomoku iki, Kaomoku nui and Kaawa and PUs in the Puu Palikea area that were threatened by the Nanakuli fire. Threat control conducted by OANRP includes removing fuel from the area with pesticides, marking the site with Seibert Stakes for water drops, and installing fuel-breaks in fallow agricultural areas along roads. 'Partial' means that the threat has been partially controlled to the whole PU, not that some plants are fully protected. Firebreaks and other control measures only partially block the threat of fire which could make it into the PU from other unprotected directions.

# Genetic Storage Summary

2017-08-08



**Genetic Storage Summary Makua Implementation Plan**

| | | # of Potential Founders | | | Partial Storage Status | | | | Storage Goals | | | | Storage Goals Met | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Population Unit Name | Management Designation | Current Mature | Current Imm. | Dead and Repres. | # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | # Plants that Met Goal | % Completed Genetic Storage Requirement |
| **Action Area: In** | | | | | | | | | | | | | | |
| **Neraudia angulata** | | | | | | | | | | | | | | |
| Kapuna | Genetic Storage | 0 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 100% |
| Makua | Manage for stability | 21 | 4 | 34 | 2 | 2 | 0 | 37 | 1 | 0 | 0 | 23 | 23 | 46% |
| Punapohaku | Genetic Storage | 2 | 0 | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 3 | 3 | 75% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Neraudia angulata** | | | | | | | | | | | | | | |
| Halona | Genetic Storage | 4 | 10 | 17 | 1 | 1 | 0 | 9 | 0 | 0 | 0 | 8 | 8 | 38% |
| Leeward Puu Kaua | Genetic Storage | 9 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 11% |
| Makaha | Manage for stability (backup site) | 3 | 8 | 12 | 3 | 2 | 0 | 15 | 2 | 1 | 0 | 14 | 14 | 93% |
| Manuwai | Manage for stability | 0 | 4 | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 4 | 4 | 100% |
| Waianae Kai Makai | Genetic Storage | 13 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 8 | 8 | 62% |
| Waianae Kai Mauka | Manage for stability | 7 | 2 | 9 | 1 | 1 | 0 | 11 | 0 | 0 | 0 | 10 | 10 | 63% |
| | | Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal | |
| | | 59 | 28 | 78 | 10 | 8 | 0 | 96 | 5 | 1 | 0 | 73 | 73 | |

The Genetic Storage Summary estimates of seeds remaining in genetic storage have been changed this year to account for the expected viability of the stored collections. The viability rates of a sample of most collections are measured prior to storage. These rates are used to estimate the number of viable seeds in the rest of the stored collection. If the product of (the total number of seeds stored) and (the initial percentage of viable seeds) is >50, that founder is considered secured in genetic storage. If each collection of a species is not tested, the initial viability is determined from the mean viability of (preference in descending order):

1. other founders in that collection
2. that founder from other collections
3. all founders in that population reference site
4. all founders of that species

**Number (#) of Potential Founders:** These first columns list the current number of live *in situ* immature and mature plants in each PU. These plants have been collected from already, or may be collected from in the future. The number of dead plants from which collections were made in the past is also included to show the total number of plants that could potentially be represented in genetic storage for each PU since collections began. Immature plants are included as founders for all taxa, but they can only serve as founders for some. For example, for *Hibiscus brackenridgei* subsp. *mokuleianus*, cuttings can be taken from immature plants for propagation. In comparison, for *Sanicula mariversa*, cuttings cannot be taken and seed is the only propagule used in collecting for genetic storage. Therefore, including immature plants in the number of potential founders for *S. mariversa* gives an over-estimate. The 'Manage reintroduction for stability/storage' PUs have no potential founders. The genetic storage status of the founder stock used for these reintroductions is listed under the source PU.

**Partial Storage Status and Storage Goals:** To meet the IP genetic storage goal for each PU for taxa with seed storage as the preferred genetic storage method, at least 50 seeds must be stored from 50 plants. This year, the number of seeds needed for each plant (50) accounts for the original viability (Estimate Viability) of seed collections. In order to show intermediate progress, this column displays the number individual plants that have collections of >10 seeds in storage. For taxa where vegetative collections will be used to meet storage goals, a minimum of three clones per plant in either the Lyon Micropropagation Lab, the Army nurseries or the State's Pahole Mid-elevation Nursery is required to meet stability goals. Plants with one or more representatives in either the Lyon Micropropagation Lab or a nursery are considered to partially meet storage goals. The number of plants that have met this goal at each location is displayed.

**# Plants that Met Goal:** This column displays the total number of plants in each PU that have met the IP genetic storage goals. As discussed above, a plant is considered to meet the storage goal if it has 50 seeds in storage or three clones in micropropagation or three in a nursery. For some PUs, the number of founders has increased in the last year; therefore, it is feasible that NRS could be farther from reaching collection goals than last year. Also, as seeds age in storage, plants are outplanted, or explants contaminated, this number will drop. In other PUs where collections have been happening for many years, the number of founders represented in genetic storage may exceed the number of plants currently extant in each PU. In some cases, plants that are being grown for reintroductions are also being counted for genetic storage. These plants will eventually leave the greenhouse and the genetic storage goals will be met by retaining clones of all available founders or by securing seeds in storage. This column does not show the total number of seeds in storage; in some cases thousands of seeds have been collected from one plant.

**% Completed Genetic Storage Requirement:** Describes the percent of Founder Plants that have met Genetic Storage goals. Genetic storage of at least 50 seeds each from 50 individuals, or at least three clones each in propagation from 50 individuals, is required for each PU. If there are fewer than 50 founders for a PU, genetic storage is required from all available founders. For example, if there are at least 50 seeds from five individuals, or at least three clones in propagation from five individuals, then listed in the tables is 10%.

See Taxon Status Summary above for details on In/Out Action Area, Population Units, and Management Designation.

## Snail Population Status Summary

### Number of Snails Counted

| Population Reference Site | Management Designation | Total Snails | Date of Survey | Size Classes: Large | Medium | Small | Unk | Threat Control: Ungulate | Weed | Rat | Euglandina rosea | Jackson's Chameleon |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Achatinella mustelina** | | | | | | | | | | | | |
| **ESU: A** Pahole to Kahanahaiki | | | | | | | | | | | | |
| MMR-A Kahanahaiki Exclosure | Manage for stability | 215 | 2017-05-02 | 86 | 107 | 22 | 0 | Yes | Partial | Yes | Yes | No |
| PAH-B Pahole Exclosure | Manage for stability | 28 | 2016-06-20 | 8 | 13 | 7 | 0 | Yes | Partial | Yes | Yes | No |
| | **ESU Total:** | 243 | | 94 | 120 | 29 | 0 | | | | | |

*=Total Snails were Trans Located or Reintroduced

**Size Class Definitions**

| SizeClass | DefSizeClass |
|---|---|
| Large | >18 mm |
| Medium | 8-18 mm |
| Small | < 8 mm |

[shaded] = Threat to Taxon at Population Reference Site
No Shading = Absence of threat to Taxon at Population Reference Site
Yes=Threat is being controlled at PopRefSite
No=Threat is not being controlled at PopRefSite
Partial=Threat is being partially controlled at PopRefSite

Table shows the number of snails, size classes, and threats to the snails in the ESU sites. Yes = threat is being controlled; In some cases the threat may be present but not actively preying on A. mustelina.

The Snail Population Status Summary describes the current population size and threat control. Size Classes varies by snail taxon and definitions are listed on the lower left corner of the report. Threat Control consists of Yes, No, or Partial. Partial is where only some of the threat is being controlled at the site.

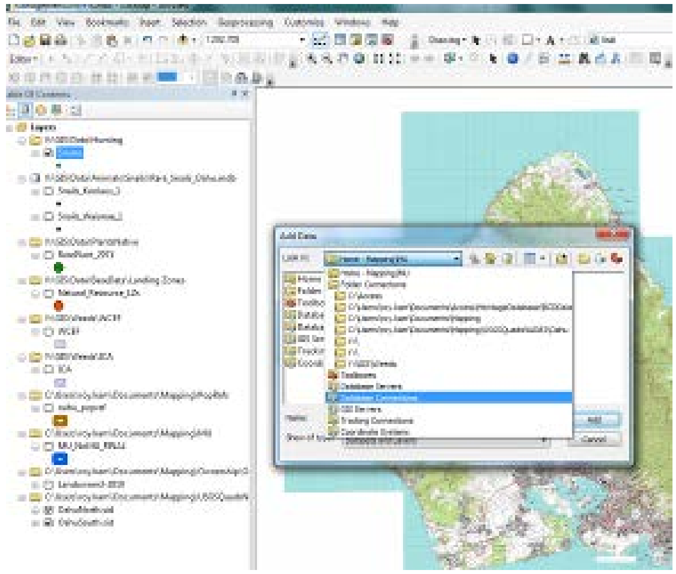
**Population Reference Site:** The first column lists the population reference code for each field site. This consists of a three-letter abbreviation for the gulch or area name. For example, MMR stands for Makua Military Reservation. Next, a letter code is applied in alphabetic order according to the order of population discovery. This coding system allows NRS to track each field site as a unique entity. This code is also linked to the Army Natural Resource geodatabase. In addition, the "common name" for the site is listed as this name is often easier to remember than the population reference code.

**Management Designation**: In the next column, the management designation is listed for each field site. The tables used in this report only display the sites chosen for MFS, where NRS is actively conducting management. These sites are generally the most robust sites in terms of snail numbers, habitat quality, and manageability. Other field sites where NRS has observed snails are tracked in the database but under the designation 'no management.' In general, these sites include only a few snails in degraded habitat where management is logistically challenging. The combined total for sites designated as MFS should be a minimum of 300 total snails in order to meet stability requirements.

**Population Numbers:** The most current and most accurate monitoring data from each field site are used to populate the 'total snails' observed column and the numbers reported by 'size class' columns. In some cases, complete monitoring has not been conducted within this reporting period because of staff time constraints, therefore, older data are used.

**Threat Control:** It is assumed that ungulate, weed, rat and Euglandina threats are problems at all the managed sites. If this is not true of a site, special discussion in the text will be included. If a threat is being managed at all in the vicinity of A. mustelina or affecting the habitat occupied by *A. mustelina* a "Yes" designation is assigned. The "No" designation is assigned when there is no ongoing threat control at the field site.

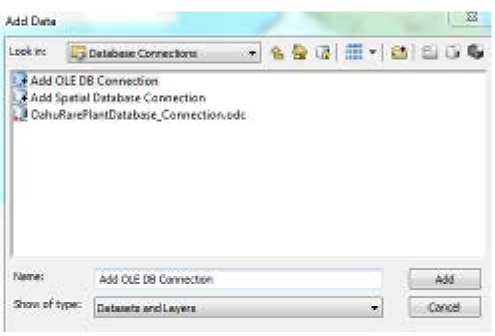
## Linking Access Database Query into ArcGIS –Distribution Database Version



There may be times that information found in the Access database is needed in a GIS map. The following shows you how to link a query from Access into an ArcGIS project. The Population Reference Site query will be used as an example. Note there are several steps needed to bring in an Access Database query. If you don't feel comfortable in doing this, contact Roy Kam (rkam@hawaii.edu) and he will walk you through.

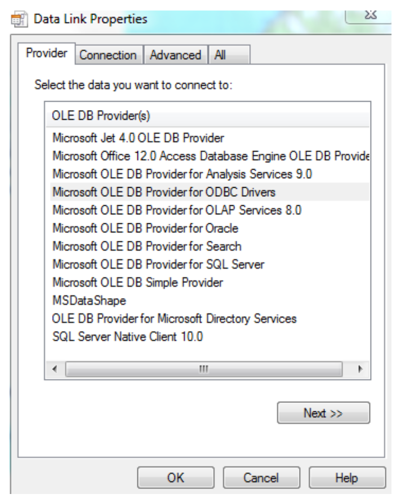
In your ArcGIS Project, make sure you have the Rare Plants or Rare Snails shapefile (or whatever shapefile you are linking) as one of your layers.

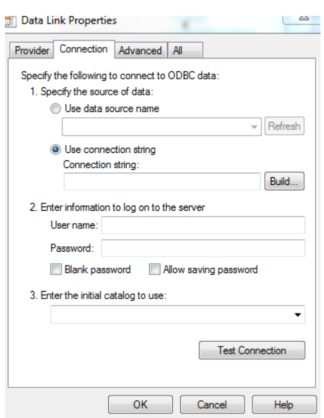
Click on the Add Button, and choose *Database Connections*. If you do not have Database Connections listed (versions ArcGIS 10.3 and up), you will need to add it before you start. Go to ArcCatalog>Customize (Tab)>Customize Mode>Under the Commands Tab, select ArcCatalog (left column) and on the right chose Add OLE DB Connection. Drag Add OLE DB Connection from the Commands list onto the toolbar in ArcCatalog.




Then select *Add OLE Database Connection*, and click on Add.

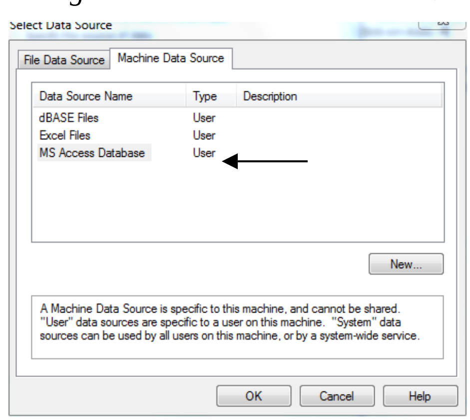
A Data Link Properties window will appear. Select *Microsoft OLE DB Provider for ODBC Drivers*.

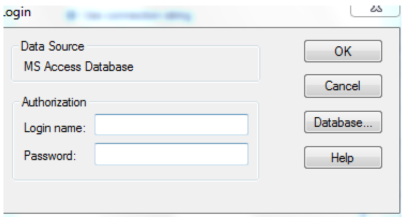



Then in the Data Link Properties window, select the *Connection tab*. Under the Connection Tab, select *Use Connection String* and click on the button *Build*.

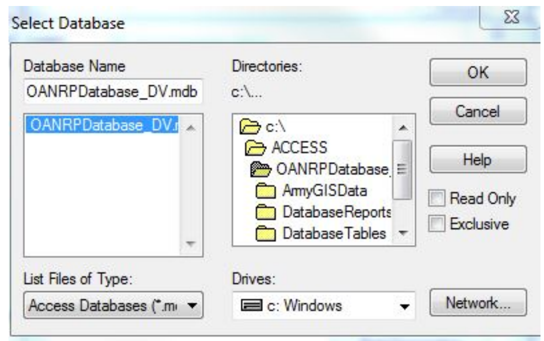
In the Select Data Source window, select the *Machine Data Source* tab, and select *MS Access Database then* click *OK*.





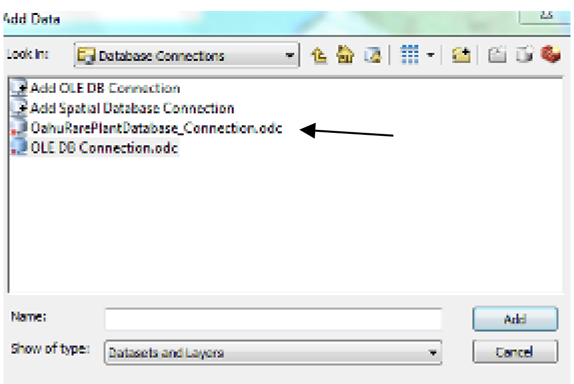

In the Login Window, Click on the *Database* button (leave Login Name and Password blank).

In the Select Database window, change the Drives to C: and browse to

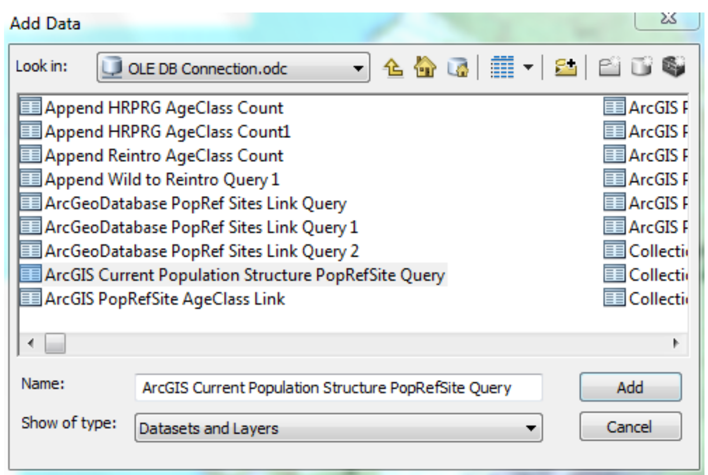



C:\Access\OANRPDatabase_DistributeVersion\ OANRPDatabase_DV.accdb

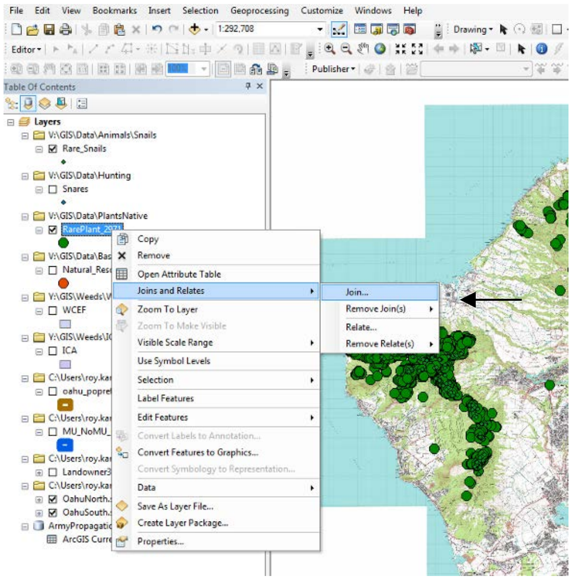
Click Ok to close the windows, until you are back at the Add Data window.  You will now see a new OLE DB Connection.odc listed.



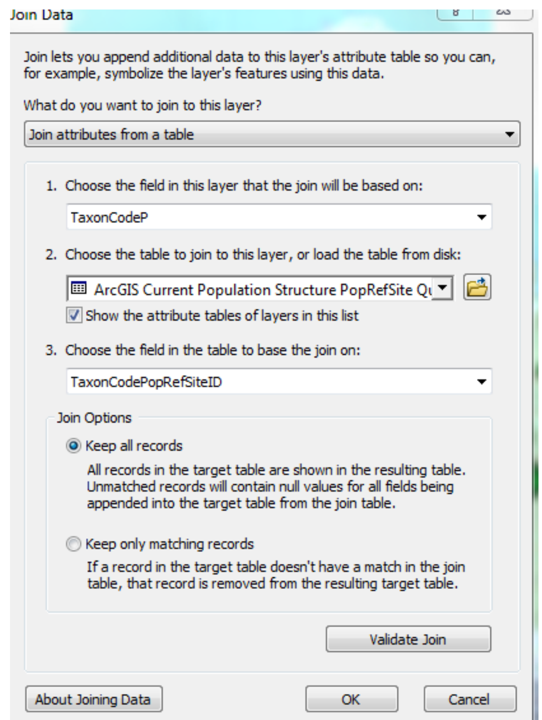

Double click on the OLE DB Connection.odc.  The window will then open the Access Database and list all tables and queries.




Browse through the list until you find *ArcGIS Current Population Structure PopRefSite Query*. This query in the Access Database lists all of the Rare Plants and Rare Snails with their current Population Structure and whether the site is In situ or Ex situ.  Click Add.  The query will now appear as a Layer in your map project.




Go to the shapefile, right click and select Join under the Joins and Relates.




The last procedure is to join the Rare Plant shapefile with the Access Query. Select TaxonCodeP from the Rare Plant GIS Shapefile, and TaxonCodePopRefSiteID from the Access database query. The data will now appear together in the Snare shapefile attribute table.

# Attribute Table from ArcGIS. Example of Rare Plant shapefile joined to Access Database Query.

← Rare Plants GIS Shapefile table data → Access Database data

RarePlants

| OBJ | ID | SPECIES | POPULATION | TaxonCodeP | LOCATION | SOU | FULL_SCIEN | X | Y | NATU | Statu | TaxonCode | PopRefName |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | AleMacMac | SBW-A | AleMacMac.SBW-A | Mohiakea gulch | JL | Alectryon macrococcus macrococcus | 590515.562 | 2376426.50004 | Yes | E | AleMacMac | Schofield Barracks Mil |
| 2 | 0 | AleMacMac | SBW-C | AleMacMac.SBW-C | Puu Kumakalii | JL | Alectryon macrococcus macrococcus | 590981.875 | 2375960.25005 | Yes | E | AleMacMac | Schofield Barracks Mil |
| 3 | 0 | AleMacMac | SBW-D | AleMacMac.SBW-D | Puu Kumakalii | JL | Alectryon macrococcus macrococcus | 591323.250 | 2375402.75002 | Yes | E | AleMacMac | Schofield Barracks Mil |
| 4 | 0 | SchTri | ALA-C | SchTri.ALA-C | Kaala | JL | Schiedea trinervis | 589030.703 | 2378443.74343 | Yes | E | SchTri | Mt. Kaala NAR |
| 5 | 0 | SchTri | SBW-G | SchTri.SBW-G | Puu Kalena | JL | Schiedea trinervis | 589641.375 | 2376627.49997 | Yes | E | SchTri | Schofield Barracks Mil |
| 6 | 0 | CyaAcu | ALA-B | CyaAcu.ALA-B | Kaala | JL | Cyanea acuminata | 589083.312 | 2378560.75002 | Yes | E | CyaAcu | Mt. Kaala NAR |
| 7 | 0 | CyaGriOba | SBW-A | CyaGriOba.SBW-A | Kaala 2400' | JL | Cyanea grimesiana obatae | 590057.000 | 2378433.99994 | Yes | E | CyaGriOba | Schofield Barracks Mil |
| 8 | 0 | CyaCal | NA | CyaCal.ALA-A | Kaala | JL | Cyanea calycina | 588965.812 | 2378293.99994 | | E | CyaCal | Mt. Kaala NAR |
| 9 | 0 | CyaCal | NA | CyaCal.ALA-A | Kaala | JL | Cyanea calycina | 588996.187 | 2378697.74996 | | E | CyaCal | Mt. Kaala NAR |
| 10 | 0 | CyaCal | NA | CyaCal.ALA-A | Kaala | JL | Cyanea calycina | 589218.125 | 2378491.00001 | | E | CyaCal | Mt. Kaala NAR |
| 11 | 0 | CyaCal | NA | CyaCal.SBW-A | Kaala | JL | Cyanea calycina | 589493.687 | 2377636.75002 | Yes | E | CyaCal | Schofield Barracks Mil |
| 12 | 0 | CyaCal | NA | CyaCal.SBW-A | Kaala | JL | Cyanea calycina | 589268.312 | 2377825.24999 | Yes | E | CyaCal | Schofield Barracks Mil |
| 13 | 0 | CyaCal | SBW-A | CyaCal.SBW-A | Kaala | JL | Cyanea calycina | 588881.999 | 2378048.50004 | Yes | E | CyaCal | Schofield Barracks Mil |
| 14 | 0 | CyaCal | SBW-C | CyaCal.SBW-C | Puu Kalena 2300' | JL | Cyanea calycina | 590479.812 | 2376867.99994 | Yes | E | CyaCal | Schofield Barracks Mil |
| 15 | 0 | CyaCal | SBW-C | CyaCal.SBW-C | Puu Kalena 2800' | JL | Cyanea calycina | 590307.312 | 2376571.74996 | Yes | E | CyaCal | Schofield Barracks Mil |

→ Access Database data joined query →

RarePlants

| PopRefName | FedStat | TaxonCodePopRefSit | PopRefSiteName | InExsitu | ObservationDate | AccObs | CurAccObs | Immature | Large | Mature | Medium | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Schofield Barracks Milita | E | AleMacMac.SBW-A | Mohiakea | In situ | 2013-05-20 | Yes | Yes | <Null> | <Null> | 2 | <Null> | < |
| Schofield Barracks Milita | E | AleMacMac.SBW-C | North of Puukumakalii (Dead) | In situ | 2012-04-04 | Yes | Yes | 0 | <Null> | 0 | <Null> | |
| Schofield Barracks Milita | E | AleMacMac.SBW-D | Southeast of Puukumakalii | In situ | 2012-06-27 | Yes | Yes | 0 | <Null> | 0 | <Null> | |
| Mt. Kaala NAR | E | SchTri.ALA-C | Lower 2 Poles Ridge | In situ | 2002-10-23 | Yes | Yes | 5 | <Null> | 5 | <Null> | |
| Schofield Barracks Milita | E | SchTri.SBW-G | Kalena, in notch | In situ | 2007-08-20 | Yes | Yes | 0 | <Null> | 0 | <Null> | |
| Mt. Kaala NAR | E | CyaAcu.ALA-B | Kaala, one gulch N of Alstri ridge | In situ | 2008-03-13 | Yes | Yes | <Null> | <Null> | 19 | <Null> | < |
| Schofield Barracks Milita | E | CyaGriOba.SBW-A | North Haleauau | In situ | 2005-10-03 | Yes | Yes | 0 | <Null> | 0 | <Null> | |
| Mt. Kaala NAR | E | CyaCal.ALA-A | Kaala | In situ | 2013-06-06 | Yes | Yes | <Null> | <Null> | 3 | <Null> | < |
| Mt. Kaala NAR | E | CyaCal.ALA-A | Kaala | In situ | 2013-06-06 | Yes | Yes | <Null> | <Null> | 3 | <Null> | < |
| Mt. Kaala NAR | E | CyaCal.ALA-A | Kaala | In situ | 2013-06-06 | Yes | Yes | <Null> | <Null> | 3 | <Null> | < |
| Schofield Barracks Milita | E | CyaCal.SBW-A | North Haleauau, Below ALA-O populati | In situ | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | < |
| Schofield Barracks Milita | E | CyaCal.SBW-A | North Haleauau, Below ALA-O populati | In situ | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | < |
| Schofield Barracks Milita | E | CyaCal.SBW-A | North Haleauau, Below ALA-O populati | In situ | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | < |
| Schofield Barracks Milita | E | CyaCal.SBW-C | Kaala-Kalena | In situ | 2006-10-25 | Yes | Yes | <Null> | <Null> | 1 | <Null> | < |
| Schofield Barracks Milita | E | CyaCal.SBW-C | Kaala-Kalena | In situ | 2006-10-25 | Yes | Yes | <Null> | <Null> | 1 | <Null> | < |
| <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | <Null> | < |

DEPARTMENT OF THE ARMY
U.S. ARMY INSTALLATION MANAGEMENT COMMAND-PACIFIC
HEADQUARTERS, UNITED STATES ARMY GARRISON, HAWAII
745 WRIGHT AVENUE, BUILDING 107, WHEELER ARMY AIRFIELD
SCHOFIELD BARRACKS, HAWAII 96857-5000

REPLY TO
ATTENTION OF

NOV 0 2 2017

Office of the Garrison Commander

Ms. Mary Abrams
Field Supervisor
U.S. Fish and Wildlife Service
300 Ala Moana Blvd., Room 3-122
Honolulu, Hawai, 96850

Dear Ms. Abrams:

This letter is to inform you of two fires that occurred on Schofield Barracks. The first occurred on Schofield Barracks, West Range, above the fire-break road, on September 19, 2017. This fire, designated the "Mountain" fire, burned a total of 1.8 acres, much less than was originally reported. Of this 1.8 acres, 0.25 acres occurred in an area designated as Critical Habitat for the Oahu Elepaio (Enclosure 1). The Army Wildland Fire Program coordinated fire-fighting actions and resources which included Aviation Brigade helicopters. The fire was deemed extinguished on October 5, 2017. Please find enclosed the fire report from the Directorate of Emergency Services (Enclosure 2). The fire burned primarily non-native Eucalyptus forest with little understory. Please find enclosed a list of plants burned in this fire (Enclosure 3).

The "Mountain" fire appears to have been caused by an artillery illumination round fired during high-wind conditions. An internal investigation is being conducted to determine how this deviation from range policy occurred and to prevent any reoccurrence.

The second fire, designated the "HALO" fire, occurred on Schofield Barracks, South Range on September 22, 2017, and burned a total of 0.33 acres, all of which occurred in area designated as Critical Habitat for the Oahu Elepaio (Enclosure 4). The Army Wildland Fire Program coordinated fire-fighting actions and resources for this fire as well, including Aviation Brigade helicopters. The fire was deemed extinguished on October 5, 2017. Please find enclosed the fire report from the Directorate of Emergency Services (Enclosure 5). The fire burned mixed native/non-native forest, including native koa, Christmas berry, paperbark, and strawberry guava, with thick Guinea grass understory. Please find enclosed a list of plants burned in this fire including pictures of the site (Enclosure 6).

The "HALO" fire was caused by demolitions training conducted by the United States Marine Corps at Firing Point HALO. The Army is reviewing policy and procedures for operations conducted at this firing point in order to minimize the chance of reoccurrence.

The total acreage of area designated as Critical Habitat for the Oahu Elepaio burned by these two fires is 0.58 acres, which does not exceed the 3.7 acres allowed for adverse modification.

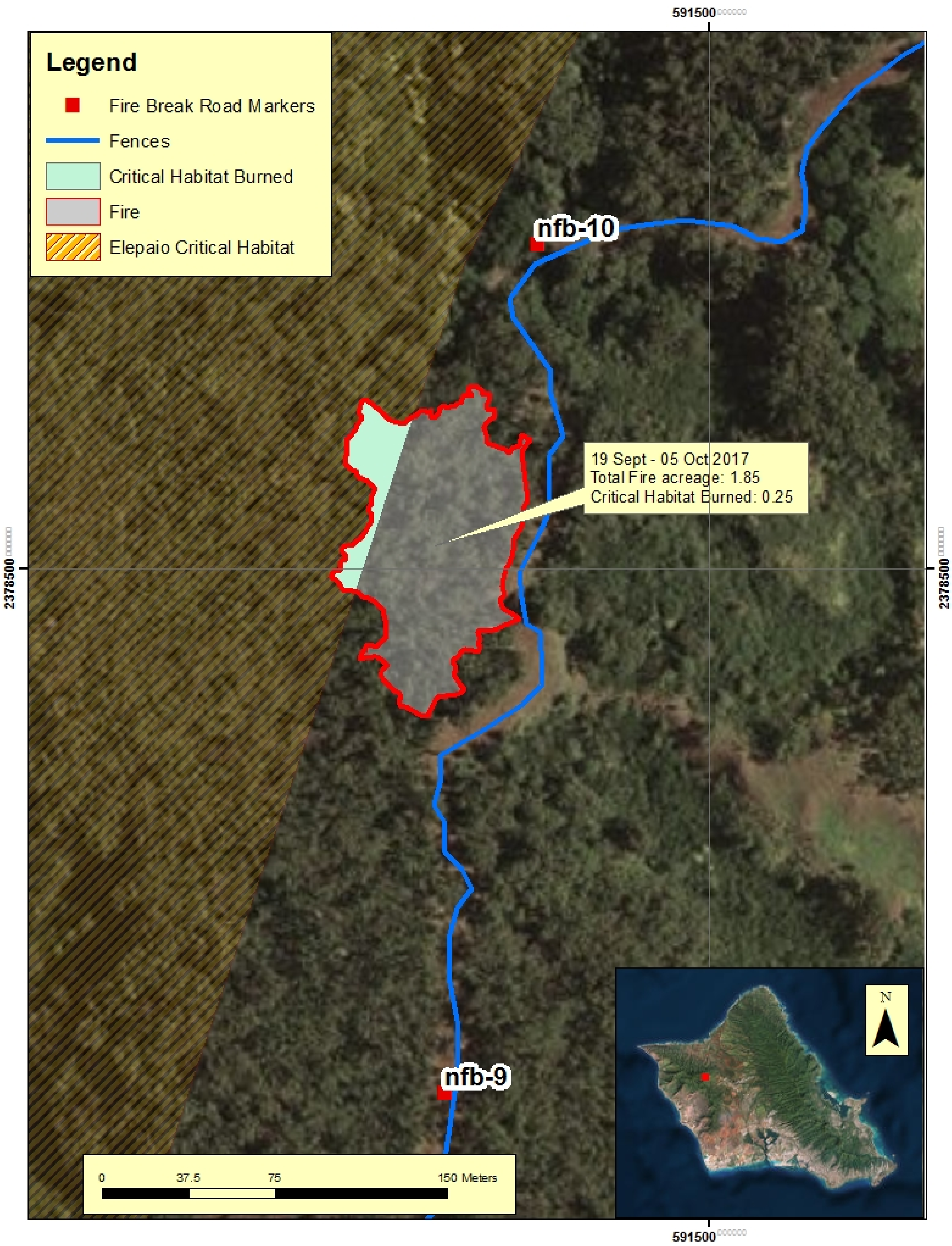
If you have any questionsplease contact Ms. Kapua Kawelo, Senior Natural Resources Manager, Directorate of Public Works, Environmental Division at (808) 655-9189 or hilary.k.kawelo.civ@mail.mil.

Sincerely,

Stephen E. Dawson
Colonel, U.S. Army
Commanding

Enclosures

Enclosure 1: Map of Mountain fire including area designated as Critical Habitat for Oahu Elepaio on Schofield Barracks, West Range. Critical Habitat impacted is 0.25 acres.



SIR/CCIR # 170913 ADD-ON # 15

REPORTING IOC, EOC, EAC: USAG-HI IOC/SSG Carter/TOR: 021738WOCT17

Subject: Add-On # 15 to Serious Incident Report # 170913

1. Category: 3-33(i)

2. Type of Incident: Range Fire

3. Date and Time:

   a. DTG of Incident: 190920WSEP17
   b. DTG of Receipt: 021738WOCT17

4. Location of Incident: Mountain Fire (4QEJ9142278490) North of Fire Break Road, Schofield Barracks, HI

5. Personnel Involved:

   a. Subject:

      (1) Name: N/A
      (2) Rank or Grade: N/A
      (3) Race: N/A
      (4) Sex: N/A
      (5) Age: N/A
      (6) Position: N/A
      (7) Security Clearance: N/A
      (8) Unit and Station of Assignment: N/A
      (9) Duty Status: N/A

6. Additional Information #15: Per ARMY FIRE IC on the Mountain Wildfire we will be starting the 72 hour watch period today at 1800 for the Mountain Fire. Fire update: Estimated containment is now 100%. Up 5% because no smoke has been observed for several days. No injuries and no property damage have been reported. Next update is in 72 hours 05OCT7 @ 1800 hours. Unless conditions change and then a new update will occur ASAP.
------------------------------------------------------------------------------------------------------------
Additional Information # 14: Good Evening, Per ARMY FIRE IC on the Mountain Wildfire at 1800 28SEP17 Fire update: Estimated containment is now 95%. Up 5% because no smoke has been observed today. There was no smoke observed today. We will keep the fire below 100% containment for several days because of the potential for re-burn as other fires have been doing this. No injuries and no property damage have been reported. Tonight:
Firefighters will remain on shift supporting other ranges for training. Next update is in 48 hours 30SEP17 @ 1800 hours. Unless conditions change and then a new update will occur ASAP.
------------------------------------------------------------------------------------------------------------
Additional Information #13 Fire update: Estimated containment is now 90%. Same as yesterday due to smoke and few logs burning still. Minimal activity today very minor smoke observed. We

will keep the fire below 100% containment for several days because of the potential for reburn as other fires have been doing this. No injuries and no property damage have been reported. Tonight: Firefighters will depart at end of shift. Next update is in 48 hours 28Sep17 @ 1800 hours. Unless conditions change and then a new update will occur ASAP

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Additional Information #12 Fire update: -3 Army Firefighter and 2 Engines were at the fire today and monitored the areas of concern on the southern line. A few pockets of unburned fuel consumed today but nothing appears to have threatened the line. –Total Fire areas is ½ acres. No changes from yesterday –fire location is at Grid: EJ 03368 75235 -80% Containment. Up 15% from yesterday. –We will keep the fire below 100% containment for several days because of the potential for reburn as other fires have been doing this. –No injuries and no property damage have been reported. Tonight: Firefighters will depart at end of shift. Next update is 26SEP17 @ 1800 hours.

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Additional Information #11: Per ARMY FIRE IC on the Mountain Wildfire at 1800 24SEP17 Fire update: Total Fire area is 6 acres. Of that 6 acres, 1.8 was in Critical Habitat. No new fire growth and no change from yesterday. Minimal activity today mostly this afternoon with interior areas still burning, Mostly logs and larger diameter fuels continuing to burn. Estimated containment is now 90%. Same as yesterday due to smoke and a few logs burning still. No injuries and no property damage have been reported. Tonight: Firefighters will depart at end of shift. Next update is 25SEP17 @ 1800 hours.

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Additional Information #10: Per ARMY FIRE IC on the Mountain Wildfire at 2000 23SEP17 Fire update: Total Fire area is 6 acres. Of that 6 acres, 1.8 was in Critical Habitat. No new fire growth and no change from yesterday. Minimal activity today mostly this afternoon with interior areas still burning, Mostly logs and larger diameter fuels continuing to burn. There are a few areas near the line that are still of concern and may need bucket drops tomorrow. Estimated containment is now 90%. Up 10% with less areas burning and very little smoke remains. No injuries and no property damage have been reported. Tonight: 2 Firefighters and 2 engines will be on and will monitor the fire as needed. Next update is 24SEP17 @ 1800 hours.

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Additional Information #9: Per ARMY FIRE IC on the Mountain Wildfire at 1000 23SEP17. Fire update: Total Fire area is 6 acres. Of that 6 acres, 1.8 was in Critical Habitat. No new fire growth and no change from yesterday. Minimal smoke observed in the interior of the fire. Estimated containment is now 80%. Today’s plan: 3 firefighters and 2 engines will monitor and respond as needed. MEDIVAC AIRCRAFT ON STANDBY IF NEEDED. Next update is 23SEP17 @ 1800 hours.

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Additional Information #8: Per Army Fire IC on the Mountain Wildfire at 2035 22SEP17 Fire update: Total Fire area is 6 acres. Of that 6 acres, 1.8 was in Critical Habitat. No new fire growth and no change from yesterday. Minimal activity today mostly this afternoon. Army Fire was able to keep the fire in check with about 6 meters of additional growth interior and along flanks. Estimated containment is now 80%. Today summary: 2 firefighters and 2 engines worked the fire mostly on eastern and southern edges. Tonight: 2 Firefighters and 2 engines will be on and will monitor the fire as needed. Next update is 23SEP17 @ 1000 hours.

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Additional Information #7: Per ARMY FIRE IC on the Mountain Wildfire at 1015 22SEP17. Fire update: The Fire acreage is estimated at 6 acres and 1.8 acres of Critical Habitat. This is not final acreage until DPW is able to verify from the ground. Estimated containment is now 70%. Today's plan of action: 4 firefighters and 2 engines will be working the fire with the assistance from the CAB. Next update is 22SEP17 @ 1800hrs.

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Additional Information #6: Per ARMY FIRE IC on the Mountain Wildfire at 1635 21SEP17 Fire update: At 0800 today DPW Environmental was able to fly the perimeter of the fire to update maps and acreage. The Fire acreage is estimated at 6 acres and 1.8 acres of Critical Habitat. This is not final acreage until DPW is able to verify from the ground. Fire cause is believed to be from an aerial cluster. Estimated containment is now 70%. Today summary: 5 firefighters and 2 engines worked the fire with the assistance from the CAB. The CH47 tail number 782 did 8 bucket drops with a 2,000 gallon bucket. The UH60 did 8 bucket drops with a 660 gallon bucket. There was very minimal fire spread today due to heavy saturation from the aircrafts. Tonight: 2 Firefighters and 2 engines will be on to support other ranges tonight and can monitor fire as needed. Next update is 22SEP17 @ 1000 hours

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Additional Information #5: Per ARMY FIRE IC on the Mountain Wildfire at 0935 21SEP17 Fire update: At 0800 today DPW Environmental was able to fly the perimeter of the fire to update maps and acreage. The fire acreage may actually be less due to better mapping today and we will update those acres as they are available. The Fire acreage is estimated at 9 acres. Elepaio Critical Habitat that was burned is estimated to be about 6 acres. Fire cause is believed to be from an aerial cluster. Estimated containment is now 40%. Today: 4 ARMY firefighters and 2 Engines are working the fire today with the assistance from the CAB with CH47 this morning and UH60 this afternoon. Last night the fire grew minimally and conditions this morning are favorable for suppression actions. The CH47, currently on scene, will be utilized to directly attack any areas that are still burning and pre-treat surrounding vegetation to eliminate any further fire spread on the flanks and head of the fire. Next update is 21SEP17 @ 1800 hours.

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Additional Information #4: Per Army Fire Mountain Wild Fire Incident at 1645 20SEP17, total fire acreage is 9 acres. Elepaio Critical Habitat that was burned is about 6 acres. Fire cause is believed to be from an aerial cluster. Estimated containment is now 40%. Up 10% from aerial bucket drops on the northern and western edge of the fire. The CAB with UH60 #440 assisted with 28 bucket drops and total of 19,000 gallons of water delivered on the fire. No injuries or property damage has been reported today. Tonight: 2 ARMY firefighters and 2 Engines will remain on shift to monitor the fire. Last night the fire grew approximately 2 acres overnight and we expect similar activity tonight. Next update is 21SEP17 @ 1000 hours.

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Additional Information #3: Per Army Fire Mountain Wild Fire Incident total acre of fire is 8.33, Elpaio Critical Habitat that was burned is about 5.07 acres. Cause of fire believed to be from an aerial cluster. Estimated containment of fire is now 30%. No injuries on property damage has been reported. 1 UH60 is on station and working the fire with buckets, 4 Army firefighter and 2 engines are also on scene and securing the fire edge along fire break road. The MEDEVAC helicopter supported the firefighting effort yesterday (19 SEP 17), 1100-1400, dropping 19 buckets (12,350 gallons).

DPW Environmental: As of 1045 20Sept17, the current range fire burning above the SB Firebreak road burned more acreage of ‘elepaio critical habitat than allowed, annually, by the current biological opinion (BO). The BO was issued by the U.S. Fish and Wildlife Service (USFWS), for potential impacts to listed endangered species by training actions on SB.

The local USFWS was notified on 20Sept2017 of the fire and current impacts, by telephone. A formal memo/report will be sent to the USFWS regarding the fire and the impacts
POC: Hilary (Kapua) Kawelo, hilary.k.kawelo.civ@mail.mil (808-655-9189/808-864-1014) or Rhonda Suzuki, rhonda.l.suzuki.civ@mail.mil (808-656-5790/808-927-6655)
---------------------------------------------------------------------------------------------------------
Additional Information #2: Per Army Fire Incident Commander on the “Mountain” wildlfire, 19Sep17 at 1710hrs. Fire update: The fire is located north of the Fire Break near NFB marker 10. Located in an area that is not accessible by foot. Medivac helicopter was ordered to assist with buckets and arrived on scene at 1100 and departed around 1400hrs. 19 buckets (12,350 gallons) were delivered on the fire. Fire cause is believed to be from a aerial cluster. The size of the fire is estimated at 5acres. Up 3 acres. This afternoon weather conditions and issues with aerial resources contributed to the additional growth. Estimated containment is now 30%. No injuries or property damage has been reported today. The fire may be Elepaio habitat. An aerial recon in the morning will confirm this and if its in the habitat the USFWS will be notified. Tonight: 2 firefighters and 2 fire engines will be on tonight supporting training and will periodically check this fire as well. Next update is 20Sep17 @ 1000 hours. 2x UH60’s were requested and approved to be on scene tomorrow morning at 0830.
---------------------------------------------------------------------------------------------------------
Additional Information: Per Army Fire Incident Commander on the “Mountain” wildfire. 19Sep17 at 1110hrs. Fire update: The fire is located north of the Fire Break burning in an area that is not accessible by foot. Medivac helicopter was ordered to assist with buckets and arrived on scene at 1100. Fire cause is unknown at this time. The size of the fire is estimated at 2 acres. Estimated containment is now 40%. No injuries or damage to resources or property has been reported today. Today: 3 Firefighters, 2 Engines, and 1 Water Tender will monitor the fire as needed. As of 1239hrs, Army Fire requested 2 UH60s ASAP to assist the Medevac UH60 on scene. Total affected acreage is 4 acres.
---------------------------------------------------------------------------------------------------------
Summary of Incident: At approximately 0900 hrs it appeared that there was smoke coming from down range, however the cloud coverage was low at this time. Army Fire was called to verify. At 0926hrs Army Fire reported that it appears to be 2 acres burnt outside the North Fire Break road. Stated that they were requesting Medevac support. OIC was called at 0950 to inform them of the fire. At 1000 hrs Mr. Au briefed on fire and Medevac called for support

7. Remarks: None

8. Publicity: No Media

9. Next of Kin Notified: No

10. Affects International Relationships: No

11. Command Reporting: COL Stephen E. Dawson, Commander, USAG-HI

12. Originating Point of Contact: Justin L. Turnbo, Directorate of Emergency Services, Wildland Fire Management, USAG-HI at 655-1434 or justin.l.turnbo.civ@mail.mil.

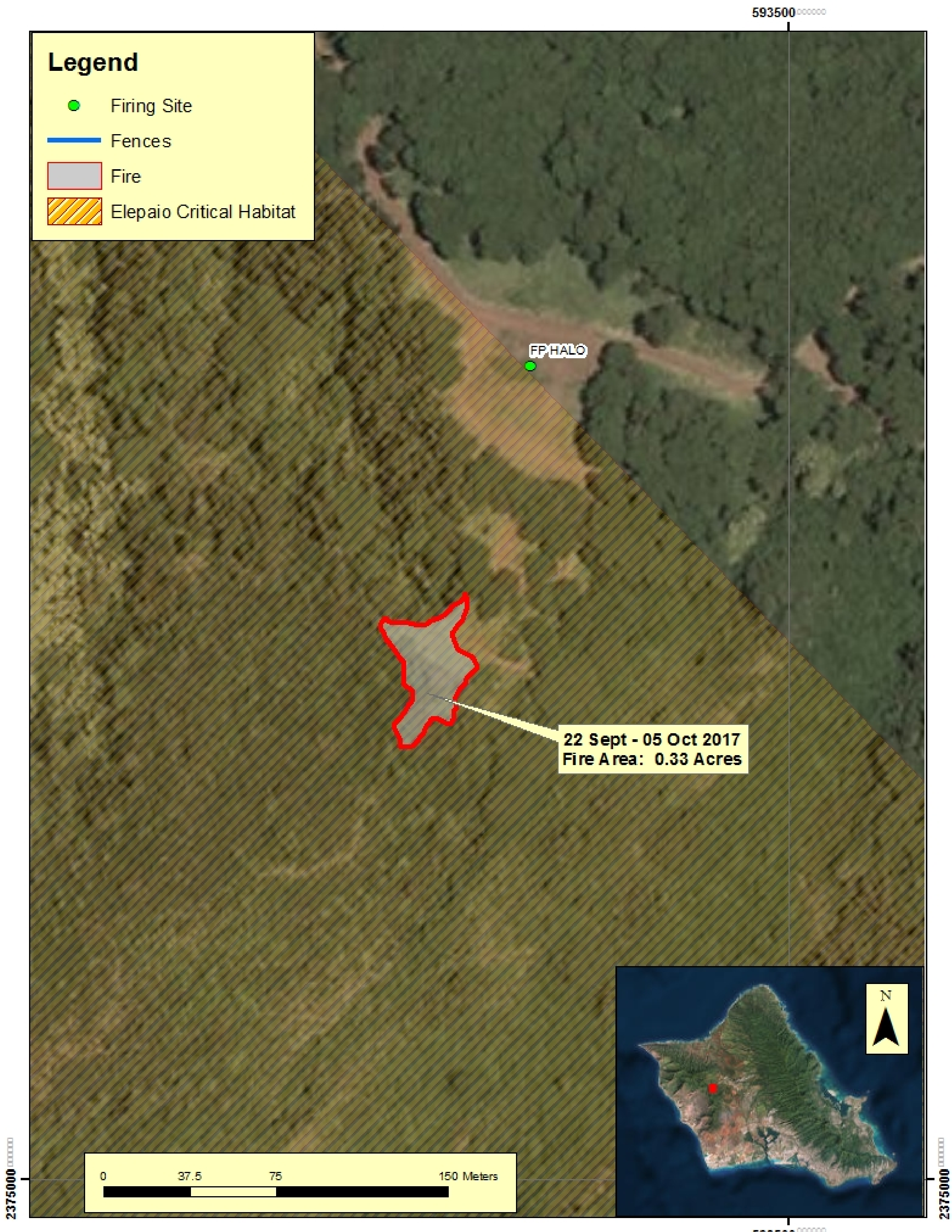
13. This Report has been Approved for Release by: Kam Y Yu, Range Technician, Schofield Barracks Range Control at 655-1434 or kam.y.yu.civ@mail.mil

14. Was USARPAC CG Informed: No

Enclosure 3: Plants burned in the "Mountain" Fire

| **Scientific Name** | **Common Name** |
|---|---|
| | |
| **PLANTS** | |
| *Clidemia hirta* | Koster's curse |
| *Eucalyptus robusta* | |
| *Lantana camara* | |
| *Melaleuca quiquinervia* | Paperbark |
| *Schinus terebinthifolius* | Christmasberry |
| *Toona ciliata* | Australian Red Cedar |
| *Urochloa maxima* | Guinea grass |

Enclosure 4: Map of HALO fire located within area designated as Critical Habitat for Oahu Elepaio on Schofield Barracks, South Range. Total acreage of fire is 0.33 acres.



IR/CCIR # 170929 ADD-ON # 9

REPORTING IOC, EOC, EAC:USAG-HI IOC/SSG Difuntorum/TOR: 051711WOCT17

Subject: Add-On # 9 to Incident Report # 170929

1. Category: 3-33(i)

2. Type of Incident: Range Fire

3. Date and Time:

    a. DTG of Incident: 221455WSEP17
    b. DTG of Receipt: 051711WOCT17

4. Location of Incident: Firing Point HALO (EJ 93368 75235), Schofield Barracks, HI

5. Personnel Involved:

    a. Subject:

        (1) Name: N/A
        (2) Rank or Grade: N/A
        (3) Race: N/A
        (4) Sex: N/A
        (5) Age: N/A
        (6) Position: N/A
        (7) Security Clearance: N/A
        (8) Unit and Station of Assignment: United States Marine Corps School of Infantry (USMC-SOI) Kaneohe Bay, HI
        (9) Duty Status: N/A

6. Additional Information # 9: Per Army Fire OP HALO fire is declared out. There will be no further updates.

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Additional Information # 8: Per ARMY FIRE IC on the OP Halo Wildfire: We will be starting the 72 hour watch period today at 1800 for the Mountain Fire .Estimated containment is now 100%. Up 5% because no smoke has been observed for several days. No injuries and no property damage have been reported. Next update is in 72 hours 05OCT7 @ 1800 hours. Unless conditions change and then a new update will occur ASAP.

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Additional Information # 7: Good Evening, Per ARMY FIRE IC on the OP Halo Wildfire at 1800 28SEP17 Fire update: No new fire growth 90% Containment. Up 5%. No smoke was observed today. We will keep the fire below 100% containment for several days because of the potential for reburn as other fires have been doing this. No injuries and no property damage have been reported. Tonight: Firefighters will remain onshift supporting other ranges for training.

Next update is in 48 hours 30SEP17 @ 1800 hours. Unless conditions change and then a new update will occur ASAP.

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Additional Information # 6: Per Army Fire IC on the OP Halo Wildfire at 1800 26Sep17. Fire update: No new fire growth. Fire location is at Grid: EJ 93368 75235-85% containment. Up 5% from yesterday. We will keep the fire below 100% containment for several days because of the potential for reburn as other fires have been doing this. No injuries and no property damage have been reported. Tonight: Firefighters will depart at end of shift. Next update is in 48 hours 28Sep17 @ 1800 hours. Unless conditions change and then a new update will occur ASAP.

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Additional Information # 5: Per Army Fire IC on the OP Halo Wildfire at 1800 25 Sep17: Fire update: 3 army Firefighters and 2 Engines were at the fire today and monitored the areas of concern on the Southern line. A few pockets of unburned fuel consumed today but nothing appears to have threatened the line. Total Fire area is ½ acres. No change from yesterday fire location is at Grid: EJ 93368 75235 -80% Containment. Up 15% from yesterday. We will keep the fire below 100% containment for several days because of the potential for reburn as other fires have been doing this. NO injuries and no property damage have reported.

------------------------------------------------------------------------------------------------------------

Additional Information # 4: Per ARMY FIRE IC on the OP Halo Wildfire update: 3 Army Firefighters and 2 Engines were at the fire today and monitored the areas of concern on the southern line. A few pockets of unburned fuel consumed today but nothing appears to have threatened the line. Total Fire area is 1/2 acres. No Change from yesterday -Fire location is at Grid: EJ 93368 75235 -65% Containment. Up 15% from yesterday. Tonight's Plan: ARMY Fire is on scene with 2 firefighter and 2 engines. Will keep monitoring the fire and ensuring that the southern area of concern does not get going. Will have to wait till daylight if direct Attack is needed and utilize aircraft. Next update will be 24 hours from now on 25SEP17 @ 1800 hours.

------------------------------------------------------------------------------------------------------------

Additional Information # 3: Per ARMY FIRE IC on the OP Halo Wildfire at 2000 23SEP17 Fire update: Total Fire area is 1/2 acres. No Change from yesterday -Fire location is at Grid: EJ 93368 75235 -50% Containment. No change from this morning. Only had UH60 for 1 fuel cycle and there are still areas on the southern flank that are of concern. CAB supported with 1 UH60 for 2 hours and delivered 6500 gallons of water (10 Buckets). UH60 worked the southern area that is still hot with fuels burning very close to containment line Tonight's Plan: ARMY Fire is on scene with 2 firefighter and 2 engines. Will keep monitoring the fire and ensuring that the southern area of concern does not get going. Will have to wait till daylight if direct Attack is needed and utilize aircraft Next update will be 24 hours from now on 24SEP17 @ 1800 hours.

------------------------------------------------------------------------------------------------------------

Additional Information # 2: Per ARMY FIRE IC on the OP Halo Wildfire at 1005 23SEP17. Fire update: Total Fire area is 1/2 acres. No Change from last night. Fire location is at Grid: EJ 93368 75235 – 50% Containment. No change from last night. Today's Plan: Army Fire is on scene with 3 firefighters and 2 engines. Waiting on support from UH60, CAB or Medivac. Once UH60 arrives then bucket drops will be used to secure the edge and interior of the fire that firefighters cannot access on the ground. Next update is 23SEP17@1800hours.

------------------------------------------------------------------------------------------------------------

Additional Information: Per ARMY FIRE IC on the OP Halo Wildfire at 2035 22SEP17. Fire update: Total Fire area is 1/2 acres. Fire location is at Grid: EJ 93368 75235 -50% Containment. Fire Cause was from demolition blasting. Summary of Actions: ARMY Fire responded to the fire at 15:22 with 4 firefighters and 2 Engines and a Water Tender. Requested air support and Medivac 30595 arrived at 1600. Flew 2.5 hours and delivered 8,500 gallons of water (13 buckets) to the fire. Tonight: 2 Firefighters and 2 engines will be on and will monitor the fire as needed. Next update is 23SEP17 @ 1000 hours.

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Summary of Incident: USMC-SOI was conducting training at FP HALO using demolitions when range was ignited. Army Fire was notified and responded with 1 brush truck and 2 personnel. Medevac air notified to be on standby by Army Fire's recommendation. No size indicated as to how much area was consumed at this time.

7. Remarks: Land Operation Center will forward report to the Respective Command Center.

8. Publicity: No Media

9. Next of Kin Notified: No

10. Affects International Relationships: No

11. Command Reporting: COL Stephen E. Dawson, Commander, USAG-HI

12. Originating Point of Contact: Justin L. Turnbo, Directorate of Emergency Services, Wildland Fire Management, USAG-HI at 655-1434 or justin.l.turnbo.civ@mail.mil

13. This Report has been Approved for Release by Justin L. Turnbo, DES, Wildland Fire Management, USAG-HI at 655-1434 or justin.l.turnbo.civ@mail.mil

14. Was USARPAC CG Informed: No

Enclosure 6.  Plants burned in the HALO fire.

| Scientific Name | Common Name |
|---|---|
| Native Plants | |
| *Acacia koa* | koa |
| Non-Native Plants | |
| *Schinus terebinthifolius* | Christmas Berry |
| *Melaleuca quinquenervia* | paperbark |
| *Chlidemia hirta* | Koster's curse |
| *Urochloa maxima* | guineagrass |

Burned koa.

Burned mixed forest.

Guinea grass dominated understory

Makaha/Keaau Fire Memorandum for Record
August 5-8, 2018

August 4, 2018

The Makaha/Keaau fire began likely due to arson in the afternoon of Saturday August 4, 2018. Senior Natural Resource Management Coordinator (Rohrer) got alerted to the fire as well as many other ignitions (Waianae 'Baby girl' fire) on Saturday afternoon by DOFAW Forester Peralta. Reports from Saturday indicated that the fires where low in elevation and not likely to impact Army areas. The fire in Makaha was at low elevation and burning near the condo towers. Peralta reported that the fires had not entered the Forest Reserve.

August 5, 2018

Rohrer received a call from Natural Resource Management Technician Dave Hoppe-Cruz at approximately 0830. Hoppe-Cruz reported fire burning through the *Hibiscus brackenridgei* fence in Keaau. The fire was burning down slope through the fence unit. The fire was also spreading through the *Gouania vitifolia* fence constructed by DOFAW. It was shocking to hear that the fire had crossed over two gulches to reach the fences in Keaau. This spread apparently happened late Saturday and early Sunday. This was terrible news as then endangered *Hibiscus* and *Gouania* was already being impacted by the flames. Rohrer alerted Peralta to the situation. Peralta reported coordinating with HFD in an attempt to get support for the area. Peralta was engaged with state crews with the Baby Girl fire in Waianae. Oahu Natural Resource Manager Kawelo began to notify Army personel of the impacts in an effort to get Army aviation support. Rohrer reported the incident to Program Manager Smith and began coordination with K&S helicopters. Kawelo and Rohrer mobilized from home to Schofield base. After collecting gear at the base Kawelo and Rohrer met Hoppe-Cruz on the road at Keaau at 1200. After a debriefing and observing the fire status, Kawelo and Rohrer continued to Makua to meet K&S pilot Lang.

Fire seen spreading into Keaau on the morning of August 5 by David Hoppe-Cruz

K&S pilot Lang arrived in Makua at 1215. A quick aerial survey was conducted by Lang and Rohrer. Unfortunately the survey revealed that the *Hibiscus* area had already burned over and the *Gouania* area was about 75% impacted. The fire was spreading downslope through the *Gouania* fence. Lang began water bucket operations in the *Gouania* fence trying to prevent damage to the *Gouania* and prevent the fire spread toward Ohikilolo ridge and Makua Military Reservation. Lang continued water drops until 1800.

Fire spreading through the *Gouania* fence at midday Sunday August 5

Fire front spreading downslope in Keaau fence at midday Sunday August 5

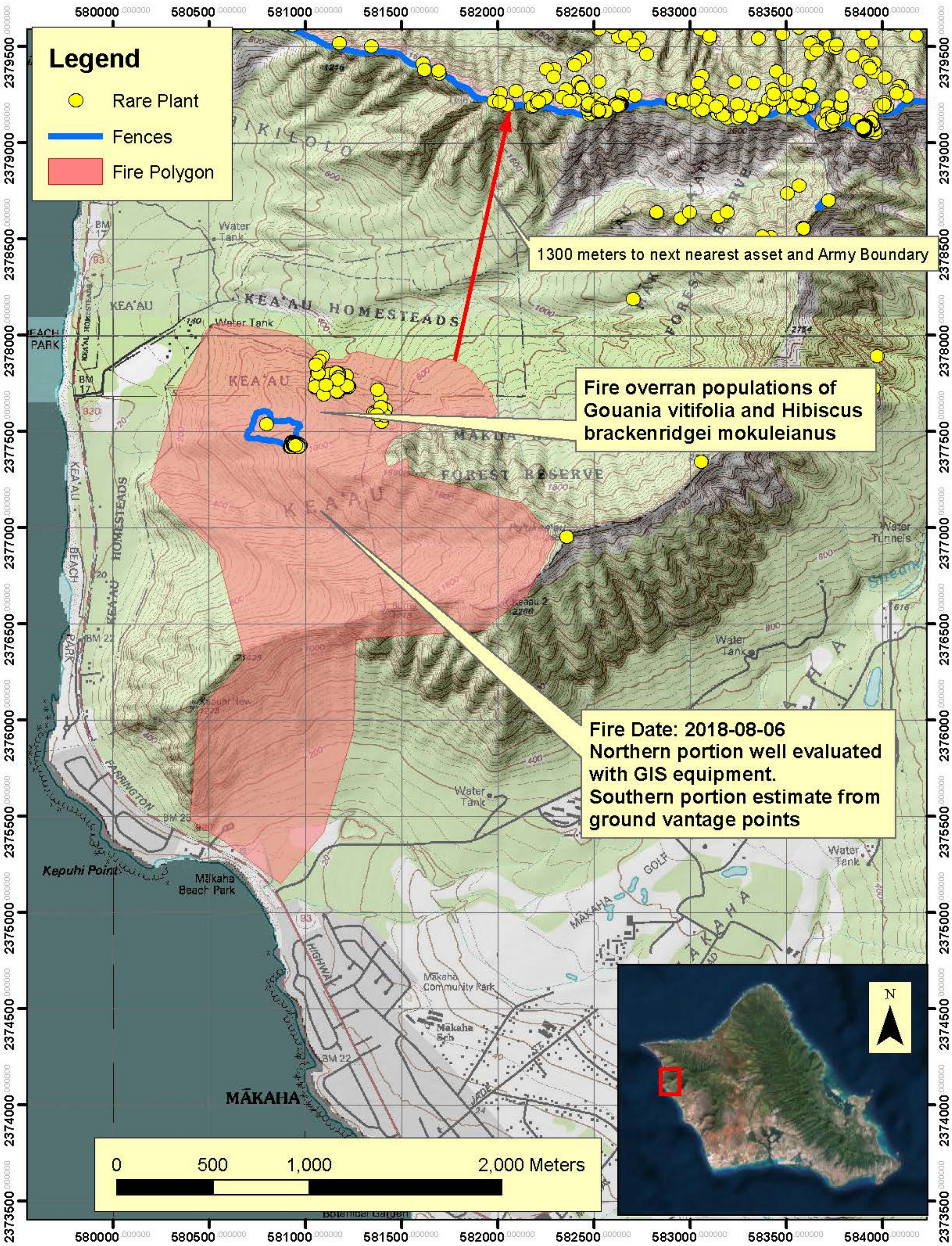
Army Biologist Smith arrived onsite a 1300 and began to assist with operations. Army Wildland crew Gibbs, Turnbo and Faber arrived on site at 1430 and debriefed with environmental staff. Wildland staff staged operation in Keaau where they had a better view of the fire and helicopter water drops. Chief Gibbs stayed in Makua to oversee operations.

Army Environmental personnel also assisted Army Wildland Fire by preparing the dip pond transferring water from storage tanks to the pond. The pond was only 1/6 full upon arrival at Makua.

Army Blackhawks reported to the area at approximately 1530. One ship (Army 446) had significant bucket issues and was forced to return to Schofield. Communications were also an issue initially however after assistance from Schofield range control, communications were established with Army pilots using frequency 122.925 on the ICOM handheld radios. Army Fire Turnbo requested 4 Blackhawk ships but due to some difficulties there were never more than two on scene. One with a long line configuration and one with a belly hook. Army ships delivered approximately two dozen 660 gallon buckets to Keaau under the direction of Army Wildland Fire. Blackhawks were onsite for approximately 3 hours.

There was one additional survey conducted by Kawelo, Army Biologist Smith and Army Fire Chief Gibbs. Preliminary mapping was completed on this flight. Unfortunately, the survey revealed that efforts had not stopped the spread through the *Gouania* fence. However the fire had been held at the gulch bottom of Keaau, stopping further spread toward Makua.

August 5, 2018 Fire Extent



Weather on Sunday was windy and mostly dry, however there were periods of showers in the back of the valley and the showers occasionally reached the shoreline. As there were no firefighters on the ground personnel did not take hourly weather.

Staff were onsite until 1930, a debrief was conducted and plans were made for the next day.

August 5 Summary

| Staff | Time | Total Hours |
|---|---|---|
| Kapua Kawelo | 1000-1930 | 8.5 |
| Joby Rohrer | 1000-1930 | 8.5 |
| Paul Smith | 1300-1930 | 6.5 |

August 5 Air Asset Summary N545PH

| Time | Note |
|---|---|
| 1215 | Arrive at Makua and depart on aerial survey |
| 1230 | Aerial survey complete and water drops started |
| 1400 | Fuel run |
| 1415 | Water drops continue |
| 1545 | Fuel run |
| 1600 | Water drops continue |
| 1730 | Fuel Run |
| 1745 | Water drops continue |
| 1845 | Return to Makua and conduct aerial survey |
| 1915 | Depart to Turtle Bay |

August 6, 2018

Army Biologist Smith reported directly to Makua arriving at 0800. Army Fire personnel were on site in Keaau at 0800. Rohrer reported to Makua at 0830. Smith and Rohrer assist with aerial operations from Makua valley. K&S pilot Kahekili arrived to Makua valley at 0830. Contract helicopter was prepared for ops. Rohrer and Smith conducted aerial survey of Keaau fire line with K&S pilot at approximated 0840. K&S pilot started bucket ops immediately following aerial survey. Rohrer and Smith started weather monitoring at 0840 and communicated conditions to Army Wildland Fire hourly. Army Blackhawk 446 flew into the area at 0830 but left with apparent bucket problems without making radio contact. Army 446 (belly hook) and Army Blackjack 98 (longline) arrived on site at 0920 and immediately began bucket ops under direction of Army Wildland Fire personnel located in Keaau Valley. At 0945, K&S pilot was called off to support HFD until they could get their aircraft airborne. At 1000 Army 446 left scene for refuel. K&S pilot returned at 1004 and immediately continued with bucket ops. At 1040, Blackjack 98 left scene to refuel. Army 446 returned to the scene at 1100 and resumed bucket ops. At 1130 K&S pilot left scene for refuel and returned at 1144. Blackjack 98 returned to scene at 1215. Army 446 left to refuel at 1230. After consultation with Army Wildland Fire personnel, K&S pilot was sent back to Turtle Bay at 1240 to shutdown for 2-3 hours to save some duty day flight hours for later in the afternoon. At 1300 Natural resource staffer Lee arrived to replace Rohrer. At 1330, Blackjack 98 left for refuel and was replaced by Dustoff 597. At 1408 Army Wildland Fire personnel request K&S pilot be recalled early due to increased fire activity and requested an additional person to assist with visual monitoring of fire line. Lee travelled to Keaau and provided visual support to Army Wildland Fire. Lee stationed along road lined with Plumerias below Our Lady of Keaau and watched the area to the South. Smith stayed at Makua LZ to assist K&S pilot upon return. Contact could not be immediately made with K&S pilot. At 1412, Army 518 arrived and commenced bucket ops. At 1423 Dustoff 597 dropped bucket at Makua LZ and left for fuel. K&S pilot was contacted and arrived back on scene at 1455 and immediately commenced bucket ops. Blackjack 98 arrived back on scene at 1455 as well. At approximately 1530, K&S pilot conducted a brief survey of Makaha valley and observed an active fireline approaching the area with the potential to crest the ridgeline and either merge with the Keaau fire or move into Makua valley. At 1543, pictures of the approaching fire were sent to Army Wildland Fire to evaluate if resources should be diverted to address this new threat. K&S pilot left to refuel at the same time. K&S pilot returned at 1553 and was directed by Army wildland Fire to conduct bucket drops on the Makaha line. At least one Army UH 60 was diverted to the Makaha line as well. Dustoff 597 arrived back on scene at 1626 and encountered bucket problems until 1645, then commenced bucket ops.

Fire spreading in Makaha on midafternoon on August 6

<u>August 6 Summary</u>

| Staff | Time | Total Hours |
|---|---|---|
| Paul Smith | 0800-1900 | 11 |
| Joby Rohrer | 0830-1330 | 5.0 |
| Julia Lee | 1300-1900 | 6.0 |

<u>August 6 Air Asset Summary N545PH</u>

| Time | Note |
|---|---|
| 0830 | Arrive at Makua shut down brief and prepare for survey |
| 0850 | Survey complete and begin water drops |
| 0945 | Depart to support HFD |

| | |
|---|---|
| 1004 | Return and begin water drops |
| 1008 | Run for fuel |
| 1018 | Return and begin water drops |
| 1130 | Run for fuel |
| 1144 | Return and begin water drops |
| 1241 | Send to Turtle Bay for shutdown and fuel |
| 1455 | Return and begin water drops |
| 1543 | Run for fuel |
| 1553 | Return and begin water drops |
| 1715 | Run for fuel |
| 1725 | Return and begin water drops |
| 1745 | Return to Makua and conduct fire survey |
| 1830 | Return to Turtle Bay |

August 6 Air Asset Summary Blackhawk 446: Short Line Configuration

| | |
|---|---|
| 0830 | Arrive on scene and recon, no coms with ground personnel depart back to wheeler |
| 0920 | Arrive back on scene and begin bucket drops in Keaau |
| 1000 | Depart to Wheeler for fuel |
| 1100 | Returns from fuel and continues bucket drops in Keaau |
| 1230 | Depart to Wheeler for fuel |
| | |

August 6 Air Asset Summary Blackhawk Blackjack 98: Long Line Configuration

| | |
|---|---|
| 0920 | Arrive back on scene and begin bucket drops in Keaau |
| 1040 | Depart to Wheeler for fuel |
| 1215 | Returns from fuel and continues bucket drops in Keaau |
| 1330 | Depart to Wheeler for fuel |
| 1455 | Returns from fuel and continues bucket drops in Keaau |
| 1630 | Depart to Wheeler |

August 6 Air Asset Summary Blackhawk Dustoff 597: Long Line Configuration

| | |
|---|---|
| 1330 | On scene and starting bucket drops in Keaau |
| 1423 | Depart to Wheeler for fuel |
| 1626 | Returns from fuel and has bucket issues |
| 1645 | Bucket issues resolved and beginning bucket drops |
| 1815 | Depart for Wheeler |

August 6 Air Asset Summary Blackhawk Army 518: Short line configuration

| | |
|---|---|
| 1412 | On scene and starting bucket drops in Keaau |
| 1600 | Depart for Wheeler |

Hourly Weather August 6, 2018

| Time | Temp | RH | Wind Speed | Wind direction |
|---|---|---|---|---|
| 0840 | 83.3 | 57 | 3.5 | ESE |
| 1000 | 89.0 | 55 | 3.0 | ESE |
| 1100 | 87.2 | 51 | 8.0 | E |
| 1200 | 86 | 49 | 6.0 | SSE |
| 1310 | 87.0 | 47 | 4.0 | SE |
| 1400 | 91.0 | 44 | 10 | SE |

| | | | | |
|---|---|---|---|---|
| 1500 | 90.0 | 48 | 10-15 | ESE |
| 1600 | 88.0 | 52 | 7 | ESE |
| 1700 | 82.0 | 57 | 10-12 | ESE |

August 7, 2018
Rohrer and Natural Resource Coordinator Valdez report to Makua at 0850. Wildland Fire Faber conducted a recon in Keaau then arrives at Makua at 0900. Army Blackhawks 597 and 483 begin bucket drops on active fire in Makaha at approximately 0850. K&S pilot Kahekili arrives in N545PH at 0915 and shuts down to remove doors. Rohrer, Valdez and Faber conducted an aerial survey, map the fire boundary and Faber sends Blackhawks to Makua to shut down and await future instruction. The survey reveals that the fire has not spread overnight in Keaau. Most active fire is in Makaha on the north side of the valley moving up valley. At 1015 Faber conducts a briefing with Blackhawk crews and while Kahekili makes a fuel run. The strategy is to continue to wet down the line in Keaau with the Blackhawk 597 with short line bucket under the direction of K&S Kahekili. Blackhawk 483 is assigned to continue working in Makaha.

Makaha valley on morning of August 7. Fire most actively burning on North side. Upper left of the photo.

North side of Makaha valley, *Tetramalopium* peak along boundary of MMR visible in background

At 1030 Valdez and Army Fire Faber relocate to Keaau to help direct helicopters. Rohrer stays in Makua. Rohrer secures access to dip ponds in Makaha by contacting Landis Ornellas. Water drops continue through the morning as directed by Wildland fire. DOFAW crew mobilize to Keaau after lunch and Army fire moves all Army ships to Makaha. Rare Plant Program manager Dan Adamski reports to the incident at 1300 and Rohrer returns to the baseyard. Adamski posts as a lookout at Keaau supporting Wildland Fire. See table below for detailed accounting of ships and personnel.

August 7 Summary

| Staff | Time | Total Hours |
|---|---|---|
| Missy Valdez | 0850-1900 | 10 |
| Joby Rohrer | 0850-1330 | 4.5 |
| Dan Admanski | 1300-1900 | 6.0 |

August 7 Air Asset Summary N545PH

| Time | Note |
|---|---|
| 0915 | Arrive at Makua shut down brief and prepare for survey |
| 1015 | Survey complete and going on fuel run |
| 1036 | Return from fueling and begin water drops |
| 1151 | Shut down at Makua to preserve flight time for later in the day |
| 1346 | Run for fuel |
| 1400 | Return and begin water drops |
| 1542 | Return to Makua drop bucket and go for fuel |
| 1700 | Done for the day; shut down, replace doors and head to TBR |

August 7 Air Asset Summary Blackhawk 597: Short Line Configuration

| Time | Note |
|---|---|
| 0830 | Arrive at Makua and after a recon begins water drops in Makaha |
| 1000 | Shut down in Makua and brief with Wildland Fire |
| 1041 | Depart Makua and begin Water drops in Keaau |
| 1137 | Drop bucket in Makua and depart to Wheeler for fuel |
| 1220 | Back on site hook bucket and resume water drops in Makaha |
| 1310 | Drop bucket in Makua and depart to Wheeler for fuel |
| 1510 | Back on site hook bucket and resume water drops in Makaha |
| 1620 | Drop bucket in Makua and depart to Wheeler for fuel |
| 1723 | Back on site hook bucket and resume water drops in Makaha |
| 1819 | Done for the day, departs for Wheeler |

August 7 Air Asset Summary Blackhawk 518: Short Line Configuration

| Time | Note |
|---|---|
| 1043 | Arrive at Makua and after a recon begins water drops in Makaha |
| 1200 | Done for the day, departs to Wheeler |

August 7 Air Asset Summary Blackhawk 483: Long Line Configuration

| Time | Note |
|---|---|
| 0830 | Arrive at Makua and after a recon begins water drops in Makaha |
| 1000 | Shut down in Makua and brief with Wildland Fire |
| 1035 | Depart Makua and begin Water drops in Makaha |
| 1137 | Drop bucket in Makua and depart to Wheeler for fuel |
| 1205 | Back on site hook bucket and resume water drops in Makaha |

| | |
|---|---|
| 1340 | Done for the day, departs for Wheeler |

August 7 Air Asset Summary Blackhawk 437: Long Line Configuration

| Time | Note |
|---|---|
| 1445 | Arrive at Makua and after a recon begins water drops in Makaha |
| 1516 | Back to Makua to fix bucket |
| 1520 | Bucket fixed and return to Makaha for water drops |
| 1558 | Drop bucket in Makua and depart to Wheeler for fuel |
| 1633 | Back on site hook bucket and resume water drops in Makaha |
| 1720 | Back to Makua to fix bucket |
| 1725 | Bucket fixed and return to Makaha for water drops |
| 1810 | Done for the day, departs for Wheeler |

Aerial efforts stop additional spread in Keaau. Extensive efforts in Makaha stop the active fire from advancing further into the valley and possible spread over toward Keaau.

Hourly Weather August 7, 2018

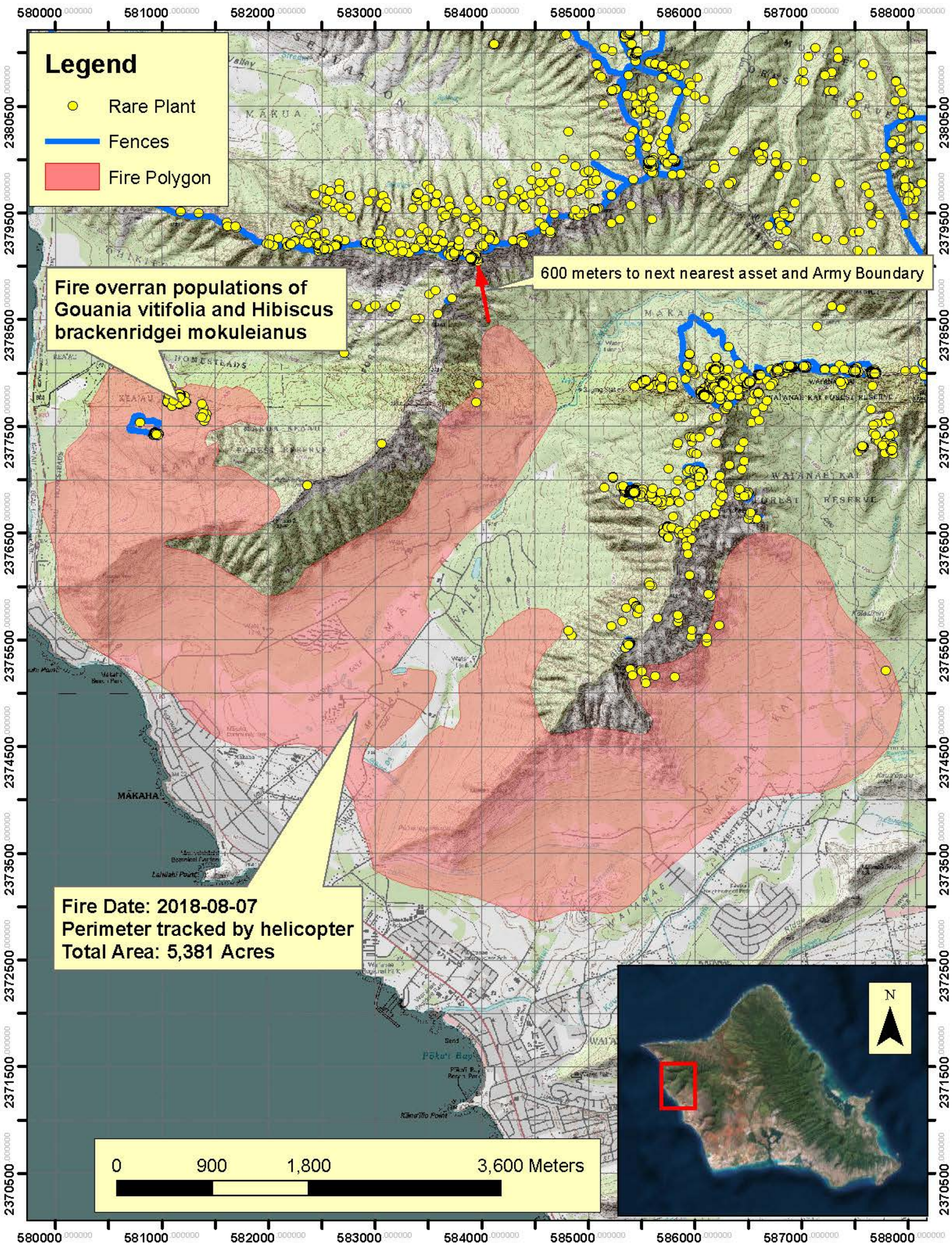
| Time | Temp | RH | Wind Speed | Wind direction |
|---|---|---|---|---|
| 0900 | 81.2 | 60.7 | 5.6 | NE |
| 0930 | 86.8 | 57 | 6 | NE |
| 1020 | 89 | 47 | 6 | NE |
| 1100 | 88 | 49 | 7 | NE |
| 1200 | 87 | 48 | 6.0 | NE |
| 1300 | 84 | 64 | 10 | NE |

Weather was hot and day until the afternoon when the RH began to raise in Makua. As this was not the case in Keaau the weather was taken after 1300 from Keaau by wildland fire.

August 8, 2018

No Army resources report to incident. DOFAW Peralta and crew work on the ground in Keaau with K&S Kahekili support. Peralta reports fire contained and crew demobilizing in the afternoon. Occasional smoke is reported from Makaha but no additional spread.

Incident Map




Key points:

1. It takes a significant amount of time for Army resources to respond. Weekend incidents are especially bad for timely response.
2. Army Wildland as exceptional in responding quickly, requesting Army support and communicating with Environmental.
3. Dip pond liners in Makua need repair.
4. Dip ponds need to be kept full, consider using range control staff to maintain while Army fire is short staffed.
5. The overnight spread of this fire was completely unexpected, in future we should work to ensure we monitor more closely.

IMPC-HI-PWA 31 August 2018

**MEMORANDUM FOR RECORD**

**SUBJECT:** Kahuku Training Area Fires 27 July-9 August 2018

1. Summary

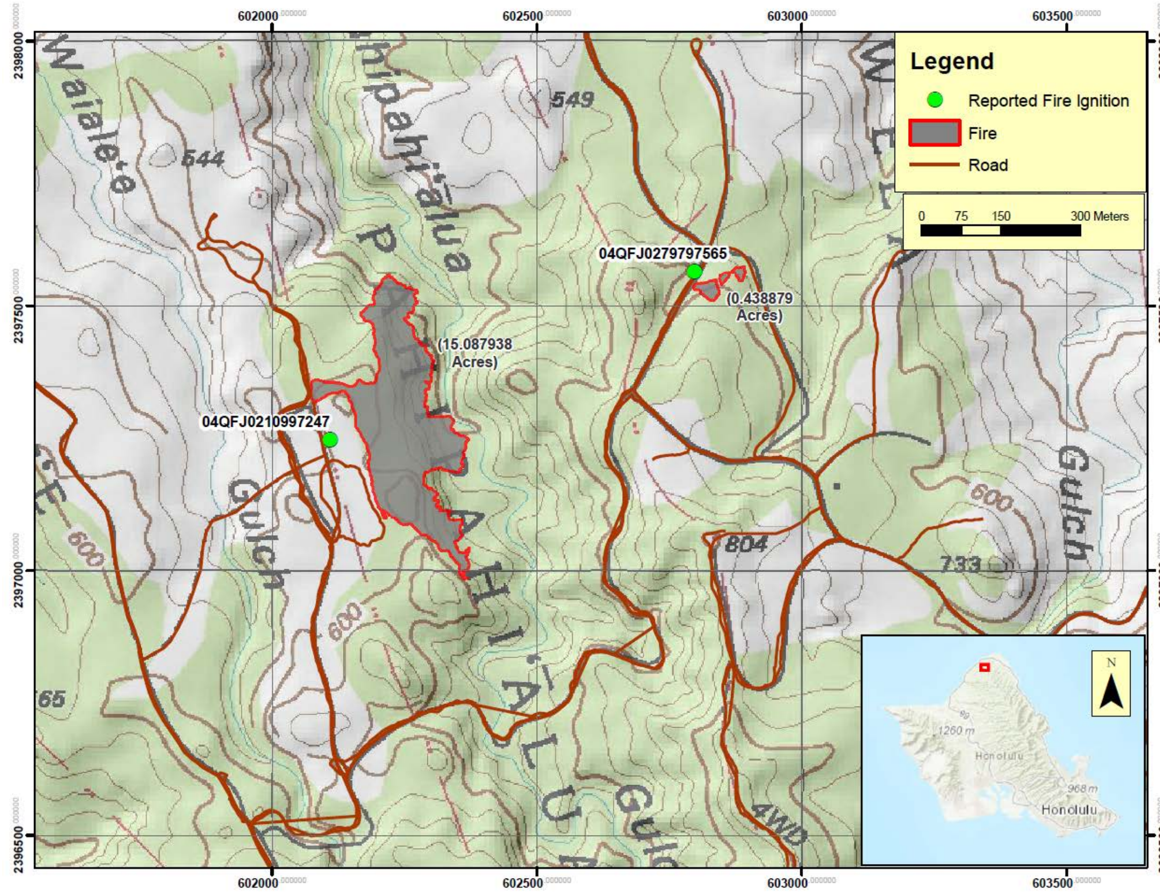
Two fires occurred at Kahuku training area on the same day and time. The fire's cause is unknown but pyrotechnics, illumination rounds and simulators, were found in area. The areas burned were dominated by introduced trees and shrubs. Some native vegetation was also burned. There are no known endangered species in these areas except for acoustic detection of the listed endangered Hawaiian Hoary bats, *Lasiurus cinereus semotus*. Post fire surveys were conducted in order to determine the scale of potential effects from these training related fires to trees >15 feet tall, potential bat roosting trees, as the fire occurred during known bat pupping season, June 1-Sept 15.

The two fires will be referred to as the X-strip fire and the Bravo gate fire. X-strip is a landing zone (LZ) adjacent to the western of the two fires. Bravo gate is located on the perimeter of the second, eastern fire. The Army's wildland fire crew was on the scene, fighting the fire using ground and Army air assets.

2. X-strip fire

The total area burned in this fire was 15.08 acres (map below). The vegetation burned was primarily ironwood. Some of the fire perimeter occurs along the margin of the open X-strip LZ. This forest, grassland buffer is preferred foraging habitat for hoary bats. At least ½ of the acreage burned was covered by trees >15 feet tall, potential bat roosting trees. As this fire occurred during bat pupping season, 1 June-15 Sept, there was potentially an effect on non-volant, roosting bat pups.

Panorama of burn site from X strip LZ. This edge is favorable foraging habitat for hoary bats.




Burned Ironwood forest, some younger trees completely scorched, taller ones still green at top of canopy

Burned ulei, *Osteomeles anthitifolia*, a native woody vine.
Bottom of Pahipahialua gulch in the distance.
The X-strip fire burned to the gulch bottom in numerous locations.

3. Bravo gate fire
   The total area burned in this fire was .44 acres (map above). The vegetation burned was primarily ironwood and Eucalyptus. Twenty-five *Eucalyptus* trees >15 feet tall burned entirely. Roughly 33 other trees >15 feet including *Eucalyptus* and Ironwood in the surrounding area were affected by the fire. As this fire occurred during bat pupping season, 1 June-15 Sept, this fire potentially affected non-volant, roosting bat pups in trees >15 feet tall.

4. A list of plant species burned in both the KTA fires are included in the table below. Both fires were dominated by *Casurina glauca*, ironwood, and are likely to re-colonize with this invasive tree. This taxon re-sprouts readily from roots. In addition, not all the tops of the ironwoods were burned, some trees were scorched closer to the bottom and should recover with time.

| Native Plants | |
|---|---|
| Scientific Name | Common Name |
| *Psydrax odoratum* | alahe'e |
| *Osteomeles anthydifolia* | ulei |
| *Sphenomeris chinensis* | pala`a |
| *Styphelia tameiameiae* | pukiawe |
| *Waltheria indica* | uhaloa |
| *Wikstroemia oahuensis* | akia |

| Non-Native Plants | |
|---|---|
| Scientific Name | Common Name |
| *Ardisia elliptica* | shoebutton ardisia |
| *Casurina glauca* | Ironwood |
| *Chromolaena odorata* | Devil weed |
| *Clidemia hirta* | Koster's curse |
| *Cordyline fruticosa* | Ti |
| *Eucalyptus robusta* | Swamp Mahogany |
| *Lantana camara* | lantana |
| *Leucaena leucocephala* | koa haole |
| *Phymatosorus grossus* | laua'e |
| *Morinda citrifolia* | noni |
| *Nephrolepis brownii* | |
| *Oplismenus hirtellus* | basket grass |
| *Passiflora suberosa* | corky passion vine |
| *Phelbodium aureum* | |
| *Pluchea carolinensis* | |
| *Psidium cattleianum* | Strawberry guava |
| *Psidium guajava* | common guava |
| *Urochloa maxima* | Guinea grass |

5. Lessons Learned
   - The Wildland fire program should be outfitted with GPS units and GIS capabilities so that fires can be accurately mapped in real time. The Natural Resource Program is relied on heavily during fires to provide maps and GPS services.
   - The SIR reports should include coordinates for both fires when two separate locations are burning. This allows for easier post fire survey follow up.

6. The potential effect on roosting Hawaiian hoary bat pups is impossible to quantify. Although more data is being collected on detection rates for bats in the Kahuku vicinity, these data do not provide information on how frequently bats use forested areas of Kahuku training area for roosting. Since this taxon is a solitary rooster, locating roosting sites is challenging. A total of 15.5 acres of habitat forested in trees >15 feet tall were impacted in these two fires.

Kapua Kawelo
Biologist
DPW Environmental

# Testing the effects of inoculation with arbuscular mycorrhizal fungi and the foliar endophytic mycoparasitic yeast *Moeziomyces aphidis* on the disease severity from *Neoerysiphe galeopsidis* in infected of *Phyllostegia kaalaensis* plants

Jerry Koko, Cameron Egan & Nicole Hynson
University of Hawaii at Manoa

## Introduction

We measured the percent infection of *Neoerysiphe galeopsidis* (powdery mildew) on the leaves of *Phyllostegia kaalaensis*, a critically endangered plant endemic to Hawaii. To combat the powdery mildew, we treated plants with an endophytic mycoparasitic yeast, *Moeziomyces aphidis* (END), arbuscular mycorrhizal fungi (AMF), as well as a combination of both AMF and END (ANE). We treated the plants before infecting them with the powdery mildew and measured disease severity after 11 weeks of exposure.

## Methods

We collected soil from two different sites: Kapuna Gulch (KP) is a site where *P. kaalaensis* was located historically and Kaluaa Gulch (HK) is a site where there is a current outplanted population of the congeneric species, *Phyllostegia mollis*. From these sites we cultured and extracted the AMF from the soil to create our AMF inoculum. We extracted the spores to ensure we only added AMF to the plants rather than various pathogens or bacteria that could have possibly been in the soil. We cultured *M. aphidis* from isolates prepared previously by Dr. Geoff Zahn.

We treated the plants with AMF by pipetting ~150 spores from our spore inoculum which we extracted from the soils. The END was added by mixing the cultured *M. aphidis* with 0.1% agar and using a spray bottle to spray the contents onto the leaves. There was also a control treatment (CON) which added filtered END treatment through a 10 um filter and no added AMF. The leaves were sprayed until they were saturated. We sprayed the leaves once every four days for 3 weeks.

To infect the plants we received leaves of *P. kaalaensis* that were infected by powdery mildew from the greenhouse at the Oahu Army Natural Resources Program. We used those infected leaves to rub the infected areas on our healthy leaves. We did this everyday until there were signs of infections on our plants. The plants showed signs of infection after 5 days of exposure.

After 78 days we measured disease severity of the pathogen by image processing. We took the third-youngest leaf that showed signs of infection from the plant. We then took the image of the leaf by scanning it to the computer. Using the imaging software ImageJ, we estimated the total area of the leaf and what percentage of the leaf area was infected.

Data in Figure 1 are presented as mean percent disease severity and standard error of the mean. All data were analyzed using R 3.5.0. Comparisons between means were based on a test of analysis of variance (ANOVA) at an $\alpha$=0.05.

**Effect of Endophyte Treatment**

The impact of the END treatment was significant in the defense against the pathogen powdery mildew (P=0.002). Our results suggest that the effect of END was 4.6-fold that of CON (Figure 1). This confirms the hypothesis of Dr. Geoff Zahn, who proposed in his study using whole leaf endophyte communities (Zahn & Amend 2017), that this mycoparasitic fungus may be responsible for defending *P. kaalaensis* against powdery mildew.

The ANE treatment had significant implications in the defense of powdery mildew relative to the control as well (P=0.001). The addition of both guilds of fungi, however did not perform significantly better than the addition of just the endophyte (P=0.97). The endophyte alone actually performed 1.3-fold on average better than the addition of both AMF and the endophyte. Thus there was intermediate effect of the performance of the ANE treatment relative to the END or AMF alone (see below and Figure 1).

**Effect of AMF Treatment**

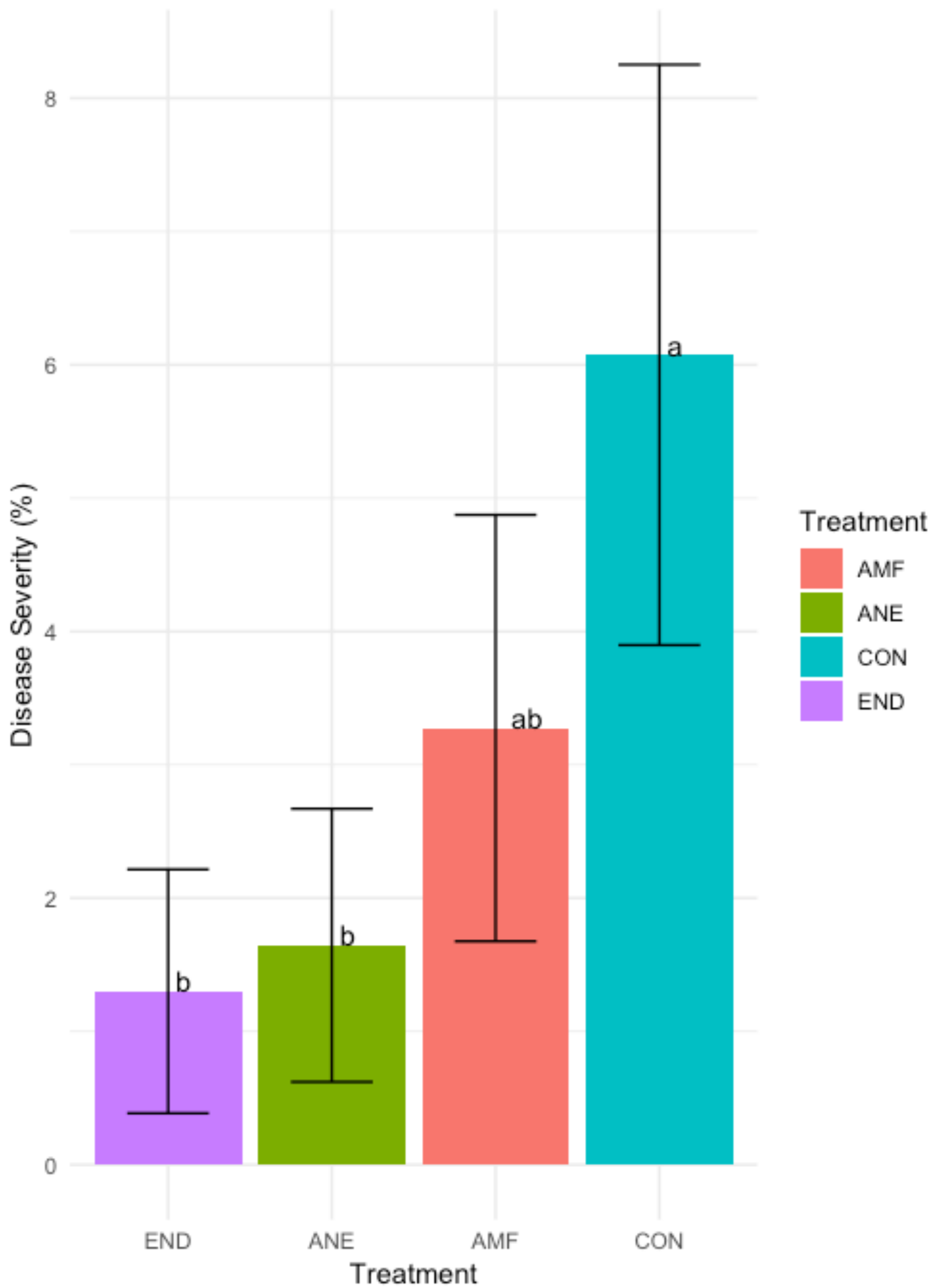
While average disease severity was lower, our AMF treatment was not significant in the prevention of powdery mildew compared to the CON (P=0.12). It was also not significantly different than the END and ANE treatments as well (P=0.19 and 0.28, respectively). However, The AMF treatment performed 1.9-fold on average better than the CON, indicating that AMF alone do confer some defense relative to untreated controls (Figure 1).

**Discussion**

With respect to the management of powdery mildew, the results suggest it would be best to spray the leaves of *P. kaalaensis* with *M. aphidis* before, or while, growing them in the greenhouse. Because we only observed the plants before they were outplanted, it’s hard to say whether it is necessary to spray the plants prior to outplanting them in the wild or if it would be very effective once they are outplanted.

The addition of AMF alone did not significantly increase the defense of *P. kaalaensis* against powdery mildew. While focusing on different species of powdery mildew, another study also found that AMF does not have any significant effect on defending against powdery mildew (Liu et al. 2018). However, other studies have found that AMF had a significant effect in defense against powdery mildew (Yousefi et al. 2011, Mustafa et al. 2016). It could be that the particular pairing of AMF and P. kaalaensis doesn’t confer increased defense under short-term greenhouse conditions relative to *Moeziomyces aphidis* alone or in tandem with AMF, but AMF alone may be important in field settings where plants are exposed to other pests and this deserves additional attention.

**Figure 1** The effect of each treatment on Disease Severity (percentage of leaf area covered by powdery mildew). The treatments are the addition of *M. aphidis* (END), addition of arbuscular mycorrhizal fungi and *M. aphidis* (ANE), addition of arbuscular mycorrhizal fungi (AMF), and a control treatment with no addition of AMF and the addition of END after being filtered through a 10 um filter (CON). Different lowercase letters represent statistically significant differences (P< 0.05, Tukey's HSD). The error bars represent 1 standard error of the mean.



**References**

Liu Y, Feng X, Gao P, Li Y, Christensen MJ, Duan T. Arbuscular mycorrhiza fungi increased the susceptibility of Astragalus adsurgens to powdery mildew caused by Erysiphe pisi . Mycology. 2018;9(3):223-232. doi:10.1080/21501203.2018.1477849.

Mustafa, G., Randoux, B., Tisserant, B. et al. (2016). Phosphorus supply, arbuscular mycorrhizal fungal species, and plant genotype impact on the protective efficacy of mycorrhizal inoculation against wheat powdery mildew. Mycorrhiza (2016) 26: 685. https://doi.org/10.1007/s00572-016-0698-z

Yousefi, Zohreh & Riahi, Hossein & Khabbaz-Jolfaei, Hossein & Zanganeh, Sima. (2011). Effects of arbuscular mycorrhizal fungi against apple Powdery Mildew disease. Life Science Journal. 8. 108-112.

Zahn G, Amend AS. (2017) Foliar microbiome transplants confer disease resistance in a critically-endangered plant. PeerJ 5:e4020 https://doi.org/10.7717/peerj.4020

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# Quantifying the effects of an invasive thief ant on the reproductive success of rare Hawaiian picture-winged flies

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ABSTRACT

Threats to endangered insect species that act independently of those associated with habitat loss are often suspected, but are rarely confirmed or quantified. This may hinder the development of the most effective recovery strategies, which are increasingly needed for listed insects. Since 2006, 14 species of flies within the large, showy Hawaiian picture-winged *Drosophila* group have been added to the US threatened and endangered species list. Many of these species are thought to be limited by host plant rarity, but also by predation on immature stages by invasive ants. We tested the latter hypothesis with a field experiment involving *Drosophila crucigera*, a more common surrogate for sympatric endangered species, and the invasive ant *Solenopsis papuana*, on the island of O'ahu. We established ant suppression and control plots across three forest sites. Within each plot we placed a host plant branch piece, into which lab-reared flies had oviposited, and subsequently tracked weekly emergence of adults. Numbers of flies that emerged were 2.4 times higher in ant-suppressed plots than in control plots; this 58% reduction in survival from egg to adult in the presence of ants was similar across all three sites. Among plots, numbers of emerged flies exhibited a pattern suggesting that the detrimental effect of ants is density dependent. These results confirm that *S. papuana*, and possibly other invasive ant species, can strongly impact the reproductive success of Hawaiian picture-winged *Drosophila*. They also point to several management actions, beyond habitat restoration, that may improve the recovery of these imperiled flies.

## 1. Introduction

Conservation of endangered and other rare species is often hindered by an incomplete understanding of their ecological requirements and threats, including the importance of potentially numerous interspecific interactions (Lawler et al., 2002). This is especially true for small and understudied taxa like insects (New, 2007b), whose daunting diversity amplifies this knowledge deficit. As a consequence, conservation of insects has generally focused first on the basic need to protect or restore habitat (New, 2007b; Samways, 2007), and the potential roles of additional threats, such as negative interactions with invasive species, are usually recognized but often remain uncharacterized. Confirming and quantifying such threats can therefore provide a more complete set of biological parameters for assessing the viability of endangered insect populations, and thereby lead to improved recovery strategies (Schultz and Hammond, 2003; New, 2007a).

Within the United States, Hawai'i has many more federally listed threatened and endangered species than any other state (USFWS, 2017). The majority of these are plants and vertebrates, but endemic Hawaiian insects and other invertebrates are increasingly being considered for listing, with 76 species now formally designated (USFWS, 2017). Among these, 14 species of Hawaiian picture-winged *Drosophila* flies have been added to the federal threatened and endangered species list since 2006 (USFWS, 2006, 2010, 2013). As with other taxa, this has triggered a need among land managers for practical information on the importance of, and potential ways to mitigate against, the various factors hypothesized to impact picture-winged fly populations, including factors that may be viewed as secondary to habitat loss.

Picture-winged *Drosophila* form a subset within the larger radiation of *Drosophila* in Hawai'i, and the > 100 recognized species are so named because of the striking and highly diverse patterns of pigmentation on their wings (Edwards et al., 2007). Most or all picture-winged species are saprophytic, with their larvae feeding on bacteria and other microbes within rotting tissues of their host plant species, typically in

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the cambium layer beneath the bark of decomposing branches or stems (Montgomery, 1975; Magnacca et al., 2008). Although a wide range of host plants are used by the picture-winged group, most species are moderately to highly specific in their host plant preferences, while a few species are known to be generalists (Montgomery, 1975; Magnacca et al., 2008). Rarity of host plants is therefore one of the primary causes of endangerment of some of the picture-winged species (Foote and Carson, 1995; USFWS, 2006, 2010, 2013).

While restoration of host plants is important for the recovery of many of the listed picture-winged species, it may not always represent a sufficient strategy. This is because non-native insect predators and competitors are believed to be important additional threats that may act independently of or synergistically with host plant declines (Foote and Carson, 1995, USFWS, 2006, 2010, 2013). The most important invasive predators are thought to be yellowjacket wasps (*Vespula pensylvanica*), which may prey on both adult and exposed larval flies in areas where they occur, and a variety of ant species, which are most likely to impact the more sedentary immature stages but are also known to attack adults (K. Magnacca pers. obs.). Invasive ants, especially a handful of ecologically dominant species such as *Linepithema humile*, *Pheidole megacephala*, *Anoplolepis gracilipes* and *Wasmannia auropunctata*, are well-known to impact invertebrate species and communities both on oceanic islands and in continental ecosystems (e.g., Perkins, 1913; Cole et al., 1992; Human and Gordon, 1997; Hoffmann et al., 1999; Le Breton et al., 2003; Carpintero et al., 2005; Abbott, 2006; Walker, 2006). Attempts to eradicate populations of these ants for the conservation benefit of native species are increasingly common, though with varying degrees of success (Hoffmann et al., 2016). While all of these ant species and others are established in Hawai‘i, they tend to be absent or occur at low densities in the mesic to wet montane forests where many of the listed picture-winged flies occur (Reimer, 1994; Krushelnycky et al., 2005; Krushelnycky, 2015), especially in the more shaded closed-canopy gulches typically favored by the flies and their host plants.

One relatively inconspicuous and globally obscure species that violates this generality is *Solenopsis papuana*. This small (ca. 1.5 mm long) thief ant, which belongs to a taxonomically confused group and whose name may change in the future (see Ogura-Yamada and Krushelnycky, 2016), was first detected in Hawai‘i in 1967 and is now widespread in mesic to wet forest ecosystems across at least several islands (Huddleston and Fluker, 1968; Gillespie and Reimer, 1993; Reimer, 1994). In these ecosystems *S. papuana* is generally rare on vegetation distant from the ground (Krushelnycky, 2015), but has occasionally been observed foraging up to a height of at least two meters on tree trunks. More commonly, it attains high densities and is most active in the soil and leaf litter (Ogura-Yamada and Krushelnycky, 2016, unpub. data). Although information on the biology and ecology of this ant is limited, other species of thief ants (small *Solenopsis* species formerly placed in the subgenus *Diplorhoptrum*) are reported to be generalist predators, scavengers, and tenders of honeydew-producing Hemiptera in subterranean environments (Thompson, 1980, 1989; Tschinkel, 2006). *Solenopsis papuana* may therefore encounter and prey upon eggs and larvae developing within decomposing host plant branches, especially if the branches have been downed by tree fall or wind breakage and then decompose on the ground. Fully grown larvae subsequently exit the branches to pupate in the soil, exposing them directly to foraging ants. Even eclosing, teneral adults may be vulnerable as they dig to the surface and rest there to harden and melanize their cuticles before they become fully flighted. Another invasive ant species, *L. humile*, has been observed or inferred to attack larvae or eclosing adults of fruit flies (Tephritidae) in orchards (Wong et al., 1984; Buczkowski et al., 2014). Alternatively, picture-winged *Drosophila* eggs and larvae may be protected from ants within their internal feeding environments, and late instar larvae, pupae and adults in the soil may not be preferred prey for tiny ants like *S. papuana*.

Our objective was to test whether *S. papuana* reduces the reproductive success of picture-winged *Drosophila* flies with an experiment that employed realistic field conditions for the ants and developing flies. We used a more common picture-winged species, *Drosophila crucigera*, that is a generalist in its host plant usage, but is sympatric with six endangered *Drosophila* species on the island of O‘ahu, and has the same life history strategy and potential exposure to ants as the rarer picture-winged species (Magnacca et al., 2008; Magnacca, 2014). This surrogate *Drosophila* species should therefore provide a good representation of the vulnerability of this group of flies to *S. papuana* and possibly other invasive ants in Hawai‘i, and clarify the magnitude of the threat posed by ants to picture-winged fly recovery.

## 2. Materials and methods

### 2.1. Field plots

Twenty-eight 5 × 5 m plots were established in November of 2016 across three mesic forest sites in the central to northern Wai‘anae Mountain range of O‘ahu: eight plots at Pu‘u Hāpapa (810 m elevation, 1185 mm annual rainfall), eight plots at ‘Ēkahanui (635 m elevation, 1210 mm annual rainfall), and 12 plots at Pahole Natural Area Reserve (NAR) (480 m elevation, 1375 mm annual rainfall). Annual rainfall estimates are obtained from Giambelluca et al. (2013). Each of the three sites is characterized by a mix of native and alien vegetation, and each is known to support both natural populations of picture-winged *Drosophila* flies (Magnacca, 2014) and high densities of *S. papuana* ants (as determined by prior mapping, Ogura-Yamada and Krushelnycky, unpub. data). Other ant species were uncommon or absent in the plots.

At each site, half of the plots were randomly assigned to an ant suppression treatment (suppressed), and the other half to an untreated control (control). A shortage of flies in the lab colony (see below) prevented the use of one of the plots at Pahole NAR, resulting in a total of 27 plots used (13 suppressed, 14 control). Numbers of *S. papuana* ants (hereafter “ants”) were monitored in each plot using nine cards (half of a 7.6 × 12.7 cm index card) baited with a smear of peanut butter: five cards were spaced around the perimeter of the fly emergence cage in the middle of the plot (used to trap emerging adult *Drosophila*, see below), and four cards were placed on the plot perimeters midway between each of the four corners. The cards were placed on the ground, collected after 90 min, and numbers of ants were summed over the upper and lower surfaces of each card. Although monitoring of ant activity with baits does not necessarily indicate ant colony density and may be influenced by weather and other factors, it is a commonly used method for assessing relative abundances of foraging ants in a given area, and is considered to be reasonably accurate provided that baiting is conducted with consistent methods and under similar conditions (Bestelmeyer et al., 2000).

Following the initial ant monitoring event, 17 stations filled with toxic ant bait were placed in each ant suppression treatment plot to suppress ants over the course of the experiment. Sixteen stations were spaced every 1.25 m in a grid pattern, with an extra station placed in the plot center (within the emergence cage), and were constructed of 3.81 cm (1.5 in.) long sections of 3.18 cm (1.25 in.) diameter PVC tubing, fitted with PVC endcaps on the upper end to exclude rain. The open bottoms were screened with Amber Lumite Screen (530 μm mesh size), and the stations were staked to the ground with wire. This station design allowed access to *S. papuana* workers but excluded nearly all other non-target arthropods, and is described in more detail in Ogura-Yamada and Krushelnycky (2016). Inside each station, we placed 2.5 ml (0.5 teaspoon) of Amdro® Ant Block® granular bait (0.88% hydramethylnon) within a disposable polypropylene tea bag, which allowed ants to imbibe pesticide-laden oil from the baits while facilitating their periodic replacement (Ogura-Yamada and Krushelnycky, 2016). Amdro® Ant Block® bait was replaced in each station every four to six weeks; timing of bait replacement at each site is indicated in Fig. 1. Ant numbers in both suppressed and control plots were also monitored

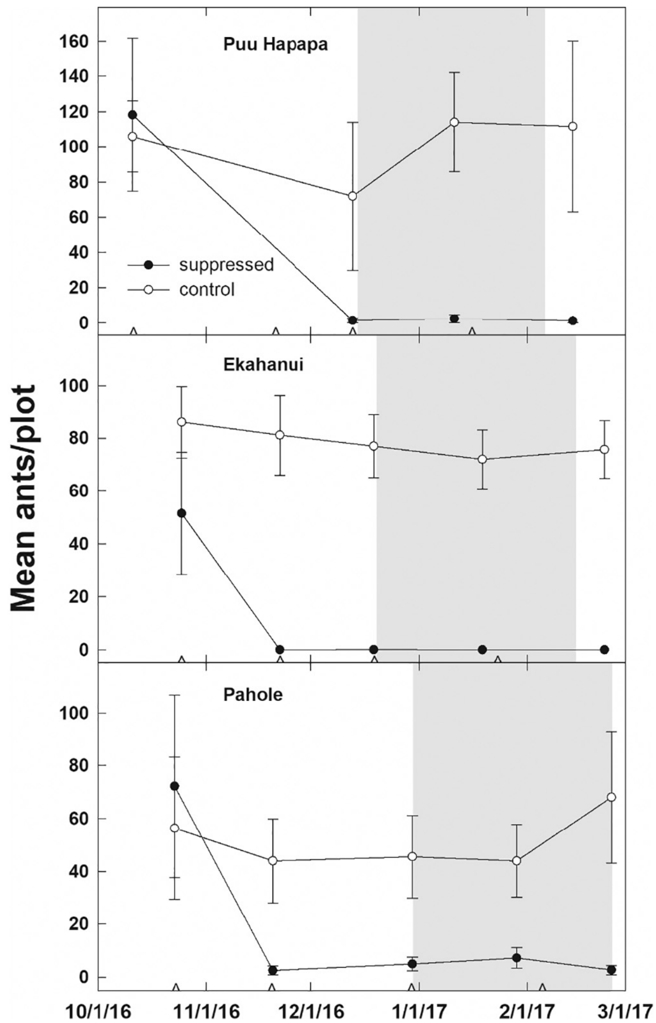


**Fig. 1.** Mean number of ants ( ± SE) at bait monitoring cards in ant-suppressed and control plots at the three field sites over the course of the experiment. First date in each panel is prior to ant suppression using bait stations; timing of ant bait placement/replacement within stations is shown with small triangles along x axis. Gray shaded areas indicate time periods spanning deployment of egg-laden host plant branches to date of final adult fly emergence.

every four to six weeks (Fig. 1), using the bait card methods described above.

### 2.2. Lab fly colonies

Wild *D. crucigera* flies were caught between March and May of 2016 from the Kaluaʻā, Pualiʻi, and Palikea areas of the central to southern Waiʻanae Mountains, Oʻahu. Isolines were established from laying females in the Drosophila Lab of the Pacific Biosciences Research Center at the University of Hawaiʻi at Mānoa, and resulting colonies were maintained at 18–19 °C on a 12 h light/dark cycle, and kept in vials with Wheeler-Clayton medium (Wheeler and Clayton, 1965). In November of 2016, mature females from the most productive colony were segregated into groups of three, and each triplet was subsequently observed for several weeks to confirm ample egg laying. Reproductively active triplets were then used for oviposition on host plant material (see below).

### 2.3. Host plant preparation

Live branches of *Pisonia umbellifera* trees (Nyctaginaceae), the most common host plant of *D. crucigera*, were harvested from Kahanahāiki Valley, in the northern Waiʻanae Mountains on 25 September 2016. The branches were cut into 28 pieces approximately 20 cm in length and 2.0–2.5 cm in diameter, and were put into a standard freezer for four days to break cell walls and hasten decomposition upon thawing, and to kill any insects that might already be in them. Soil and leaf litter was also collected from Kahanahāiki Valley to inoculate the branch pieces with the wild strains of bacteria and other microorganisms upon which the fly larvae feed. This soil and leaf material was placed into plastic tubs (30 × 18 × 11 cm), moistened with approximately 150 ml of water per tub, and was covered with a snug but non-airtight plastic lid to create a humid rotting environment. On 29 September, the host plant branch pieces were thawed and paired to match diameters as closely as possible, placed into screen bags (Phifer BetterVue Screen, charcoal fiberglass window screen), and each pair was then placed into one of the aforementioned tubs under a cover of damp leaf litter to initiate the rotting process. The screen bags were used to exclude larger detritivorous insects within the soil and leaf litter that might compete with *D. crucigera* larvae, while allowing entry of smaller invertebrates like Acari and Collembola that might help transfer microorganisms to the rotting branches. After 27 days, the branch pieces were judged to have achieved a desirable stage of decomposition; to avoid further breakdown, they were placed back into the freezer until needed.

### 2.4. Oviposition and field trial

Frozen prepared host branch pieces were thawed for three days prior to oviposition, and each branch piece from a matched pair was randomly assigned to either the ant suppression or control treatment. Branch pieces were then individually placed in clean tubs (same dimensions as above) lined on the bottom with 2–3 cm of damp sand, and a randomly selected triplet of female flies (subject to constraints described below) was added to each tub for an oviposition period of approximately 72 h, then returned to a vial containing Wheeler-Clayton medium. The next day, we carried the egg-laden branch pieces to the field and placed them in the plots that matched their predetermined random treatment assignments. Each branch piece was placed on the ground in the center of its plot, loosely covered with leaf litter taken from nearby, and a conical emergence cage was affixed over it. Emergence cages were constructed of standard fiberglass window screen material (Phifer BetterVue Screen, charcoal), and were 1 m in diameter and supported by a central PVC post approximately 1 m tall, with the perimeter staked to the ground with wire. This allowed *Drosophila* larvae leaving the host branch to pupate in the soil, and trapped adults subsequently emerging after pupation, while excluding naturally-occurring *Drosophila* in the forest but presenting little if any barrier to the movement of ants. Inside each cage, we placed a yellow sticky trap (7.6 × 12.7 cm, Bioquip Products) held approximately 20 cm above the ground, and hung a Multilure (McPhail) trap (Better Trap, Inc.) containing a 50:50 propylene glycol:water preservative mixture and smeared on the interior surfaces with an attractant bait consisting of fermenting mashed bananas inoculated with baker's yeast. Emergence was monitored by checking for adult flies caught by either trap, or resting on the cage walls, on a weekly basis from approximately three to ten weeks post oviposition. Any flies detected were removed through a zippered opening, without removing the cage; monitoring was terminated after two consecutive weeks passed with no new adult emergence at a site.

Due to a shortage of reproductively active triplets of female flies in the lab colony, oviposition on the branch pieces destined for each of the three field sites was conducted in turn, re-using some of the triplets for more than one site. We used eight fly triplets for the eight Puʻu Hāpapa branch pieces (randomly assigned) from 9 to 12 December 2016; the same triplets were then used again for the eight ʻĒkahanui branch pieces from 15 to 18 December 2016, with the constraint that each triplet was randomly assigned to a branch piece with the opposite treatment designation (ant suppression vs. control) as in the first oviposition period. Mortality of flies in the lab after the second oviposition period necessitated replacement of many of the original females with new females that became available, and three new triplets were added for the 11 branch pieces used during the third oviposition period, from 26 to 29 December 2016, for the Pahole site.

### 2.5. Analysis

To compare numbers of ants between ant-suppressed and control plots prior to treatment application, we used a Wilcoxon test comparing the averages of the ant counts for each plot ($n = 13$ suppressed, $n = 14$ control) on the initial monitoring dates. To compare numbers of ants between treatments during the fly development period, we used a median test to compare average ant counts for each plot because of highly divergent variances between suppressed and control plot data after ant-suppression was imposed. For this comparison, we used the average of all ant counts over the final three monitoring events for each plot ($n = 13$ suppressed, $n = 14$ control), which roughly spanned the period from when egg-laden branch pieces were placed in the plots to when the final adults emerged (Fig. 1). To compare numbers of adult flies emerged between ant-suppressed and control plots, we used a generalized linear model fit with a negative binomial distribution and a log link function to address the overdispersed nature of the count data. Explanatory variables included in the model were treatment (suppressed, control) and site (Pu'u Hāpapa, 'Ēkahanui, Pahole). Statistical analyses were performed using JMP Pro Version 13.

## 3. Results

Ant numbers in the field plots on the initial monitoring date averaged approximately 50–120 ants/card (Fig. 1), and were not significantly different between plots assigned to ant suppression and control treatments (Wilcoxon test, S = 173, $p = 0.680$). Ant numbers subsequently dropped sharply in the suppressed plots after bait stations were deployed, but remained relatively stable in the control plots (Fig. 1). Over the final three monitoring events that spanned the period during which flies were present in the plots, ant numbers in suppressed plots were reduced relative to pre-treatment values by 96.5% ± 1.1% (mean ± SE), compared to a 3.0% ± 10.9% increase in the control plots. Ant numbers during this period were highly significantly different between suppressed and control treatments (median test, S = 0, $p < 0.001$).

*Drosophila crucigera* adults emerged in the field cages from approximately four weeks after oviposition to about nine weeks after oviposition, with a peak emergence at around six weeks after oviposition (Fig. 2). The timing of emergence was very similar between all three sites, but numbers of flies emerged per plot were much lower at Pahole compared to the other two sites (Fig. 2). We believe this likely resulted from lower rates of oviposition on the branch pieces used at Pahole, rather than from lower survival rates at Pahole. We infer this because 51.5% (17 of 33) of the lab flies died during the 3-day oviposition period for the Pahole site. This compared to 0% (0 of 24) mortality during the Pu'u Hāpapa oviposition period and 4.2% (1 of 24) during the 'Ēkahanui oviposition period.

Higher numbers of flies emerged in the ant-suppressed plots compared to the control plots at all three sites, even at Pahole where fewer flies emerged overall (Fig. 3, left panel). Across all plots, the treatment factor contributed significantly to variation in emerged fly numbers (GLM, Wald $\chi^2 = 6.38$, $p = 0.012$), indicating that emergence rates were different between suppressed and control plots (Fig. 3, right panel). The site factor also contributed significantly to variation in fly numbers (GLM, Wald $\chi^2 = 13.99$, $p = 0.001$), owing to the large difference in emergence rates between Pahole and the other two sites. Back-transformation of fitted coefficient estimates from the model yielded estimates of 6.8 flies per ant-suppressed plot (4.2–10.8, 95% CI) and 2.9 flies per control plot (1.7–4.8, 95% CI), indicating that an

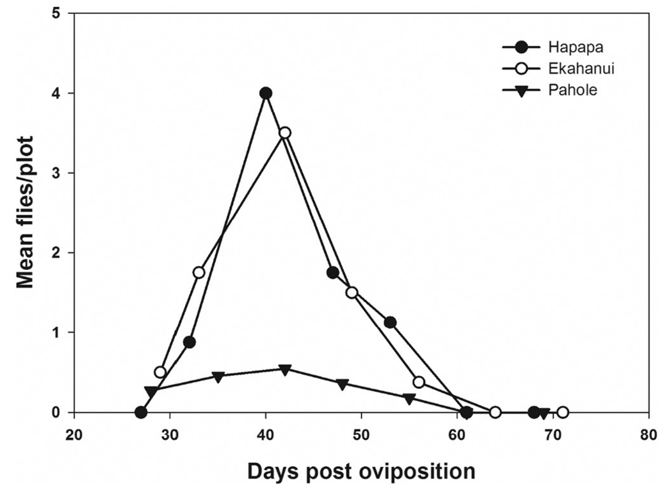


**Fig. 2.** Temporal pattern of adult fly emergence at each site over the course of the experiment, as measured by captures in field cages monitored approximately weekly.

estimated 2.4 times as many flies emerged, on average, in plots where ants were suppressed. One fly was observed on the central post of the emergence cage in one of the control plots at 'Ēkahanui immediately after the cage was removed at the end of the experiment, two weeks after the last fly was seen inside the cage. We believe that this was likely a naturally-occurring fly that landed on the post from outside the cage after it was lifted, attracted to the baited trap inside. However, we reran the GLM analysis with this fly included: the results were very similar (Wald $\chi^2 = 6.05$, $p = 0.014$ for the treatment factor), so we felt comfortable excluding this fly from the dataset.

Excluding the 11 Pahole plots in which low fly emergence was likely due to low oviposition rates in the lab, numbers of flies emerged per plot exhibited a general negative relationship with the mean number of ants recorded in the central portion of the plot (central five bait cards, averaged over the final three monitoring events) (Fig. 4). However, variation in fly emergence rates was high at lower ant densities, and the strongly uneven variation in fly emergence across the range in ant density (strong heteroscedasticity), as well as an under-representation of values at higher ant densities, precludes a robust statistical test of this relationship.

## 4. Discussion

Our results provide confirmation of the presumed detrimental effects of invasive ants on Hawaiian picture-winged *Drosophila* flies. For our study species, *D. crucigera*, suppression of *S. papuana* ants in field plots resulted in a 2.4-fold increase, on average, in the rate of successful development from egg to adult. Equivalently, ambient densities of these ants reduced the fly's survival rate to adulthood by 58%. This mortality figure provides an important metric that can be used to parameterize population models, and may help prioritize different management actions aimed at recovery of similar listed species.

We observed no evidence for direct impacts of our ant-suppression treatment on non-target predatory arthropods, as no other species were seen inside our bait stations with the exception of several individual detritivorous springtails (Collembola). It is possible that some secondary effects on non-ant predators, arising from their consumption of poisoned ants, could have occurred and thereby contributed to the observed increase in *Drosophila* survival. However, we believe such an effect is likely to be very minimal. In a concurrent study that examined the effects of *S. papuana* suppression on the wider soil arthropod community, there was no evidence for declines in the abundances of predatory (or other) taxa post-treatment (Ogura-Yamada unpub. data). Similarly, no non-target impacts on soil-surface arthropods were detected when the same bait was applied in bait stations on Cousine

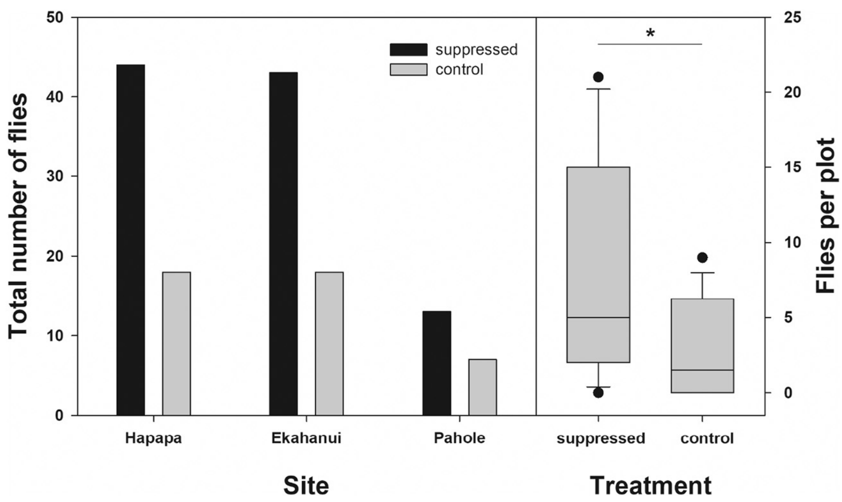


**Fig. 3.** Left panel: Total number of flies emerged in ant-suppressed and control plots at each site. Right panel: Box plots of numbers of emerged flies per plot for ant-suppressed and control treatments across all sites. Box forms first and third quartiles, with median line inside; whiskers show 5% and 95% extents, and dots are outliers. Number of flies emerged per plot is significantly different between treatments ($p = 0.012$), as assessed with a GLM (see text).

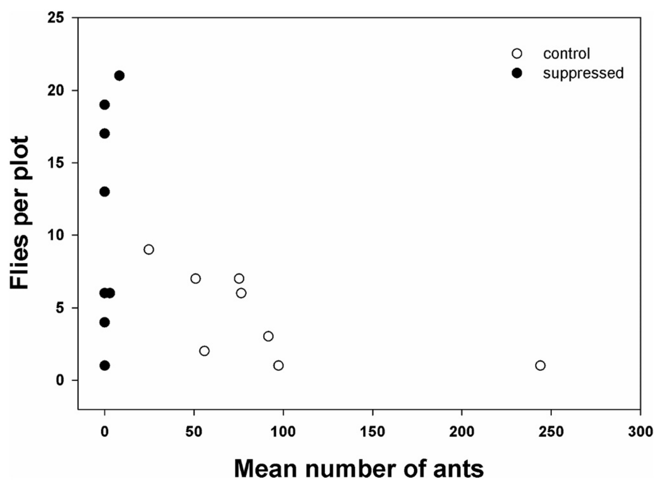


**Fig. 4.** Relationship between ant abundance and the total number of adult flies that emerged in the 16 Puʻu Hāpapa and ʻĒkahanui plots. Ant numbers are the means of the central five bait cards placed around the emergence cage in each plot, and averaged over the final three monitoring events when flies were present and developing. Ant suppression or control treatment is indicated for each plot.

Island, Seychelles (Gaigher et al., 2012). Even when the same or similar ant baits have been broadcast, non-target impacts have either been undetectable (Hoffmann, 2014) or restricted to generalist scavenging species like cockroaches and crickets (Plentovich et al., 2010, 2011) that would be unlikely to prey on picture-winged *Drosophila*.

Without additional detailed life history data, it is difficult to be certain of the magnitude of population impact resulting from our observed level of ant-induced mortality on picture-winged flies. For example, we were unable to determine the number of *D. crucigera* eggs laid in each host branch piece, because most of the eggs are inserted beneath the bark, and so the rate of mortality from other causes is unknown. We also were not able to determine which immature or early adult life stages were most vulnerable to attack from ants. Similarly, adult survival, mating success rates, and other parameters needed to construct life tables or other population models are unknown. Even so, some insight might be drawn from a relationship observed in biological control projects: an analysis of 74 control efforts found that parasitoid-induced mortality rates higher than about 40% often leads to successful population suppression of the target insect species (Hawkins et al., 1993). This level of immature-stage mortality, which was exceeded in our study, may therefore serve as an approximate benchmark against which to judge likelihood of strong population-level impacts on picture-winged *Drosophila* flies. In actuality this benchmark may be conservative, because certain life history traits may make these flies less resilient to high mortality rates than the prolific species typically targeted for biological control. In particular, their reliance on comparatively sparse and ephemeral breeding sites, namely the decaying tissues of a limited range of host plant species, likely predisposes them to possessing relatively small, fluctuating populations, even in the absence of novel limiting factors.

Although we did not perform our experiment on any federally listed threatened or endangered *Drosophila* species, we see no reasons why the resulting inferences should not apply to listed species occurring in the same mesic forest ecosystems. Six species of endangered picture-winged *Drosophila* species occur or were historically collected in the Waiʻanae Mountains of Oʻahu in the same or similar habitats represented by our field sites (USFWS, 2006), and are therefore potentially threatened by *S. papuana* ants. *Solenopsis papuana* is also widespread in wetter mid-elevation forests of the Koʻolau Mountains of Oʻahu, where four of the same endangered species occur or were historically collected (USFWS, 2006). Moreover, many other Hawaiian *Drosophila* species in these ecosystems also appear to be quite rare, even though they have not received federal protection (Magnacca, 2014). Similarly, rare *Drosophila* species on other islands, including federally listed taxa, also likely co-occur with *S. papuana* or other invasive ant species (USFWS, 2006, 2010, 2013). The populations of most or all of these rare species may in fact be more strongly impacted than *D. crucigera* by ant predation, as a result of synergism with other factors contributing to their rarity. Conversely, *Drosophila* species occurring in higher elevation wet forests should be largely unaffected by ants, owing to the absence or low density of ants in these habitats (Reimer, 1994; Krushelnycky et al., 2005).

Not surprisingly, our results exhibited a pattern suggesting that ant-induced fly mortality may be related to the local density of ants, with few adults emerging in plots supporting high relative ant abundances. Fly emergence rates were more variable in plots with low ant densities, including the ant-suppressed plots. This likely resulted from variation in oviposition rates, or perhaps from variable pressure from non-ant predators or competitors among plots, or possibly because low ant densities result in variable detection of fly prey. More complete distribution and density mapping of *S. papuana* and other invasive ants across habitats supporting picture-winged *Drosophila* flies, particularly in the vicinity of host plants of rare species, would therefore be valuable. This would identify breeding locations where ant pressures are highest, as well as potential refuge sites where ants are absent or occur at low densities, and where flies might be translocated. Furthermore, while *S. papuana* is now too widespread to make eradication realistic, our method for suppressing it using bait stations was quite effective, if laborious, and could be used to create relatively small ant-free refuges at important existing or restored breeding locations. Gaigher et al. (2012) report on an analogous effort to conserve native species on a tropical island through the targeted control of invasive ants using bait stations. Broadcasting the granular ant bait to control *S. papuana* at high-value sites would be considerably less labor intensive, and may also result in more effective suppression of ants, but for longer-term management scenarios we would advise careful examination of non-target risks to native insects before considering this approach.

In summary, our results clarify the nature of an important limiting factor for potentially many rare species of Hawaiian picture-winged *Drosophila* flies, and point to several practical actions that could be taken to assist the recovery of this imperiled group of insects. Quantifying the threats posed by invasive species on endangered insects is likely to be especially important on highly invaded oceanic islands, but many other regions worldwide also now support moderate numbers of invasive species, including ants (Dawson et al., 2017). Furthermore, although invasive ants have been found to impact a wide variety of native arthropods both in Hawaiʻi and in many other locations (Lach and Hooper-Bùi, 2010), not all species appear to be affected, and it has been a challenge to identify comprehensive taxonomic or trait-based criteria that reliably separate vulnerable from more resistant species (Holway et al., 2002; Krushelnycky and Gillespie, 2010). This is likely to be true with respect to other invasive predators as well. For rare species that are difficult to sample quantitatively with standard monitoring methods, specialized and targeted experimental studies such as the present one may therefore be needed to understand the level of risk from non-native predators or competitors. Consideration of these types of pressures in conjunction with efforts to restore habitat may in turn greatly strengthen recovery strategies for threatened and endangered insects and other invertebrates.

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## References

Abbott, K.L., 2006. Spatial dynamics of supercolonies of the invasive yellow crazy ant, *Anoplolepis gracilipes*, on Christmas Island, Indian Ocean. Divers. Distrib. 12, 101–110.
Bestelmeyer, B.T., Agosti, D., Alonso, L.E., Brandao, C.R.F., Brown Jr., W.L., Delabie, J.H.C., Silvestre, R., 2000. Field techniques for the study of ground-dwelling ants: an overview, description, and evaluation. In: Agosti, D., Majer, J.D., Alonso, L.E., Schultz, T.R. (Eds.), Ants: Standard Methods for Measuring and Monitoring Biodiversity. Smithsonian Institution Press, Washington and London, pp. 122–144.
Buczkowski, G., Roper, E., Chin, D., Mothapo, N., Wossler, T., 2014. Hydrogel baits with low-dose thiamethoxam for sustainable Argentine ant management in commercial orchards. Entomol. Exp. Appl. 153, 183–190.
Carpintero, S., Reyes-López, J., Arias de Reyna, L., 2005. Impact of Argentine ants (*Linepithema humile*) on an arboreal ant community in Doñana National Park, Spain. Biodivers. Conserv. 14, 151–163.
Cole, F.R., Medeiros, A.C., Loope, L.L., Zuehlke, W.W., 1992. Effects of the Argentine ant on arthropod fauna of Hawaiian high-elevation shrublands. Ecology 73, 1313–1322.
Dawson, W., Moser, D., van Kleunen, M., Kreft, H., Pergl, J., Pysek, P., Weigelt, P., Winter, M., Lenzner, B., Blackburn, T.M., Dyer, E.E., Cassey, P., Scrivens, S.L., Economo, E.P., Guenard, B., Capinha, C., Seebens, H., García-Díaz, P., Nentwig, W., García-Berthou, E., Casal, C., Mandrak, N.E., Fuller, P., Meyer, C., Essl, F., 2017. Global hotspots and correlates of alien species richness across taxonomic groups. Nat. Ecol. Evol. 1, 0186.
Edwards, K.A., Doescher, L.T., Kaneshiro, K.Y., Yamamoto, D., 2007. A database of wing diversity in the Hawaiian *Drosophila*. PLoS One 2 (5), e487. http://dx.doi.org/10.1371/journal.pone.0000487.
Foote, D., Carson, H.L., 1995. *Drosophila* as monitors of change in Hawaiian ecosystems. In: LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., Mac, M.J. (Eds.), Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C, pp. 368–372.
Gaigher, R., Samways, M.J., Jolliffe, K.G., Jolliffe, S., 2012. Precision control of an invasive ant on an ecologically sensitive tropical island: a principle with wide applicability. Ecol. Appl. 22, 1405–1412.
Giambelluca, T.W., Chen, Q., Frazier, A.G., Price, J.P., Chen, Y.-L., Chu, P.-S., Eischeid, J.K., Delparte, D.M., 2013. Online Rainfall Atlas of Hawaiʻi. Bull. Amer. Meteor. Soc. 94, 313–316. http://dx.doi.org/10.1175/BAMS-D-11-00228.1.
Gillespie, R.G., Reimer, N.J., 1993. The effect of alien predatory ants (Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae: Tetragnathidae). Pac. Sci. 47, 21–33.
Hawkins, B.A., Thomas, M.B., Hochberg, M.E., 1993. Refuge theory and biological control. Science 262, 1429–1432.
Hoffmann, B., 2014. Assessment of the progress of the African big-headed ant eradication program on Lord Howe Island. CSIRO, Darwin, Australia.
Hoffmann, B.D., Andersen, A.N., Hill, G.J.E., 1999. Impact of an introduced ant on native rain forest invertebrates: *Pheidole megacephala* in monsoonal Australia. Oecologia 120, 595–604.
Hoffmann, B.D., Luque, G.M., Bellard, C., Holmes, N.D., Donlan, C.J., 2016. Improving invasive ant eradication as a conservation tool: a review. Biol. Conserv. 198, 37–49.
Holway, D.A., Lach, L., Suarez, A.V., Tsutsui, N.D., Case, T.J., 2002. The causes and consequences of ant invasions. Annu. Rev. Ecol. Evol. Syst. 33, 181–233.
Huddleston, E.W., Fluker, S.S., 1968. Distribution of ant species of Hawaii. Proc. Hawaiian Entomol. Soc. 20, 45–69.
Human, K.G., Gordon, D.M., 1997. Effects of Argentine ants on invertebrate biodiversity in northern California. Conserv. Biol. 11, 1242–1248.
Krushelnycky, P.D., 2015. Ecology of some lesser-studied introduced ant species in Hawaiian forests. J. Insect Conserv. 19, 659–667.
Ogura-Yamada, C.S., Krushelnycky, P.D., 2016. Testing the attractiveness and efficacy of baits for the monitoring and control of the thief ant, *Solenopsis papuana*. Proc. Hawaiian Entomol. Soc. 48, 95–108.
Krushelnycky, P.D., Gillespie, R.G., 2010. Correlates of vulnerability among arthropod species threatened by invasive ants. Biodivers. Conserv. 19, 1971–1988.
Krushelnycky, P.D., Loope, L.L., Reimer, N.J., 2005. The ecology, policy, and management of ants in Hawaii. Proc. Hawaiian Entomol. Soc. 37, 1–25.
Lach, L., Hooper-Bùi, L.M., 2010. Consequences of ant invasions. In: Lach, L., Parr, C.L., Abbott, K.L. (Eds.), Ant Ecology. Oxford University Press, Oxford, pp. 261–286.
Lawler, J.J., Campbell, S.P., Guerry, A.D., Kolozsvary, M.B., O'Connor, R.J., Seward, L.C.N., 2002. The scope and treatment of threats in endangered species recovery plans. Ecol. Appl. 12, 663–667.
Le Breton, J., Chazeau, J., Jourdan, H., 2003. Immediate impacts of invasion by *Wasmannia auropunctata* (Hymenoptera: Formicidae) on native litter ant fauna in a New Caledonian rainforest. Austral Ecol. 28, 204–209.
Magnacca, K.N., 2014. Chapter 5: *Drosophila* species management. In: OANRP 2014. Status Report for the Makua and Oahu Implementation Plans. Prepared by the Oahu Army Natural Resources Program, U.S. Army Garrison, Hawaii, and Pacific Cooperative Studies Unit, Schofield Barracks.
Magnacca, K.N., Foote, D., O'Grady, P.M., 2008. A review of the endemic Hawaiian Drosophilidae and their host plants. Zootaxa 1728, 1–58.
Montgomery, S.L., 1975. Comparative breeding site ecology and the adaptive radiation of picture-winged *Drosophila* (Diptera: Drosophilidae) in Hawaii. Proc. Hawaiian Entomol. Soc. 22, 65–103.
New, T.R., 2007a. Recovery plans for insects: what should they contain, and what should they achieve? J. Insect Conserv. 11, 321–324.
New, T.R., 2007b. Understanding the requirements of the insects we seek to conserve. J. Insect Conserv. 11, 95–97.
Perkins, R.C.L., 1913. Introductory essay on the fauna. In: Fauna Hawaiiensis 1: xv-ccxxviii. University Press, Cambridge, UK, Cambridge.
Plentovich, S., Swenson, C., Reimer, N., Richardson, M., Garon, N., 2010. The effects of hydramethylnon on the tropical fire ant, *Solenopsis geminata* (Hymenoptera: Formicidae), and non-target arthropods on Spit Island, Midway Atoll, Hawaii. J. Insect Conserv. 14, 459–465.
Plentovich, S., Eizenga, J., Eizenga, H., Smith, D., 2011. Indirect effects of ant eradication efforts on offshore islets in the Hawaiian Archipelago. Biol. Invasions 13, 545–557.
Reimer, N.J., 1994. Distributional and impact of alien ants in vulnerable Hawaiian ecosystems. In: Williamns, D.F. (Ed.), Exotic Ants Biology, Impact, and Control of Introduced Species. Westview Press, Colorado, pp. 11–22.
Samways, M.J., 2007. Insect conservation: a synthetic management approach. Annu. Rev. Entomol. 52, 465–487.
Schultz, C.B., Hammond, P.C., 2003. Using population viability analysis to develop recovery criteria for endangered insects: case study of the Fender's blue butterfly. Conserv. Biol. 17, 1372–1385.
Thompson, C.R., 1980. Solenopsis (Diplorhoptrum) (Hymenoptera: Formicidae) of Florida (Ph.D. dissertation). University of Florida, Gainesville, Florida.
Thompson, C.R., 1989. The thief ants, *Solenopsis molesta* group, of Florida (Hymenoptera: Formicidae). Fla. Entomol. 72, 268–283.
Tschinkel, W.R., 2006. The Fire Ants. The Belknap Press of Harvard University Press, Cambridge, Massachusetts, and London, England.
United States Fish and Wildlife Service (USFWS), 2006. Endangered and threatened wildlife and plants; determination of status for 12 species of picture-wing flies from the Hawaiian Islands. Fed. Regist. 71 (89), 26835–26852.
United States Fish and Wildlife Service (USFWS), 2010. Endangered and threatened wildlife and plants; determination of endangered status for 48 species on Kauai and designation of critical habitat. Fed. Regist. 75 (70), 18960–19008.
United States Fish and Wildlife Service (USFWS), 2013. Endangered and threatened wildlife and plants; determination of endangered species status for 15 species on Hawaii Island. Fed. Regist. 78 (209), 64638–64690.
United States Fish and Wildlife Service (USFWS), 2017. Endangered species. available at: https://www.fws.gov/endangered/, Accessed date: 31 March 2017.
Walker, K.L., 2006. Impact of the little fire ant, *Wasmannia auropunctata*, on native forest ants in Gabon. Biotropica 38, 66–673.
Wheeler, M.R., Clayton, F.E., 1965. A New *Drosophila* Culture Technique. 40. Drosophila Information Service, pp. 98.
Wong, T.T.Y., McInnis, D.O., Nishimoto, J.I., Ota, A.K., Chang, V.C.S., 1984. Predation of the Mediterranean fruit fly (Diptera: Tephritidae) by the Argentine ant (Hymenoptera: Formicidae) in Hawaii. J. Econ. Entomol. 77, 1454–1458.

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# Microhabitat heterogeneity and a non-native avian frugivore drive the population dynamics of an island endemic shrub, *Cyrtandra dentata*

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## Summary

**1.** Understanding the role of environmental change in the decline of endangered species is critical for designing scale-appropriate restoration plans. For locally endemic rare plants on the brink of extinction, frugivory can drastically reduce local recruitment by dispersing seeds away from geographically isolated populations. Dispersal of seeds away from isolated populations can ultimately lead to population decline. For localized endemic plants, fine-scale changes in microhabitat can further limit population persistence. Evaluating the individual and combined impact of frugivores and microhabitat heterogeneity on the short-term (i.e. transient) and long-term (i.e. asymptotic) dynamics of plants will provide insight into the drivers of species rarity.

**2.** In this study, we used 4 years of demographic data to develop matrix projection models for a long-lived shrub, *Cyrtandra dentata* (H. St. John & Storey) (Gesneriaceae), which is endemic to the island of O'ahu in Hawai'i. Furthermore, we evaluated the individual and combined influence of a non-native frugivorous bird, *Leiothrix lutea*, and microhabitat heterogeneity on the short-term and long-term *C. dentata* population dynamics.

**3.** Frugivory by *L. lutea* decreased the short-term and long-term population growth rates. However, under the current level of frugivory at the field site the *C. dentata* population was projected to persist over time. Conversely, the removal of optimum microhabitat for seedling establishment (i.e. rocky gulch walls and boulders in the gulch bottom) reduced the short-term and long-term population growth rates from growing to declining.

**4.** Survival of mature *C. dentata* plants had the greatest influence on long-term population dynamics, followed by the growth of seedlings and immature plants. The importance of mature plant survival was even greater when we simulated the combined effect of frugivory and the loss of optimal microhabitat, relative to population dynamics based on field conditions. In the short-term (10 years), however, earlier life stages had the greatest influence on population growth rate.

**5.** *Synthesis and applications*. This study emphasizes how important it is to decouple rare plant management strategies in the short vs. long-term in order to prioritize restoration actions, particularly when faced with multiple stressors not all of which can be feasibly managed. From an applied conservation perspective, our findings also illustrate that the life stage that, if improved by management, would have the greatest influence on population dynamics is dependent on the timeframe of interest and initial conditions of the population.

**Key-words:** avian frugivory, *Cyrtandra dentata*, elasticity analysis, endangered species, microhabitat heterogeneity, plant population dynamics, restoration ecology, stage-structured demographic model, stochastic demography, transient dynamics

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## Introduction

The spatial distribution and abundance of organisms are shaped by interactions with the environment. Human-induced changes in the environment, such as alterations in plant-animal interactions and degradation in abiotic conditions, influence demographic vital rates (i.e. survival, growth, and reproduction) and population dynamics, such as the population growth rate. Recent research suggests that plant endangerment is the result of the combined influence of multiple environmental stressors (Sala *et al.* 2000; Didham *et al.* 2007; Brook, Sodhi & Bradshaw 2008). To explicitly evaluate the individual or combined influence of targeted environmental change on population growth rate requires a demographic modelling approach (Morris & Doak 2002). Though many demographic studies have quantified the influence of various environmental factors on plant population dynamics, few studies have focused on the individual or combined impact of non-native frugivores and alterations in abiotic conditions (Godínez-Alvarez & Jordano 2007; Loayza & Knight 2010).

Tropical islands are biodiversity hotspots and, unfortunately, have some of the highest rates of extinction and species endangerment. For these reasons, tropical island ecosystems are often ranked as high conservation priority (Mittermeier *et al.* 1998; Myers *et al.* 2000). The high rates of extinction and species endangerment on islands are due, in part, to the sheer number of localized endemic species (Shaffer 1981; Gilpin & Soule 1986; Menges 1990; Brigham & Schwartz 2003). Due to their geographically limited ranges and adaptations to narrow ecological conditions (Brown 1984), island endemic plants are likely more sensitive to environmental change than common widespread species. As a consequence, even small-scale changes in the environment may have a disproportionally large effect on the population persistence of island plants. Thus, to effectively manage endangered species in an island context, it is critical to understand how changing environmental conditions influence population persistence (Mittermeier *et al.* 1998; Myers *et al.* 2000). Surprisingly, the demographic consequence of plant interactions with environmental stressors is rarely studied for localized island endemic species (but see, Krushelnycky *et al.* 2013; Simmons *et al.* 2012).

A primary environmental driver of biodiversity loss on islands is the introduction of non-native plants and animals (Wilcove *et al.* 1998). Some of the most successful non-native animals to invade island ecosystems are non-native frugivores (Meyer & Butaud 2009; Shiels *et al.* 2014). The effectiveness of non-native frugivores to replace the role of native frugivores is dependent on the ecological similarity of the dispersal agents (Schupp, Jordano & Gómez 2010). Removal of seeds from a population to microsites that are unfavourable for germination and establishment can lead to localized recruitment depression (Godínez-Alvarez, Valiente-Banuet & Rojas-Martínez 2002; Loayza & Knight 2010). In contrast, if seeds are not destroyed following consumption and are dispersed away from the population to suitable habitat for establishment, non-native frugivores could have a positive influence on plant dynamics by decreasing conspecific competition and increasing gene flow between isolated plant populations (Slatkin 1985; Howe 1986; Bacles, Lowe & Ennos 2006; Schupp, Jordano & Gómez 2010). Island species are also threatened by habitat degradation and altered abiotic conditions (Wilcove *et al.* 1998). Altered abiotic conditions, such as a reduction of optimal microhabitats, can have a particularly pronounced impact on seedling establishment (Fetcher, Strain & Oberbauer 1983; Eriksson & Ehrlen 1992; Dostálek & Münzbergová 2013). The suitability of microhabitat for seedling establishment can be highly variable among species. Important characteristics of optimal microhabitats for seedling establishment include light availability (Denslow 1980), substrate characteristics (Dostálek & Münzbergová 2013), disturbance frequency (Crawley & Nachapong 1985), and sufficient water availability (Fetcher, Strain & Oberbauer 1983).

In this study, we investigated the combined effects of abiotic and biotic environmental factors on the dynamics of a localized endemic shrub, *Cyrtandra dentata* (H. St. John & Storey) (Gesneriaceae), confined to a narrow ecological threshold on the Island of O'ahu in Hawai'i. The biotic stressor that we examined was a non-native generalist bird, *Leiothrix lutea*, and the abiotic factor that we assessed was alterations in microhabitats that varied in suitability for seedling establishment, optimal microhabitat (rock outcrops, defined as boulders covered by moss in the gulch bottom and the rocky gulch walls) and suboptimal microhabitat (soil). To assess how these environmental factors influence local population dynamics we asked the following questions: (i) Does seed frugivory by *L. lutea* and removal of optimal microhabitat influence the short and long-term population dynamics of *C. dentata*? (ii) Under what combination of these stressors does *C. dentata* maintain positive population growth over the short and long-term? (iii) What life stages and associated vital rates have the greatest influence on population growth rate over the short and long-term? (iv) Does the intensity of these stressors influence the relative importance of life stages and associated vital rates on the short and long-term population growth rates?

## Materials and methods

### STUDY SPECIES

*Cyrtandra dentata* is an endangered long-lived shrub endemic to the island of O'ahu in Hawai'i. *Cyrtandra dentata* reaches reproductive maturity at 0·8 m (L. Bialic-Murphy, unpublished data) and produces white subumbelliform cymes, 3–9 cm long with white fleshy ovate berries, 1–2·6 cm long (Wagner, Herbst & Sohmer 1999). The mean age of first reproduction for *C. dentata* is

6 years (L. Bialic-Murphy, unpublished data). The reproductive biology of *C. dentata* is poorly understood, but the white flowers it produces suggest it is moth pollinated (OANRP 2003). The mean number of *C. dentata* seeds per mature fruit is 1873 (L. Weisenberger, unpublished data) and mean seed size is ca. 0·5 mm long (Wagner, Herbst & Sohmer 1999). The *C. dentata* fruiting season is between September and November, with peak fruiting in October (L. Bialic-Murphy, unpublished data). The long-distance dispersal agents for *Cyrtandra* species in the Pacific is unresolved but columbiform birds have been implicated (Cronk *et al.* 2005). Previous research also suggests passive transport by water is a short-distance dispersal vector for Hawaiian *Cyrtandra* species (Kiehn 2001). Adventitious roots are produced from the lower section of the main stems, anchoring plants to soil, rocky gulch walls, and boulders in the gulch bottom (L. Bialic-Murphy, pers. obs.).

Historically, *C. dentata* spanned the northern Wai'anae Mountains and the leeward side of the northern Ko'olau Mountains on the island of O'ahu, 300–610 m in elevation (Wagner, Herbst & Sohmer 1999). The typical habitat is shady gulch bottoms of mesic to wet forests. In 1996, *C. dentata* was listed as endangered and by 2010, it was restricted to five geographically isolated locations (USFWS, 2012). Of those populations, only two sites, Kahanahāiki and Pahole to West Makaleha, have >16 mature plants and are representative of plants in earlier life stages (i.e. immature plants and seedlings).

*Leiothrix lutea* is one of the most common non-native generalist birds in Hawai'i. The body mass of males is 21·3 ± 0·28 g and the body mass of females is 21·21 ± 0·24 g (Male, Fancy & Ralph 1998). *Leiothrix lutea* gut passage time is unknown but the average gut passage time of avian seed and pulp consumers with similar body size (i.e. 19·9–23·8 g) is 1·73 hours (Herrera 1984). The diet preference of *L. lutea* is a mix of insects and small–seeded fruits (Male, Fancy & Ralph 1998). *Leiothrix lutea* primarily forage in the understory several metres off the ground, rapidly moving from plant to plant (Male, Fancy & Ralph 1998). The home range of *L. lutea* in Hawai'i is 3·07 ± 0·32 ha for males and 2·68 ± 0·27 ha for females (Male, Fancy & Ralph 1998). *Leiothrix lutea* pair formation occurs in March and breeding season is from March to mid August. During the non-breeding season, *L. lutea* are highly nomadic, moving in large flocks (<100 individuals) (Male, Fancy & Ralph 1998).

## STUDY SITE AND MANAGEMENT HISTORY

We studied the demography of *C. dentata* in the Kahanahāiki Management Unit (36 ha), located in the northern Wai'anae Mountain Range, on the island of O'ahu (21° 32′ N, −158°12′ W). Kahanahāiki is a tropical mesic forest with a mix of native and non-native flora and fauna. The mean monthly rainfall is 53–227 mm (Giambelluca *et al.* 2013), and the mean daily temperature range is 16–24 °C (Shiels & Drake 2011). The Kahanahāiki population is one of the two known *C. dentata* locations, with more than 16 mature plants and has individuals in earlier life stages (i.e. seedlings and immature plants). The population is located in the main Kahanahāiki drainage, spanning from the base of a seasonal waterfall to c. 150 m to the north. Within the Kahanahāiki drainage, the plants are scattered throughout the gulch bottom and along the steep rock walls. Though plants occur throughout the study site, they are rooted in higher density on rock outcrops than on soil.

Since 1995, the O'ahu Army Natural Resources Program (OANRP) has managed the Kahanahāiki *C. dentata* population. Restoration efforts by OANRP included the control of feral pigs (*Sus scrofa*) and semi-annual suppression of ecosystem-altering invasive vegetation (OANRP, 2009). *Sus scrofa* directly impact many plants through their physical disturbance to the forest. In general, native seedlings, saplings, and mature plants increase in density following *S. scrofa* control (Loh & Tunison 1999; Busby, Vitousek & Dirzo 2010; Cole *et al.* 2012). Non-native plants are a threat through their competitive displacement of native plants (Vitousek 1996; Ostertag *et al.* 2009; Minden *et al.* 2010). Following the suppression of these top-down stressors in the Kahanahāiki fence, *C. dentata* started establishing at higher rates leading to greater numbers of seedlings and small juvenile plants (M. Kiehn, unpublished data).

## DEMOGRAPHY DATA AND PROJECTION MATRIX MODEL

The life cycle of *C. dentata* was divided into four biologically discrete life stages based on height to the apical meristem: reproductive mature (>80 cm), large immature (20 cm–80 cm), small immature (2 cm–20 cm) plants, and seedling (<2 cm). We used 80 cm as the cut off for the reproductive mature life stage because it was the minimum height that plants produced fruits at the study site. Small and large juvenile were divided into two categories based on expert opinion by conservation practitioners and observed differences in survival at the field site. In 2010, at the start of this study, the Kahanahāiki *C. dentata* population consisted of 45 mature plants, 158 immature, and 600 seedlings. For four consecutive years (2010–2014), we permanently tagged and monitored a subset of plants in the population annually. Over the study period, a total of 507 plants were tagged and monitored. For the mature and large immature life stages, all individuals were monitored. For the small immature and seedling life stages, we monitored a minimum of 60 plants annually to ensure our effects on *C. dentata* habitat were minimal. For each tagged plant, we collected data on height to apical meristem (when possible), survival, and reproduction.

We used these field data to estimate the survival, growth, and fecundity rates for each life stage and parameterize a matrix projection model (Caswell 2001):

$$n(t+1) = An(t) \qquad \text{eqn 1}$$

where the vector $n(t)$ represented the number of plants in four discrete life stages at time $t$ and $n\ (t + 1)$ was the number of plants in each life stage the following year. The transition matrix **A** was composed of eight non-zero matrix elements ($a_{ij}$), which represented the transition probabilities of the seedling ($s$), small immature ($si$), large immature ($li$), and mature ($m$) life stages from time $t$ to $t + 1$. Unobserved transitions over the study period were represented in matrix **A** as zeros:

$$\mathbf{A} = \begin{pmatrix} \sigma_s(1-\gamma_s) & 0 & 0 & \varphi_m \\ \sigma_s\gamma_s & \sigma_{si}(1-\gamma_{si}) & 0 & 0 \\ 0 & \sigma_{si}\gamma_{si} & \sigma_{li}(1-\gamma_{li}) & 0 \\ 0 & 0 & \sigma_{li}\gamma_{li} & \sigma_m \end{pmatrix}$$

Matrix **A** was parameterized to include the probability of survival ($\sigma_i$), growth to the next stage class ($\gamma_i$), and fecundity ($\varphi_m$). Fecundity ($\varphi_m$) was calculated by dividing the number of seedlings counted in a given year by the number of mature plants the previous year. Matrix **A** captured the population demographic transitions under management of feral pigs and invasive plant competition while including frugivory by *L. lutea*. In 2011–2012, there was unintentional impact of herbicide drift on mature plants (based on qualitative field observations). Mature plants wilted and shed their leaves 2 weeks after the control of ecosystem altering vegetation, which occurred directly around the plants. For this reason, the 2011–2012 survival of matures ($\sigma_m$ = 47%) was lower than to the other transition years ($\sigma_m$ = 98%–81%). Since mortality from herbicide drift was not expected to occur in the future and we wanted to make our results were generalizable to other sites, we did not use the 2011–2012 $\sigma_m$ data to calculate mature plant survival for the 2011–2012 matrix **A** transition year. Instead, we used the mean survival of mature plants in 2010–2011, 2012–2013, and 2013–2014 for the 2011–2012 matrix $\mathbf{A}\cdot\sigma_m$ term.

### SIMULATING THE EFFECTS OF MICROHABITAT HETEROGENEITY AND FRUGIVORY

Matrix **A** represents field microhabitat conditions while maintaining frugivory by *L. lutea*. To simulate the effects of changes in microhabitat heterogeneity and frugivory by *L. lutea* on the dynamics of the *C. dentata* population, we constructed three additional matrices **B**, **C**, and **D** by modifying matrix **A**. Based on the results of additional field experiments, we found that frugivory by *L. lutea* and the availability of optimal microhabitat impacted the fertility $\varphi_m$ of matrix **A** (see Appendix S1A and S1B, Supporting Information). To construct matrix **B**, which captures the removal of frugivory while maintaining field microhabitat conditions, we increased the $\varphi_m$ element of matrix **A** by the percentage of fruits consumed by *L. lutea* at our field site. To construct matrix **C**, which represents the removal of frugivory and suboptimal microhabitat, we decreased the $\varphi_m$ element of matrix **B** by the difference in seedling establishment between the optimal and suboptimal microhabitat. Lastly, to construct matrix **D**, which simulates the influence of both stressors (i.e. frugivory and suboptimal microhabitat), we decreased $\varphi_m$ of matrix **A** by the percent difference in seedling establishment between the optimal and suboptimal microhabitat. Given the relatively short duration of the *C. dentata* fruiting season (i.e. 3 months), we assumed *C. dentata* germination and the number of seeds per fruit was not temporally variable.

### STOCHASTIC LONG-TERM POPULATION DYNAMICS

For the four scenarios **A**, **B**, **C**, and **D** we projected the stochastic long-term population growth rate $\lambda_s$. To incorporate the effect of temporal variation in demographic processes to fluctuations in environmental conditions (i.e. environmental stochasticity) on population dynamics, we used the 4 years of demographic data to develop temporally varying stochastic matrix models for each scenario **A**, **B**, **C**, and **D** previously defined:

$$n(t+1) = X(t)n(t) \qquad \text{eqn 2}$$

where $\mathbf{X}(t)$ is a random population projection selected at given time $t$ from a pool of four yearly matrix transitions (2010–2011, 2011–2012, 2012–2013, and 2013–2014) for the corresponding scenario (**A**, **B**, **C**, and **D**). The yearly matrices had an equal probability of being selected each iteration. The stable stage distribution (SSD) was used as the initial stage structure $n(0)$. We assumed the time-varying model followed an identically independent distribution (*i.i.d.*). For each scenario, we used eqn (2) to calculate the stochastic growth rate $\lambda_s$ with 95% confidence intervals by simulation using 50 000 iterations, following Tuljapurkar, Horvitz & Pascarella (2003):

$$\log \lambda_s = \lim_{t\to\infty} \left(\frac{1}{t}\right) \log[P(t)/P(0)] \qquad \text{eqn 3}$$

where $P(t)$ is the population size, i.e. the sum of the elements of $n(t)$ at a given time $t$. Confidence intervals were calculated using a standard bootstrap approach, as outlined in (Caswell 2001; Morris & Doak 2002). To evaluate the individual and combined influence of the microhabitat and seed consumption by *L. lutea* on population dynamics, we compared the $\lambda_s$ of each scenario (**A**, **B**, **C**, and **D**). To identify the relative importance of different life stages on the stochastic population growth rate $\lambda_s$ for each scenario, we calculated the elasticity $E^{\mu S}$ of $\lambda_s$ to perturbation of mean matrix elements $\mu_{ij}$ following Tuljapurkar, Horvitz & Pascarella (2003).

### STOCHASTIC SHORT-TERM POPULATION DYNAMICS

We calculated the stochastic short-term population growth rate for each management scenario (**A**, **B**, **C**, and **D**), using the following formula:

$$r(t_1, t_{10}) = \frac{1}{t_{10} - t_1} \log \frac{N(t_{10})}{N(t_1)} \qquad \text{eqn 4}$$

The transient population growth rate was calculated as the average of a 1000 independent sample paths of length $t$ = 10 years. The stage structure at $n\ (t + 1)$ was calculated using eqn (2). For a given year $t$ ($t$ < 10), and for each management scenario, we randomly selected one of the four yearly transition matrices (2010–2011, 2011–2012, 2012–2013, and 2013–2014) with equal probability to account for the effect of environmental variability. The timeframe of $t$ = 10 years was used because it is the recommended timeframe to evaluate population dynamics of critically endangered plants by the IUCN red listing guideline (IUCN, 2001) and a reasonable length of time of a restoration management plan. Lower survival of mature plants in 2011–2012, due to herbicide drift, likely resulted in a lower proportion of individuals with high reproductive value in 2014 than would otherwise be expected. If the stage structure of the population had not been affected by herbicide drift, the short-term growth rate would likely have been slightly higher (i.e. population amplification) prior to SSD being achieved. However, in order to simulate short-term projections that could be used by conservation practitioners to manage the Kahanahāiki *C. dentata* population, we chose to use the observed population size in 2014 as the initial stage structure $n(0)$.

To identify the relative importance of life stages on the short-term population growth rate, we conducted stochastic transient elasticity analyses with respect to small changes in matrix elements to unperturbed stage structure, $e_{1,i,j}$ (Haridas & Tuljapurkar 2007; Haridas & Gerber 2010). The $e_{1,i,j}$ distribution for each scenario (**A**, **B**, **C**, and **D**) was iteratively calculated by simulation, using 1000 iterations. The four yearly transition matrices $\mathbf{X}(t)$ were selected with equal probability each iteration.

## Results

### STOCHASTIC LONG-TERM POPULATION GROWTH RATES

The stochastic growth rate of the *C. dentata* population for scenario **A** (i.e. frugivory and field microhabitat conditions) was positive ($\lambda_s$ = 1·032, 95% CI [1·028–1·037]), indicating a moderately growing population in the long-term (Fig. 1a). Removal of frugivory by *L. lutea* while maintaining field microhabitat conditions (scenario **B**) increased the stochastic population growth rate by 1·7% ($\lambda_s$ = 1·049, 95% CI [1·044–1·054]), relative to scenario **A** (Fig. 1a).

Maintaining frugivory while removing optimal microhabitat (scenario **C**) shifted the population growth rate from positive to negative ($\lambda_s$ = 0·968, 95% CI [0·964–0·971]). The combined influence of both stressors (scenario **D**) decreased the stochastic population growth rate ($\lambda_s$ = 0·955, 95% CI [0·952–0·959]) and led to a declining population trajectory (Fig. 1a).

### STOCHASTIC SHORT-TERM POPULATION GROWTH RATES

Over the short-term, the *C. dentata* population was projected to grow moderately under current field conditions (i.e. frugivory and field microhabitat conditions) ($r_s$ = 1·087, 95% CI [1·083–1·091]; Fig. 1b). Similar to long-term projections, removal of frugivory increased the short-term population growth rate ($r_s$ = 1·119, 95% CI [1·115–1·124]). Removal of optimal microhabitat reduced the short-term population growth rate ($r_s$ = 0·973, 95% CI [0·969–0·976]). The combined impact of frugivory and the removal of optimal microhabitat had the greatest negative impact on the population growth rate ($r_s$ = 0·941, 95% CI [0·938–0·944]).

### STOCHASTIC SHORT AND LONG-TERM ELASTICITY

In the long-term, the survival of mature plants had the greatest proportional impact on the population growth rate, followed by the growth of seedlings, small immature, and large immature plants and fertility (Fig. 2a). Removal of optimal microhabitat for seedling establishment and frugivory increased the relative importance of the survival of mature plants on the long-term population growth rate. It also decreased the relative importance of the survival and growth of seedling, small immature, and large immature plants on the population growth rate (Fig. 2a).

In the short-term, fecundity had the greatest relative importance on the population growth rate followed by the growth of seedlings to the small immature life stage (2b). The individual and combined impacts of seed consumption by *L. lutea* and removal of optimal microhabitat (scenario **A**, **C**, and **D**) reduced the relative importance of the fecundity and growth of seedlings to the small immature life stage (Fig. 2b).

## Discussion

The influence of abiotic factors (e.g. light, soil type, elevation) on plant population dynamics has been well examined (Alvarez-Buylla *et al.* 1996; Brys *et al.* 2005; Colling & Matthies 2006; Dahlgren & Ehrlén 2009; Souther & McGraw 2014). However, the influence of frugivorous animals or the combined effects of frugivory and microhabitat heterogeneity on plant population dynamics are rarely measured, and studies on this topic have produced mixed results (Godínez-Alvarez & Jordano 2007; Loayza

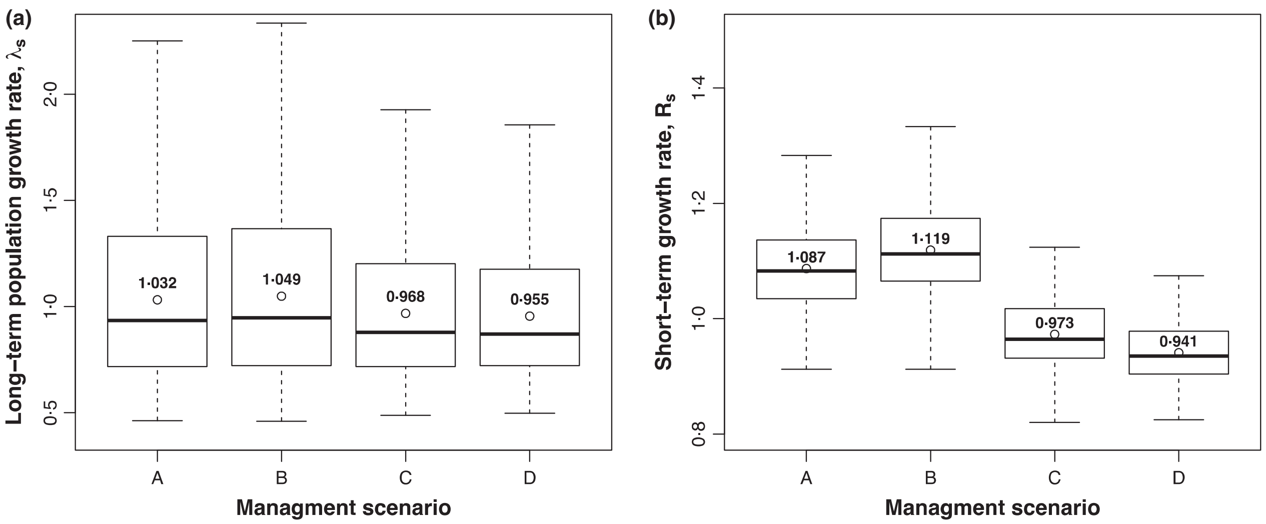


**Fig. 1.** Stochastic short ($R_s$) and long-term ($\lambda_s$) population growth rates of *Cyrtandra dentata*. The black bar is the median and the boxes represent the inter-quartile range. The limits of the whiskers are 1·5× the inter-quartile range. The open circle is the mean of each management scenario. Scenario **A** = Field conditions (i.e. field microhabitat conditions and frugivory), **B** = No frugivory while maintaining field microhabitat conditions, **C** = No frugivory and suboptimal microhabitat, **D** = Frugivory and suboptimal microhabitat.

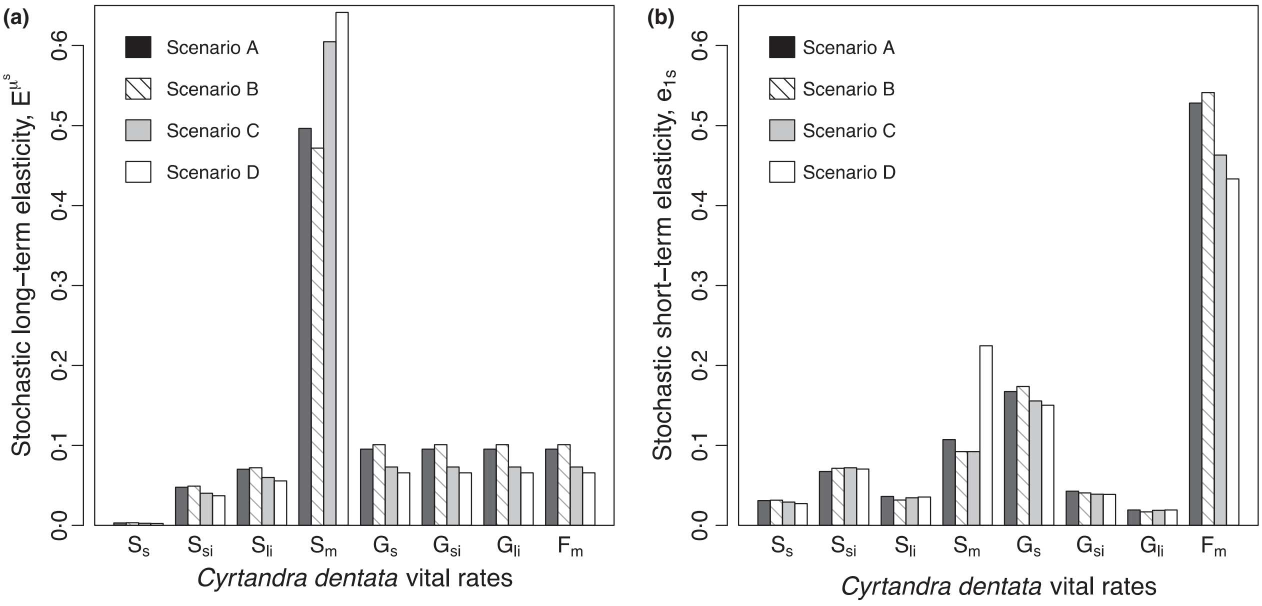


**Fig. 2.** Stochastic elasticities of *Cyrtandra dentata* (a) long- and (b) short-term growth rates to perturbation of mean vital rates. The vital rates are survival (S), growth (G), and fertility (F) and the life stages are seedling (*s*), small immature (*si*), large immature (*li*), and mature (*m*). Scenario **A** = Field conditions (i.e. field microhabitat conditions and frugivory), **B** = No frugivory while maintaining field microhabitat conditions, **C** = No frugivory and suboptimal microhabitat, **D** = Frugivory and suboptimal microhabitat.

& Knight 2010). Due to their adaptation to narrow ecological conditions and limited geographical distribution, localized endemics are likely to suffer stronger effects of such stressors. Thus, to fully understand the drivers of species decline, it is critically important to evaluate the individual and combined impact of environmental change, such as alterations in abiotic conditions and non-native frugivores, on the short-term (i.e. transient) and long-term (i.e. asymptotic) dynamics of rare species.

In this study, we found that rock outcrops (i.e. rocky gulch walls and small boulders in the gulch bottom) were an optimal microhabitat for *C. dentata* seedling establishment. Though the mechanism underpinning higher seedling establishment on rock outcrops is unknown, previous research suggests that rocks covered by moss can maintain a moist microsite favourable for seedling establishment (Ren *et al.* 2010). We also found that *C. dentata* seeds that were not contributing to local dynamics were consumed by *L. lutea* and dispersed away from the population. Under current field conditions (i.e. intensity of frugivory by *L. lutea* and microhabitat conditions at the field site), *C. dentata* was projected to persist in the long-term. Removal of frugivory moderately increased the long-term population growth rate, as compared to field conditions. Under suboptimal microhabitat conditions the long-term population growth rate was negative, regardless of frugivory pressure. These results suggest that for *C. dentata*, the removal of optimal microhabitat availability for seedling establishment would have a greater influence on population dynamics than frugivory by *L. lutea*. Furthermore, we found that the short-term transient growth rate (i.e. over 10 years) was slightly higher than the long-term growth rate. However, for each scenario, the projected direction of the short and long-term growth rates was not different. Additionally, there was more variation in the long-term projections than in the short-term projections (Fig. 1). In the transient phase, the population dynamics are strongly influenced by the initial condition of the population (Ellis & Crone 2013). Conversely, the stochastic long-term dynamics are strongly influenced by variation in vital rates (Ellis & Crone 2013). Thus, greater variation in long-term dynamic than in the short-term dynamics of *C. dentata* can be explained, in part, by the effects of the year to year differences in targeted vital rates, after the strong effects of initial population structures has damped out. Though herbicide drift altered the stage structure of the population by decreasing the proportion of plants with high reproductive value, the population was still projected to persist in the short-term. If herbicide drift had not occurred, however, the population would likely have grown faster in the short-term (i.e. transient amplification), which is important to consider when evaluating the population dynamics of other *C. dentata* population not experiencing this demographic disturbance.

Dispersal agents can provide enemy escape from predators in close proximity to parent plants, reduce conspecific seedling competition, and increase seed germination for species reliant on gut passage to maintain high seed viability (Howe & Smallwood 1982; Willson & Traveset 2000). For species that produce more seeds than are needed to maintain a persistent population, dispersal away from geographically isolated populations can have a positive effect on metapopulation dynamics. However, for species on the brink of extinction the removal of seeds away from a population can shift the population trajectory from persistent to declining. In this study, we found that a majority of the seedlings at the field site either established slightly down gulch or underneath the crown of reproductively mature plants. This observation supports previous studies that suggest passive transport by water is a short-distance dispersal strategy for *Cyrtandra* species in Hawaii (Kiehn 2001). We also found that seed germination from whole *C. dentata* fruits was relatively high, which suggest this taxon is not dependent on gut passage by frugivores to maintain high seed viability (see Appendix S1, Fig. 2). These results suggest *C. dentata* is not reliant on avian dispersal to maintain locally persistent populations.

Following massive extinction of native Hawaiian birds it is likely that many native species are dispersal limited, which may eventually reduce plant fitness by decreasing gene flow between populations. However, decreased gene flow between populations may be mitigated by cross-pollination between populations. For *C. dentata*, there are only five known extant populations, only two of which, Kahanahāiki and Pahole to West Makaleha, have >16 mature plants and individuals in earlier life stages (i.e. immature plants and seedlings). Of those populations, Pahole to West Makaleha was the only population closer to Kahanahāiki (<3 ha) than the home range of *L. lutea*. If rare long-distance dispersal between the Kahanahāiki and Pahole to West Makaleha populations is occurring by *L. lutea*, it may have an effect on plant fitness over time by increasing gene flow between populations. However, to fully understand the effect of rare long-distance dispersal would require a metapopulation approach, incorporating extinction and re-colonization events, and this is beyond the scope of this study.

For long-lived species, it is expected that later life stages will have a larger impact than earlier life stages on the long-term population growth rate (Silvertown *et al.* 1993; Haridas & Gerber 2010). The importance of later life stages on population dynamics of long-lived species is commonly explained by life history strategy. High survival of mature plants can insulate long-lived species from environmental variability and thus is the most important vital rate for maintaining population persistence in the long-term. However, recent research suggests that long-term elasticity does not always adequately describe the importance of life stages and associated vital rate in the short-term (Haridas & Tuljapurkar 2007; Haridas & Gerber 2010). In some scenarios, earlier life stages disproportionally contributed to the population growth rate of long-lived species over the short-term (e.g. 10 years), relative to later life stages (Haridas & Tuljapurkar 2007; McMahon & Metcalf 2008; Ezard *et al.* 2010; Haridas & Gerber 2010; Gaoue 2016). Consistent with these studies, we also found a shift in the short and long-term elasticity patterns of the *C. dentata* population growth rate to perturbation of vital rates. *Cyrtandra dentata* long-term stochastic elasticity was dominated by the survival of mature plants. However, in the short-term, the establishment of *C. dentata* seedlings had the greatest influence on the population growth rate. These results have several management implications for *C. dentata*. First, with high mature plant survival (81% – 97%), there is likely little that can be done to improve that vital rate. However, the importance of mature plants on the long-term population growth rate emphasizes the gravity of maintaining high survival of matures over time. Secondly, management actions that increase seedling establishment would have the greatest positive impact on the population growth rate in the short-term.

Studying the demography of rare and endangered species is challenging due to limited replication (Morris & Doak 2002). Despite the constraint of limited replication valuable insight can be gained from population dynamic studies of endangered species, such as quantifying the likely outcome of management actions and assessing the potential impact of environment parameters on population dynamics (Morris *et al.* 2002; García 2003; Ellis, Weekley & Menges 2007; Marrero-Gómez *et al.* 2007; Crone *et al.* 2011; Dostálek & Münzbergová 2013). It can also provide a proactive method of predicting the likely outcome of management actions, which would otherwise take several generations to detect (Menges 2000). For this study, we were limited to one study site because it was the only *C. dentata* population that was composed of more than several individuals that we had permission to access. Thus, results from this study may not be extrapolated across varying habitat and ecological conditions. Future integrative studies on the combined impact of plant interactions with multiple environmental parameters would benefit from having replication across multiple study sites. Plant population response to environmental stressors should be studied for more species varying in life history in order to investigate if generalized patterns emerge, which could be used to effectively manage rare plants and the habitat that they depend on.

Regardless of the difficulties of studying endangered species, the results of this study emphasize the importance of protecting optimal microhabitat for seedling establishment to maintain a positive population trajectory for endangered species that are sensitive to fine-scale environmental change. For *C. dentata*, a management strategy that would prevent degradation of optimal abiotic conditions for seedling establishment is the suppression of competitive vegetation. One of the most invasive ecosystem altering species at Kahanahāiki is *Blechnum appendiculatum*, which is a non-native fern that forms large clonal colonies and prevents germination of many native species in Hawaii (Wilson 1996). *Blechnum appendiculatum* has started to encroach on rock outcrops at the Kahanahāiki *C. dentata* field site. If left uncontrolled, *B. appendiculatum* will ultimately degrade optimal microhabitat for seedling establishment and negatively impact local population dynamics. The influence of fine-scale abiotic conditions on population dynamics also emphasizes the importance of selecting reintroduction sites with appropriate microhabitat for *C. dentata*, which will be necessary to delist this taxon following the United States Fish and Wildlife criteria (USFWS, 1998). The results of this study also illustrate that for localized endemic species on the brink of extinction, such as *C. dentata*, non-native frugivores can reduce local seedling recruitment of geographically isolated populations. In combination with other environmental stressors, such as degradation of abiotic conditions, frugivory by non-native birds can shift the population growth rate of endangered plants from growing to declining over time.

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## Data accessibility

Matrices used to simulate short and long-term population dynamics of each scenario are deposited in Dryad Digital Repository https://doi.org/10.5061/dryad.35b38 (Bialic-Murphy, Gaoue & Kawelo 2017).

## References

Alvarez-Buylla, E., Garcia-Barrios, R., Lara-Moreno, C. & Martínez-Ramos, M. (1996) Demographic and genetic models in conservation biology: applications and perspectives for tropical rain forest tree species. *Annual Review of Ecology and Systematics*, **27**, 387–421.

Bacles, C.F., Lowe, A.J. & Ennos, R.A. (2006) Effective seed dispersal across a fragmented landscape. *Science*, **311**, 628.

Bialic-Murphy, L., Gaoue, O. & Kawelo, K. (2017) Data from: Microhabitat heterogeneity and a non-native avian frugivore drive the population dynamics of an island endemic shrub (*Cyrtandra dentata*). *Dryad Digital Repository*, https://doi.org/10.5061/dryad.35b38

Brigham, C.A. & Schwartz, M.W. (2003) *Population Viability in Plants: Conservation, Management, and Modeling of Rare Plants*, vol. **165**. Springer, Berlin, Germany.

Brook, B.W., Sodhi, N.S. & Bradshaw, C.J. (2008) Synergies among extinction drivers under global change. *Trends in Ecology & Evolution*, **23**, 453–460.

Brown, J.H. (1984) On the relationship between abundance and distribution of species. *American Naturalist*, **124**, 255–279.

Brys, R., Jacquemyn, H., Endels, P., De Blust, G. & Hermy, M. (2005) Effect of habitat deterioration on population dynamics and extinction risks in a previously common perennial. *Conservation Biology*, **19**, 1633–1643.

Busby, P.E., Vitousek, P. & Dirzo, R. (2010) Prevalence of tree regeneration by sprouting and seeding along a rainfall gradient in Hawai'i. *Biotropica*, **42**, 80–86.

Caswell, H. (2001) *Matrix Population Models: Construction, Analysis, and Interpretation, 2001*. Sinauer, Sunderland, MA, USA.

Cole, R.J., Litton, C.M., Koontz, M.J. & Loh, R.K. (2012) Vegetation recovery 16 years after feral pig removal from a wet Hawaiian Forest. *Biotropica*, **44**, 463–471.

Colling, G. & Matthies, D. (2006) Effects of habitat deterioration on population dynamics and extinction risk of an endangered, long-lived perennial herb (*Scorzonera humilis*). *Journal of Ecology*, **94**, 959–972.

Crawley, M. & Nachapong, M. (1985) The establishment of seedlings from primary and regrowth seeds of ragwort (*Senecio jacobaea*). *The Journal of Ecology*, **73**, 255–261.

Crone, E.E., Menges, E.S., Ellis, M.M. *et al.* (2011) How do plant ecologists use matrix population models? *Ecology Letters*, **14**, 1–8.

Cronk, Q.C., Kiehn, M., Wagner, W.L. & Smith, J.F. (2005) Evolution of Cyrtandra (Gesneriaceae) in the Pacific Ocean: the origin of a supertramp clade. *American Journal of Botany*, **92**, 1017–1024.

Dahlgren, J.P. & Ehrlén, J. (2009) Linking environmental variation to population dynamics of a forest herb. *Journal of Ecology*, **97**, 666–674.

Denslow, J.S. (1980) Gap partitioning among tropical rainforest trees. *Biotropica*, **12**, 47–55.

Didham, R.K., Tylianakis, J.M., Gemmell, N.J., Rand, T.A. & Ewers, R.M. (2007) Interactive effects of habitat modification and species invasion on native species decline. *Trends in Ecology & Evolution*, **22**, 489–496.

Dostálek, T. & Münzbergová, Z. (2013) Comparative population biology of critically endangered *Dracocephalum austriacum* (Lamiaceae) in two distant regions. *Folia Geobotanica*, **48**, 75–93.

Ellis, M.M. & Crone, E.E. (2013) The role of transient dynamics in stochastic population growth for nine perennial plants. *Ecology*, **94**, 1681–1686.

Ellis, M.M., Weekley, C.W. & Menges, E.S. (2007) Evaluating stability in *Ziziphus celata*, a highly endangered clonal shrub endemic to Lake Wales Ridge, central Florida. *Endangered Species Research*, **3**, 125–132.

Eriksson, O. & Ehrlen, J. (1992) Seed and microsite limitation of recruitment in plant-populations. *Oecologia*, **91**, 360–364.

Ezard, T.H., Bullock, J.M., Dalgleish, H.J., Millon, A., Pelletier, F., Ozgul, A. & Koons, D.N. (2010) Matrix models for a changeable world: the importance of transient dynamics in population management. *Journal of Applied Ecology*, **47**, 515–523.

Fetcher, N., Strain, B.R. & Oberbauer, S.F. (1983) Effects of light regime on the growth, leaf morphology, and water relations of seedlings of two species of tropical trees. *Oecologia*, **58**, 314–319.

Gaoue, O.G. (2016) Transient dynamics reveal the importance of early life survival to the response of a tropical tree to harvest. *Journal of Applied Ecology*, **53**, 112–119.

García, M.B. (2003) Demographic viability of a relict population of the critically endangered plant *Borderea chouardii*. *Conservation Biology*, **17**, 1672–1680.

Giambelluca, T.W., Chen, Q., Frazier, A.G., Price, J.P., Chen, Y.-L., Chu, P.-S., Eischeid, J.K. & Delparte, D.M. (2013) Online Rainfall Atlas of Hawai'i. *Bulletin of the American Meteorological Society*, **94**, 313–316.

Gilpin, M.E. & Soule, M.E. (1986) *Minimum Viable Population: Processes of Species Extinction*. Sinauer Associates Inc, Sunderland, MA, USA.

Godínez-Alvarez, H. & Jordano, P. (2007) An empirical approach to analysing the demographic consequences of seed dispersal by frugivores. *Seed Dispersal: Theory and Its Application in a Changing World*, **1**, 391–406.

Godínez-Alvarez, H., Valiente-Banuet, A. & Rojas-Martínez, A. (2002) The role of seed dispersers in the population dynamics of the columnar cactus *Neobuxbaumia tetetzo*. *Ecology*, **83**, 2617–2629.

Haridas, C.V. & Gerber, L.R. (2010) Short-and long-term population response to changes in vital rates: implications for population viability analysis. *Ecological Applications*, **20**, 783–788.

Haridas, C.V. & Tuljapurkar, S. (2007) Time, transients and elasticity. *Ecology Letters*, **10**, 1143–1153.

Herrera, C.M. (1984) Adaptation to frugivory of Mediterranean avian seed dispersers. *Ecology*, **65**, 609–617.

Howe, H.F. (1986) Seed dispersal by fruit-eating birds and mammals. *Seed Dispersal*, **123**, 189.

Howe, H.F. & Smallwood, J. (1982) Ecology of seed dispersal. *Annual Review of Ecology and Systematics*, **13**, 201–228.

IUCN (2001) *IUCN Red List Categories and Criteria*. IUCN, Gland, Switzerland.

Kiehn, M. (2001) South Pacific and Hawaiian *Cyrtandra*: molecular and micromorphological studies. *Malayan Nature Journal*, **55**, 21–27.

Krushelnycky, P.D., Loope, L.L., Giambelluca, T.W., Starr, F., Starr, K., Drake, D.R., Taylor, A.D. & Robichaux, R.H. (2013) Climate-associated population declines reverse recovery and threaten future of an iconic high-elevation plant. *Global Change Biology*, **19**, 911–922.

Loayza, A.P. & Knight, T. (2010) Seed dispersal by pulp consumers, not "legitimate" seed dispersers, increases *Guettarda viburnoides* population growth. *Ecology*, **91**, 2684–2695.

Loh, R.K. & Tunison, J.T. (1999) *Vegetation Recovery Following Pig Removal in'Ola'a-Koa Rainforest Unit, Hawaii Volcanoes National Park*. Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Department of Botany, Honolulu, HI, USA. PCSU Technical Report, 123.

Male, T.D., Fancy, S.G. & Ralph, C.J. (1998) *Red-billed Leiothrix*. Birds of North America, Incorporated, Philadelphia, PA, USA.

Marrero-Gómez, M.V., Oostermeijer, J.G.B., Carqué-Álamo, E. & Bañares-Baudet, Á. (2007) Population viability of the narrow endemic *Helianthemum juliae* (CISTACEAE) in relation to climate variability. *Biological Conservation*, **136**, 552–562.

McMahon, S.M. & Metcalf, C.J.E. (2008) Transient sensitivities of non-indigenous shrub species indicate complicated invasion dynamics. *Biological Invasions*, **10**, 833–846.

Menges, E.S. (1990) Population viability analysis for an endangered plant. *Conservation Biology*, **4**, 52–62.

Menges, E.S. (2000) Applications of population viability analyses in plant conservation. *Ecological Bulletins*, **48**, 73–84.

Meyer, J.-Y. & Butaud, J.-F. (2009) The impacts of rats on the endangered native flora of French Polynesia (Pacific Islands): drivers of plant extinction or coup de grâce species? *Biological Invasions*, **11**, 1569–1585.

Minden, V., Jacobi, J., Porembski, S. & Boehmer, H. (2010) Effects of invasive alien kahili ginger (*Hedychium gardnerianum*) on native plant species regeneration in a Hawaiian rainforest. *Applied Vegetation Science*, **13**, 5–14.

Mittermeier, R.A., Myers, N., Thomsen, J.B., Da Fonseca, G.A. & Olivieri, S. (1998) Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conservation Biology*, **12**, 516–520.

Morris, W.F. & Doak, D.F. (2002) *Quantitative Conservation Biology*. Sinauer Associates, Sunderland, MA, USA.

Morris, W.F., Bloch, P.L., Hudgens, B.R., Moyle, L.C. & Stinchcombe, J.R. (2002) Population viability analysis in endangered species recovery plans: past use and future improvements. *Ecological Applications*, **12**, 708–712.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A. & Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature*, **403**, 853–858.

OANRP (2003) *Makua and Oahu Implementation Plans*. Pacific Cooperative Studies Unit: Honolulu, HI, USA.

OANRP (2009) *Status Report for the Makua and Oahu Implementation Plans*. Pacific Cooperative Studies Unit, Honolulu, HI, USA.

Ostertag, R., Cordell, S., Michaud, J., Cole, T.C., Schulten, J.R., Publico, K.M. & Enoka, J.H. (2009) Ecosystem and restoration consequences of invasive woody species removal in Hawaiian lowland wet forest. *Ecosystems*, **12**, 503–515.

Ren, H., Zhang, Q., Wang, Z., Guo, Q., Wang, J., Liu, N. & Liang, K. (2010) Community ecology knowledge for conservation through possible re-introduction: a case study of a rare plant *Primulina tabacum* Hance in China. *Plant Species Biology*, **25**, 43–50.

Sala, O.E., Chapin, F.S., Armesto, J.J. *et al.* (2000) Global biodiversity scenarios for the year 2100. *Science*, **287**, 1770–1774.

Schupp, E.W., Jordano, P. & Gómez, J.M. (2010) Seed dispersal effectiveness revisited: a conceptual review. *New Phytologist*, **188**, 333–353.

Shaffer, M.L. (1981) Minimum population sizes for species conservation. *BioScience*, **31**, 131–134.

Shiels, A. B. & Drake, D.R. (2011) Are introduced rats (*Rattus rattus*) both seed predators and dispersers in Hawaii? *Biological Invasions*, **13**, 883–894.

Shiels, A.B., Pitt, W.C., Sugihara, R.T. & Witmer, G.W. (2014) Biology and impacts of pacific island invasive species. 11. *Rattus rattus*, the Black Rat (Rodentia: Muridae). *Pacific Science*, **68**, 145–184.

Silvertown, J., Franco, M., Pisanty, I. & Mendoza, A. (1993) Comparative plant demography–relative importance of life-cycle components to the finite rate of increase in woody and herbaceous perennials. *Journal of Ecology*, **81**, 465–476.

Simmons, C.L., Auld, T.D., Hutton, I., Baker, W.J. & Shapcott, A. (2012) Will climate change, genetic and demographic variation or rat predation pose the greatest risk for persistence of an altitudinally distributed island endemic? *Biology*, **1**, 736–765.

Slatkin, M. (1985) Gene flow in natural populations. *Annual Review of Ecology and Systematics*, **16**, 393–430.

Souther, S. & McGraw, J.B. (2014) Synergistic effects of climate change and harvest on extinction risk of American ginseng. *Ecological Applications*, **24**, 1463–1477.

Tuljapurkar, S., Horvitz, C.C. & Pascarella, J.B. (2003) The many growth rates and elasticities of populations in random environments. *The American Naturalist*, **162**, 489–502.

USFWS (1998) *Recovery Plan for Oahu Plants*. United States Fish and Wildlife Service, Portland, OR, USA.

USFWS (2012) *Endangered species*. Portland, OR. http://www.fws.gov/pacificislands/species.html (accessed 1 June 2016).

Vitousek, P.M. (1996) Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. *Ecosystem Management*, **1**, 183–191. Springer.

Wagner, W.L., Herbst, D.R. & Sohmer, S.H. (1999) *Manual of the Flowering Plants of Hawai'i, Vols. 1 and 2*. University of Hawai'i and Bishop Museum Press, Honolulu, HI, USA.

Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A. & Losos, E. (1998) Quantifying threats to imperiled species in the United States. *BioScience*, **48**, 607–615.

Willson, M.F. & Traveset, A. (2000) The ecology of seed dispersal. *Seeds: The Ecology of Regeneration in Plant Communities*, **2**, 85–110.

Wilson, K.A. (1996) Alien ferns in Hawai'i. *Pacific Science*, **50**, 127–141.

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## Supporting Information

Details of electronic Supporting Information are provided below.

**Appendix S1.** (A) Results of frugivory by *Leiothrix lutea* and (B) Results of microhabitat heterogeneity.

**Fig. S1.** (1) Typical laceration markings on the remaining pericarp of mature *Cyrtandra dentata* fruits. Incisor marks (white arrows) are indicative of fruit consumption by birds. (2) Seedling germination from a mature *C. dentata* fruit when places on a mist bench in the greenhouse.

**Name:** Samuel Case
**Project Title:** Introduced game birds as seed dispersers in Hawaiian forests

Background and Justification

1. **Project Background**

Forest ecosystems of the Hawaiian Islands have increasingly faced threats of species extinction and biological invasion, resulting in novel communities composed of native and non-native species. Although many native Hawaiian plants rely on birds for seed dispersal, nearly all native frugivorous birds are extinct (all on Oahu). Introduced vertebrate species have the potential to substitute vacant roles in seed dispersal networks, but if they predate native seeds or consume and disperse non-native seeds more frequently than native seeds, their cumulative impact on native plant communities will be negative. To conserve Hawaiian forest ecosystems and secure populations of at-risk plant species, it is important to understand the role of non-native invasive, frugivorous species in seed dispersal of native and nonnative plants.

In the last century, several game bird species (Galliformes) were introduced to the Hawaiian Islands for recreational hunting. On Oahu, the Kalij Pheasant (*Lophura leucomelanos*) and Erckel's Francolin (*Pternistis erckelii*) occupy a large range of forested habitat varying in elevation and plant community composition. Both species are known to consume fruit, but their roles in seed dispersal networks have remained largely unknown. The Kalij Pheasant and Erckel's Francolin are larger than any extant native forest bird, and their gape width and foraging behavior might suit dispersal of native seeds adapted for consumption and dispersal by extinct corvids or large flightless geese. On the other hand, anatomical differences, such as the powerful gizzards of gallinaceous birds, may impair viability of certain seeds. Furthermore, there is concern that these introduced game birds might predate endangered Oahu tree snails (*Achatinella spp.*).

Our study of game birds began in January 2017. We are using a multidisciplinary effort involving advanced field techniques, experimentation, and predictive ecological modeling to comprehensively measure the ecological impacts of these game bird species on seed dispersal. Our project includes the following components: (1) Identification of diet; (2) Estimates of population abundance; (3) Movement of birds; (4) Gut passage experiments; and (5) Fruit preference trials. For (1) we are using game cameras and collecting fecal samples. From fecal samples, we will sort and identify whole seeds and seed fragments and use genetic sequencing to classify invertebrates in diet. For (2) we are using surveys of distribution and abundance at sites. For (3) we are live-capturing game birds and attaching GPS transmitters to birds using harnesses. Transmitters are supplying movement data for up to three years. During captures, we are banding birds and taking morphological measurements. We are also recording fruiting phenology of plants at sites to identify optimal fruiting times for long-distance dispersal based on game bird movement patterns. We have tagged six birds thus far. For (4) and (5), we have collected live birds from the field and temporarily contained them in an aviary where we will conduct fruit preference trials and gut passage germination experiments starting in July 2018. Feeding trials will allow us to discern food preference and resource tracking from opportunistic foraging, and through gut passage germination experiments, we are measuring the effects of the game bird digestive tract on seed germinability, germination rate, and viability for each plant species considered. This project is supplying DoD, DOFAW, OANRP, and other natural resource managers with important information concerning novel ecosystem interactions and native plant conservation.

## 2. Preliminary Results

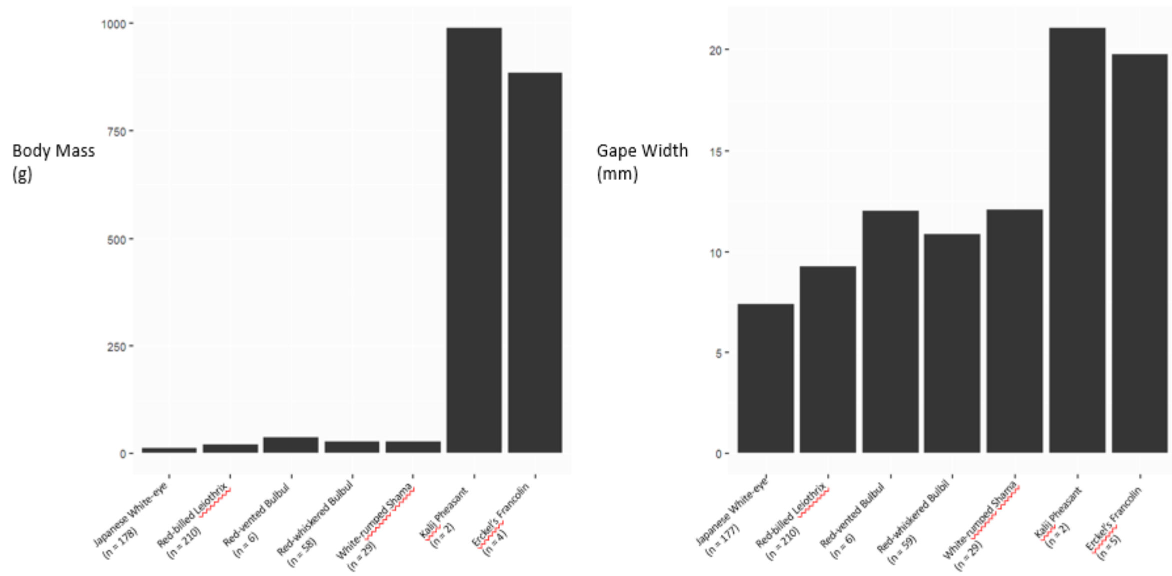
Our preliminary results suggest that game birds are important seed dispersers (or predators) at our sites. Within Pahole Natural Area Reserve and Kahanahaiki, we are collecting fecal samples and deploying game cameras. We are also necropsying individuals collected by local hunters. So far, we've found that both Kalij Pheasants and Erckel's Francolins are consuming seeds of native and non-native plants (Table 1).

TABLE 1: Seeds consumed by game birds during 2017-2018 at Pahole Natural Area Reserve and Kahanhaiki.

| Kalij Pheasant (*Lophura leucomelanos*) | | |
|---|---|---|
| Plant Species | Native Status | Endangered Species Status |
| *Delissea waianaeensis* | Native | Federally listed |
| *Dianella sandwicensis* | Native | Not listed |
| *Solanum sandwicense* | Native | Federally listed |
| *Rubus rosifolius* | Non-native | Not listed |
| *Psidium cattleyanum* | Non-native | Not listed |
| *Passiflora edulis flavicarpa* | Non-native | Not listed |
| *Clidemia hirta* | Non-native | Not listed |
| Erckel's Francolin (*Pternistis erckelii*) | | |
| Plant Species | Native Status | Endangered Species Status |
| *Delissea waianaeensis* | Native | Federally listed |
| *Leptecophylla tameiameiae* | Native | Not listed |
| *Cyanea grimesiana* | Native | Federally listed |
| *Solanum sandwicense* | Native | Not listed |
| *Psidium guajava* | Non-native | Not listed |
| *Rubus rosifolius* | Non-native | Not listed |
| *Rubus argutus* | Non-native | Not listed |
| *Clidemia hirta* | Non-native | Not listed |

We captured game birds for telemetry, banding, and morphological measurements. As a part of a larger study of seed dispersal in Hawaii, the Hawaii VINE Project has collected morphological data from common forest birds of Oahu. In comparing the morphology of game birds to introduced passerines (Figure 1), we found that game birds had the largest gape width and body mass in the current avian assemblage. This suggests that game birds may be capable of consuming larger seeds and more seeds compared to songbirds; they may also disperse seeds farther due to a longer digestive tract.

FIGURE 1: Comparative morphology of common frugivorous birds of Oahu. Data was collected by the Hawaii VINE Project from 2014-2017.




### 3. Effects of Gut Passage on Seed Condition

A common mode of seed dispersal, endozoochory, involves ingestion of fruit by frugivorous vertebrates. Following fruit consumption, seeds within fruit are dispersed away from parent plants with movement and gut passage of animals. Fruit-eating vertebrates disperse the majority of woody plant species worldwide, however each plant-animal species interaction is unique. The conditions within an animal's gut have the potential to increase germinability of seeds by removing fruit pulp or scarifying seed surfaces. Alternatively, frugivores can depredate seeds during gut passage. The duration of time for a seed to pass through an animal's gut is also species-specific. Importantly, gut passage time affects seed dispersal distance, since animals are expected to move farther distances with increased time intervals.

### 4. Previous Research

We are the first to study game bird ecology on Oahu. Previous studies have examined Kalij Pheasant diet, social behavior, and capture methods within Hawaii Volcanoes National Park, Hawaii. Other studies in Hawaii have surveyed game bird population distribution or examined them as vectors of parasites or disease. To our knowledge, we are the first to investigate diet of the Erckel's Francolin in the Hawaiian Islands, as well as to collect long-term movement data on these two species. We will disseminate our findings through publication and presentation at state, national, and international conferences, including the annual Hawaii Conservation Conference. We would be enthusiastic to plan direct meetings with Department staff to discuss research results. Previous studies that share some similarities with this project are cited below.

Cole, F. Russell, et al. "Conservation Implications of Introduced Game Birds in High-Elevation

Hawaiian Shrubland." *Conservation Biology* 9.2 (1995): 306-313.
Lewin, Victor, and Geraldine Lewin. "The Kalij pheasant, a newly established game bird on the island of Hawaii." *The Wilson Bulletin* (1984): 634-646.
Zeng, Lijin. "Social behavior and cooperative breeding of Kalij Pheasants (Lophura leucomelanos) in Hawai'i." (2014).

## 5. Management Implications

Kalij Pheasants and Erckel's Francolins are well-established on Oahu and other major islands in Hawaii. We have evidenced that these birds are important in seed dispersal networks, but we are uncertain as to whether they are benefiting or impeding native plant conservation efforts. For the protection of at-risk native plant species of Hawaii, it will be critical to understand the overall impacts of game bird introductions, including effects of gut passage on seed condition.

# Artificially Induced Frugivory by Birds: A Management Tool for Rare Plants?

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## Objective

### Question

Can frugivorous birds be enticed to consume fruit in a selected area or from a target plant species via broadcasting vocalizations?

### Hypotheses

$H_1$: Frugivorous birds elicit strong behavioral responses to vocalizations from members within their dietary guild

$H_2$: Frugivorous birds are attracted to other fruit-eating birds when making foraging decisions

$H_3$: Frugivorous birds prefer familiar food sources when making foraging decisions

$H_4$: Frugivorous birds are more gregarious during the non-breeding season

### Predictions

$P_1$: Exotic avian frugivores will elicit behavioral responses of equal strength to each others broadcasted vocalizations

$P_2$: Broadcasting vocalizations will increase frugivore abundance and frugivory rates of nearby plant species

$P_3$: Frugivorous birds will forage on common fruit more than rare fruit

$P_4$: Frugivorous bird's behavioral response to broadcasted vocalizations will be less strong during breeding season

## Background

- ▲ Roughly 50% of Hawai'i's endemic flora rely solely on birds for seed dispersal services
- ▲ Almost 70% of Hawai'i's avifauna have become extinct along with nearly every endemic fruit-eating bird species
- ▲ Recently, several fruit-eating bird species have successfully invaded Hawaiian forests and are now among the most abundant and widespread birds
- ▲ A shift in the composition of the frugivore assemblage may have far-reaching impacts on the population dynamics of native, fleshy-fruited plants
- ▲ Many native, fleshy-fruited plants have become uncommon in the landscape and large, old individuals may be the 'living dead'
- ▲ The local fruiting neighborhood in many Hawaiian ecosystems has become heavily dominated by invasive plants
- ▲ **Therefore, attracting frugivorous birds into areas with high-densities of native species may help restore eroding seed dispersal networks**

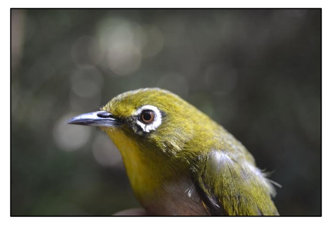
- ▲ Birds select habitat based upon a combination of direct resource cues and indirect social cues (i.e. conspecifics)
- ▲ Conspecific attraction (CA) is the tendency for individuals of the same species to settle near one another and often improves their ability to locate food or reduce depredation
- ▲ CA has been successfully exploited by conservation practitioners to augment songbird populations by attracting individuals (i.e. decoys and recordings) to previously unoccupied, suitable habitat to establish breeding territories
- ▲ Conspecific cues can override habitat cues under certain conditions showcasing the influence and potential management implications of CA
- ▲ **'Assisted migration' has been proposed, but not implemented, as a possible solution to the growing, global, seed dispersal crisis**

## Methods

### Study Species

Red-billed leiothrix *(Leiothrix lutea)*

- ▲ Introduced 1918 from SE Asia
- ▲ Widespread and abundant; fluctuating populations
- ▲ Habitat: Dense understory in forested highlands
- ▲ Behavior: cryptic and cautious

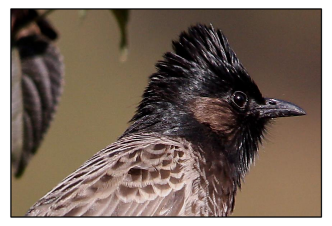


Japanese white-eye (*Zosterops japonicus*)

- ▲ Introduced 1929 from East Asia
- ▲ Most abundant and widespread passerine in HI
- ▲ Habitat: All vegetation layers and densities
- ▲ Behavior: bold and curious

Red-whiskered bulbul *(Pycnonotus jocosus)*

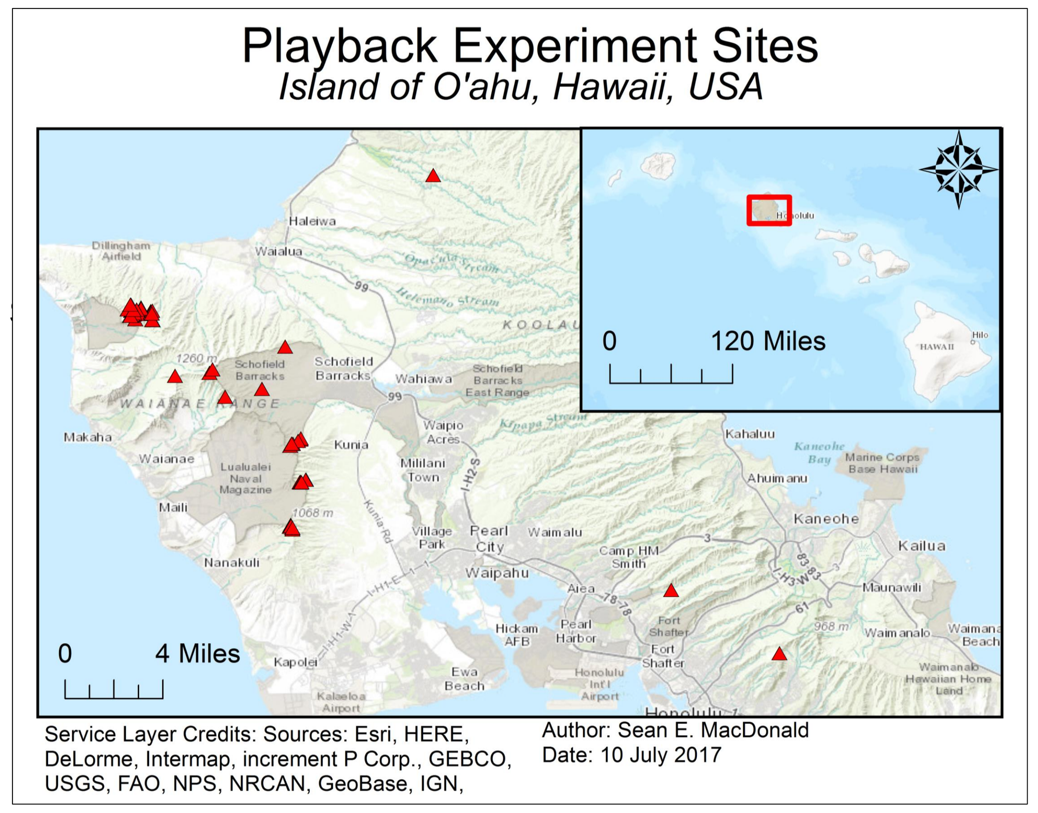
- ▲ Introduced 1965 from SE Asia
- ▲ Rapid population growth and range expansion
- ▲ Habitat: Upper canopy in forested highlands
- ▲ Behavior: cautious, but highly gregarious



Red-vented bulbul *(Pycnonotus cafer)*

- ▲ Introduced 1966 from India
- ▲ Rapid population growth and range expansion
- ▲ Habitat: Upper canopy near agricultural lands
- ▲ Behavior: wary, but gregarious

### Study Sites

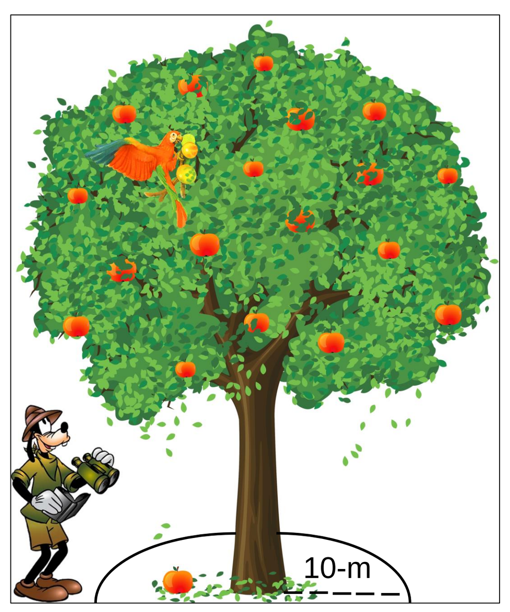



### Study Design

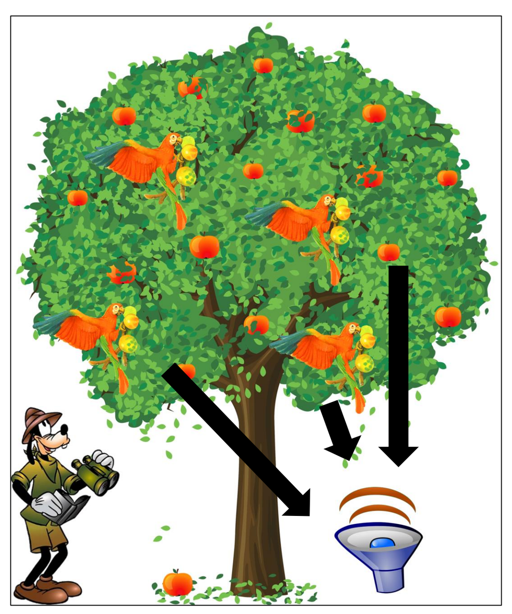
*Conspecific attraction experiment*

- ▲ 2-hr trial
- ▲ Broadcast vocalizations of focal species in four 15-min periods
- ▲ Assess birds within 10m of focal plant
- ▲ Native and exotic fruiting plants
- ▲ 7 exemplars/track/species
- ▲ Record species, distance, height, foraging behavior, species of plant foraging in, & behavioral response to playbacks

Control – Hour 1




Treatment – Hour 2



## Results

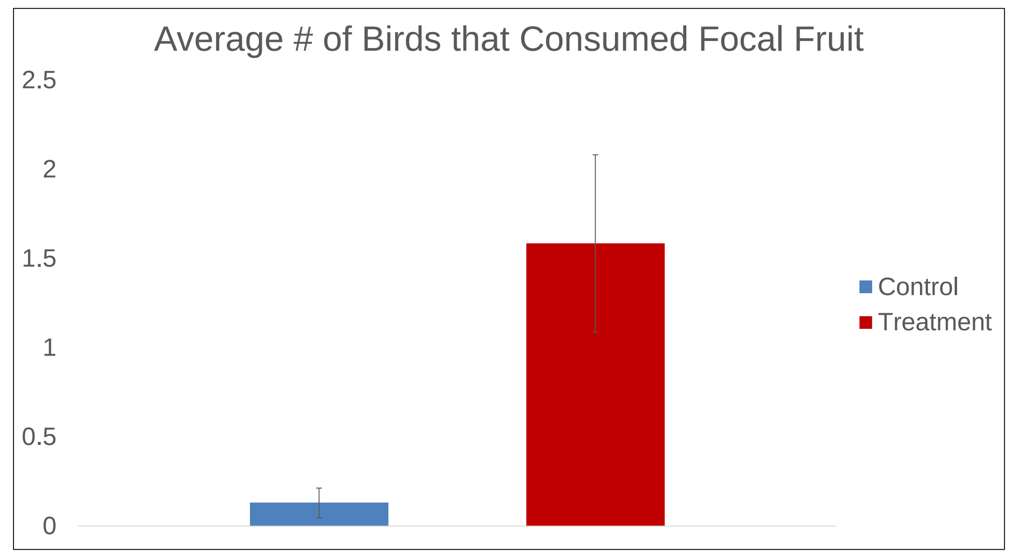



*Figure 1. Average number of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye that consumed the focal fruit during the control and treatment periods across 77 conspecific attraction experiments conducted from summer 2016 – summer 2017 on the Island of O'ahu, HI, USA.*

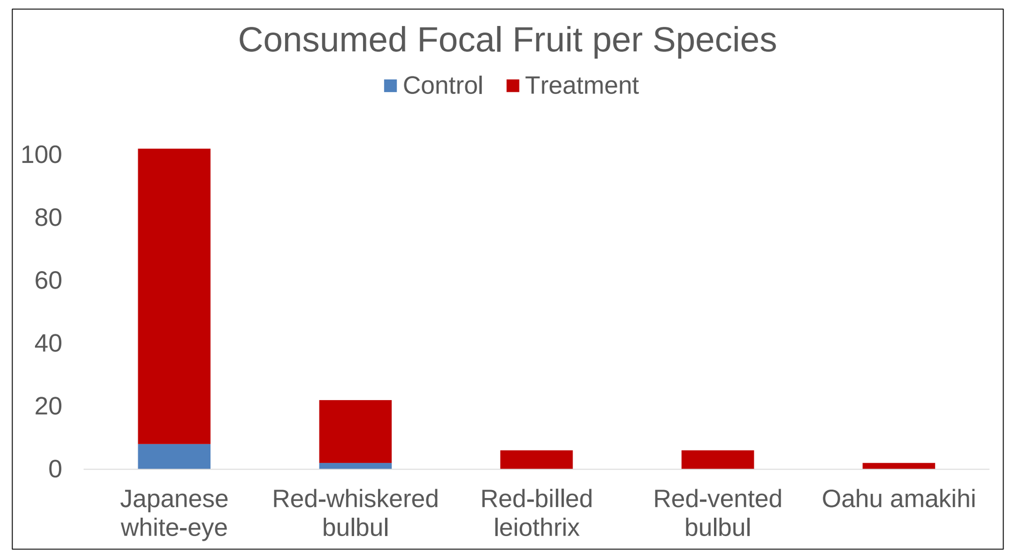



*Figure 2. Sum of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye that consumed focal fruit during control and treatment periods across 77 conspecific attraction experiments conducted from summer 2016 – summer 2017 on the Island of O'ahu, HI, USA.*

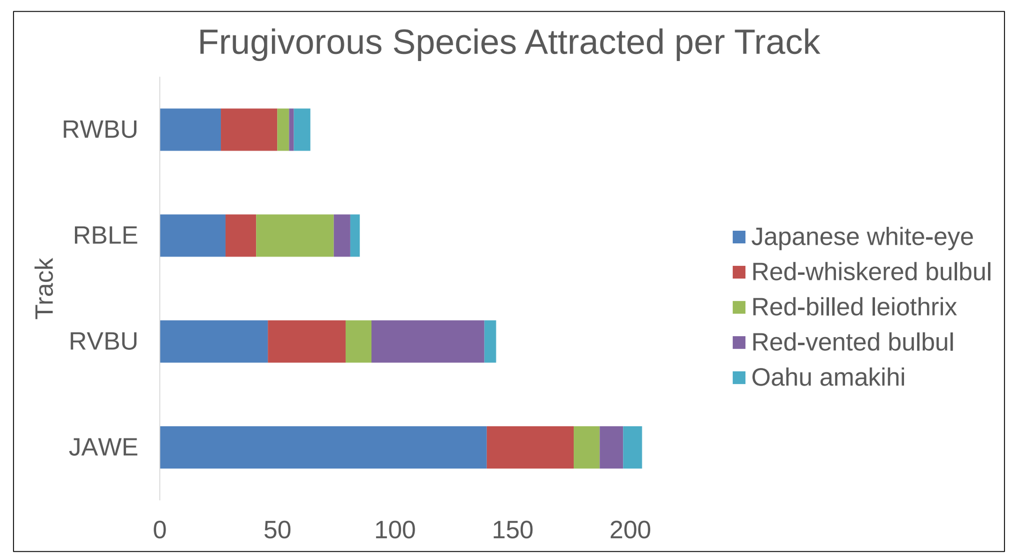



*Figure 3. Sum of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye attracted to Red-vented bulbul (RVBU), Red-whiskered bulbul (RWBU), Red-billed leiothrix (RBLE), and Japanese white-eye (JAWE) playback tracks broadcasted during treatment periods across 45 conspecific attraction experiments conducted in 2017 on the Island of O'ahu, HI, USA.*

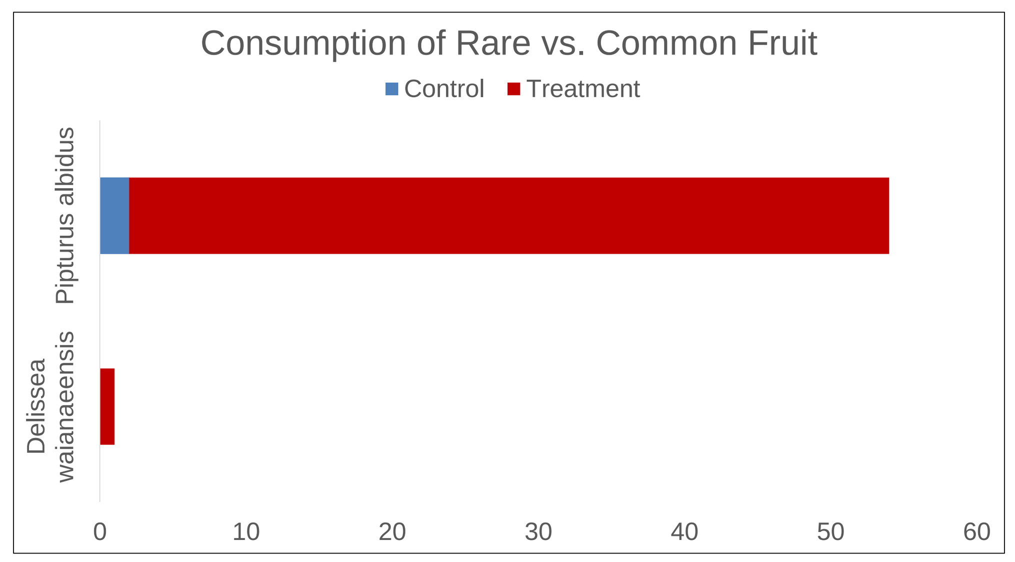



*Figure 4. Sum of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye that consumed focal fruit of rare Delissea waianaeensis and common Pipturus albidus fruit during control and treatment periods across 20 conspecific attraction experiments from summer 2016 – summer 2017 on the Island of O'ahu, HI, USA.*

## Discussion

### Summary

- ▲ The Japanese white-eye was the most effective species consuming the focal fruit in 20 of the 22 successful experiments, and comprising 540 of the 996 fruit-eating birds attracted
- ▲ Birds consumed focal fruit in 5% of control periods, which grew to almost 30% during treatment periods
- ▲ Māmaki (*Pipturus albidus*) comprised more than half of all observed frugivory events
- ▲ 56% of all foraging observations occurred in native plants

### Management Implications

This experimental design was used to establish proof of concept and is narrow in scope. Thus its inference outside of O'ahu is weak. As such, more research is needed to address if these exotic species can ingest all native seed sizes, seeds are viable after ingestion/regurgitation, dispersal distances are effective, and if the habitat in which seeds were dispersed would be suitable.

However, preliminary evidence suggests that audio lures may be a practical tool for land managers to foster seed dispersal mutualisms between bird and plant taxa, which could have far reaching impacts on seedling recruitment of threatened or endangered species.

## Results

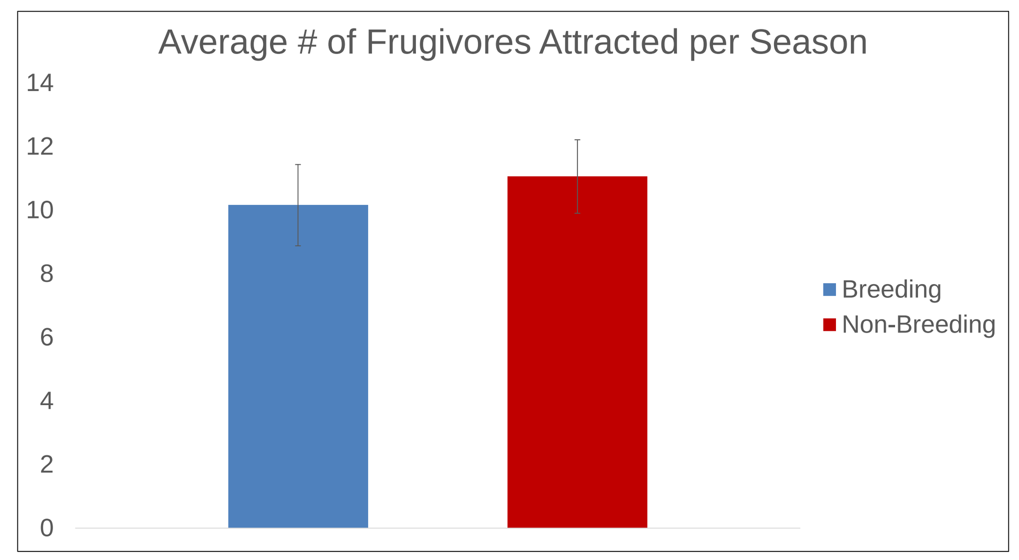



*Figure 5. The average number of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye attracted during the breeding (February – August) and non-breeding (September – January) seasons across 77 conspecific attraction experiments conducted from summer 2016 – summer 2017 on the Island of O'ahu, HI, USA.*

## Acknowledgments

Mahalo nui loa to Jinelle Sperry, Mike Ward, Kapua Kawelo, Michelle Akamine, Lauren Weisenberger, Don Drake, Corey Tarwater, Patrick Kelly, Jeff Foster, Amy Hruska, Jason Gleditsch, Becky Wilcox, Erika Dittmar, Lalasia Bialic-Murphy, Tyler Bogardus, and all the hard workers of the Hawai'i VINE project!

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# Ecosystem Restoration Management Plan

## MIP Year 15-19, Oct. 2018 – Sept. 2023

## MU: Pahole

### Overall MIP Management Goals:

- Form a stable, native-dominated matrix of plant communities which support stable populations of IP taxa.
- Control ungulate, weed, predatory snail, rodent, and slug threats in the next five years to allow for stabilization of IP taxa. Implement all control methods by 2023.

## Background Information

Location: Northern Waianae Mountains

Land Owner: State of Hawaii (State)

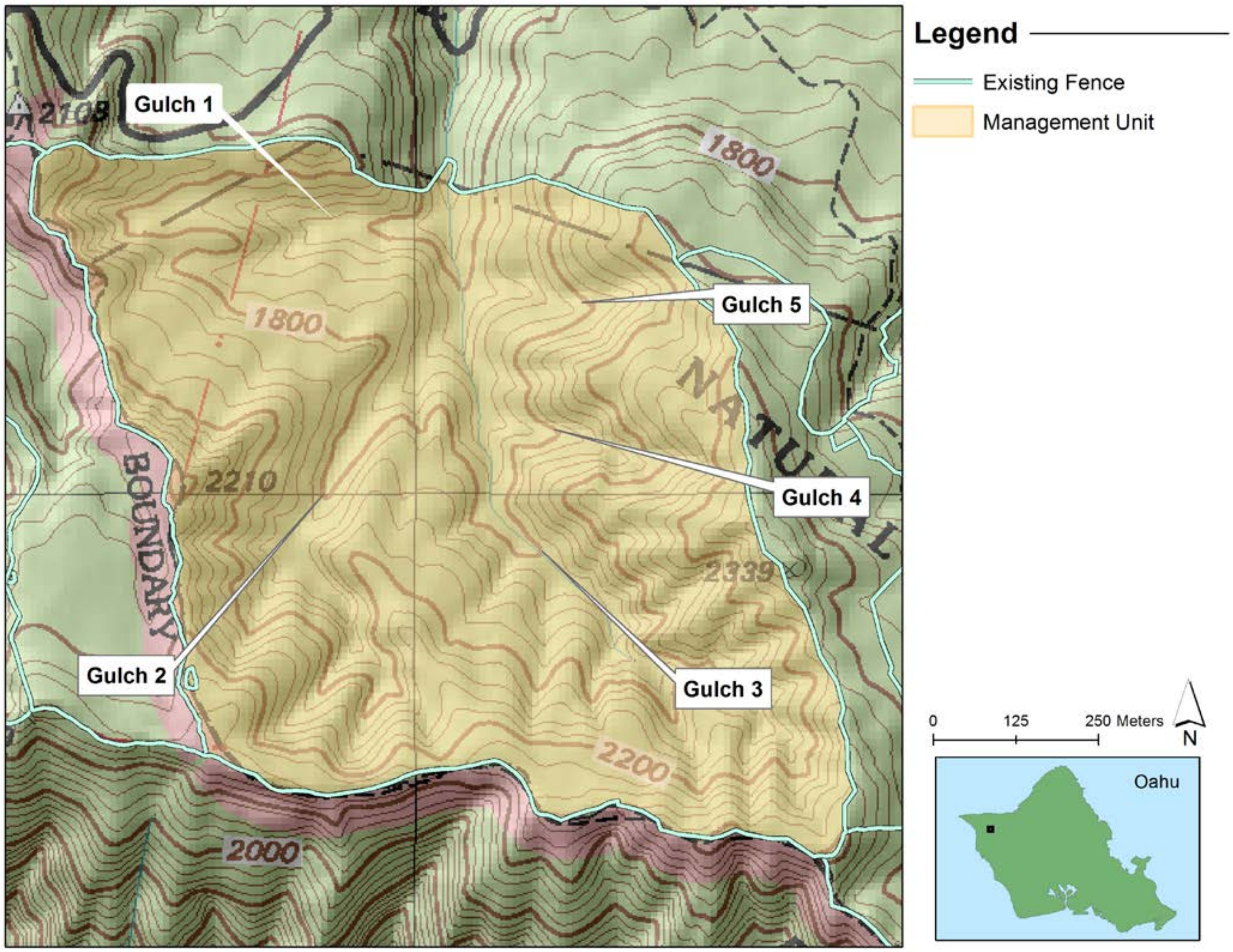
Land Managers: State of Hawaii: Natural Area Reserves System (NARS), Army Natural Resource Program - Oahu (OANRP)

Acreage: 215 acres

Elevation Range: 1,500-2,400 ft.

Description: Pahole MU is the most western of three main gulches located in the Pahole Natural Area Reserve (NAR). Going from west to east within the NAR, the major gulch systems include Pahole, Kapuna and Keawapilau. Kahanahaiki MU borders the west and Makua Military Reservation borders the south of Pahole MU. The Pahole MU itself is divided into five gulches. When facing South, these five gulches are shaped like a left handprint, with Gulch 1 representing the thumb (see picture below). Gulch 1 ends in the main Waianae Summit ridge separating Pahole from Kahanahaiki, Gulch 2 and 3 reaches back to the Makua rim, and gulches 4 and 5 end at the ridge that separates Pahole from Kapuna. The Pahole MU as a whole is diverse, mesic, and contains numerous rare taxa. The east rim of Pahole contains many wild and reintroduced endangered MIP plant sites as well as the ridges dividing each gulch. The most intact native habitat is found above Gulches 2, 3, while the weediest areas are in gulches 4 and 5. Pahole MU can be accessed two ways: through the gulch via Mokuleia Forest Reserve Access Road (a.k.a. Pahole Rd. or from the ridge via the Kahanahaiki overlook trail.

## Map of Pahole showing gulch system

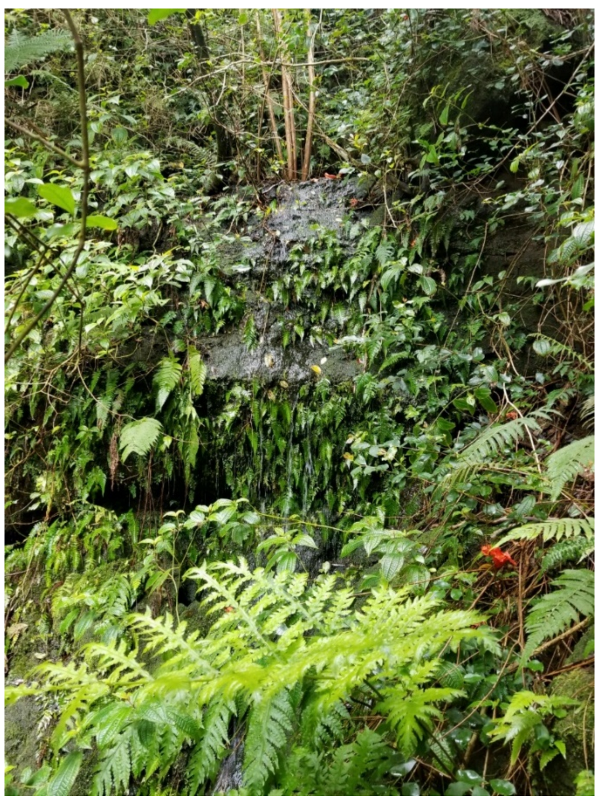



## Native Vegetation Types

| Wai'anae Vegetation Types | | |
|---|---|---|
| Mesic mixed forest | Mesic ridge/crest | Canopy includes: The canopy is dominated by *Acacia koa* and/or *Metrosideros polymorpha*. Other canopy associates include *Psychotria* spp., *Antidesma platyphylum*, *Bobea elatio*r, and *Santalum freycinetianum* var. *freycinetianum*.<br>Understory includes: *Microlepia strigosa*, *Sphenomeris chinensis*, *Alyxia stellata*, and *Coprosma* spp. |
| | Mesic slope | Canopy includes: *Diospyros sandwicensis*, *Sapindus oahuensis*, *Nestigis sandwichensis*, *Planchonella sandwicensis*, *Antidesma platyphylum*, and *Pisonia* spp.<br>Understory includes: *A. stellata*, *Psydrax odorata*, and *Bidens* spp. |
| | Mesic gulch | Canopy includes: *Pisonia* spp., *Charpentiera tomentosa*, *Psychotria* spp, and *D. hillebrandii*<br>Understory includes: *Diplazium sandwicensis*, *Microlepia strigosa* and *Tectaria gaudichaudii*, *Freycinetia arborea*, *Urera glabra*, *Pipturus albidus*, and *Coprosma* spp. |
| NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted. | | |

**Terrain and Vegetation Types at Pahole**

Pahole gulch from Kahanahaiki/Pahole trail crossover (Looking south).



Mesic gulch

## MIP/OIP Rare Resources at Pahole

| Organism Type | Species | Pop. Ref. Code | Population Unit | Management Designation | Wild/ Reintroduction |
|---|---|---|---|---|---|
| Plant | *Alectryon macrococcus* var. *macrococcus* | PAH-A*,B*,F*,G* | Kahanahaiki to West Makaleha | MFS | Wild* |
| Plant | *Cenchrus agrimonioides* var. *agrimonioides* | PAH-A†,B,C,D†,E,F†,T | Kahanahaiki and Pahole | MFS | Both |
| Plant | *Cyanea grimesiana* subsp. *obatae* | PAH-A*,B,C†,D† | Pahole to West Makaleha | MFS | Both |
| Plant | *Cyanea longiflora* | PAH-A,B,C*,G,H,I,J† | Pahole | MFS | Both |
| Plant | *Cyanea superba* subsp. *superba* | PAH-A,B | Pahole to Kapuna | MFS | Reintroduction, Wild* |
| Plant | *Cyrtandra dentata* | PAH-A,B,C,D,E,F,G | Pahole to Kapuna to West Makaleha | MFS | Wild |
| Plant | *Delissea waianaeensis* | PAH-B,C,E, F** | Kahanahaiki to Keawapilau | MFS | Both |
| Plant | *Euphorbia herbstii* | PAH-E*,F,G,H*,I*,R†, S† | Kapuna to Pahole | MFS | Both |
| Plant | *Flueggea neowawraea* | PAH-A*,C,D | Kahanahaiki to Kapuna | MFS | Both |
| Plant | *Kadua degeneri* subsp.*degeneri* | PAH-A,B | Kahanahaiki to Pahole | MFS | Wild |
| Plant | *Nototrichium humile* | PAH-A* | Pahole | GSC | Wild |
| Plant | *Phyllostegia kaalaensis* | PAH-A*,B* | Pahole | MFS | Reintroduction* Wild* |
| Plant | *Plantago princeps* var. *princeps* | PAH-A | Pahole | GSC | Wild |
| Plant | *Schiedea kaalae* | PAH-A*,B*,C†,D*,E* | Pahole | MFS | Reintroduction Wild* |
| Plant | *Schiedea nuttallii* | PAH-A,B,D†,E† | Kahanahaiki to Pahole | MFS | Both |
| Plant | *Schiedea obovata* | PAH-A*,C,D,E | Kahanahaiki to Pahole | MFS | Reintroduction Wild* |
| Snail | *Achatinella mustelina* | ESU-A | Kahanahaiki to Pahole | MFS | Wild |

MFS= Manage for Stability *= Extirpated **= Seed Sow
GSC= Genetic Storage Collection †=Reintroduction not yet done

**Other Rare Taxa at Pahole**

| Organism Type | Species | Status |
|---|---|---|
| Plant | *Asplenium dielfalcatum* | Endangered |
| Plant | *Bonamia menziesii* | Endangered |
| Plant | *Dissochondrus biflorus* | At Risk |
| Plant | *Exocarpos gaudichaudii* | At Risk |
| Plant | *Labordia kaalae* | At Risk |
| Plant | *Lobelia yuccoides* | At Risk |
| Plant | *Neraudia melastomifolia* | At Risk |
| Plant | *Nothocestrum longifolium* | Endangered |
| Plant | *Pteralyxia macrocarpa* | Endangered |
| Plant | *Polyscias kavaiensis* | At Risk |
| Plant | *Urera glabra* | Vulnerable |

**Rare Resources at Pahole**

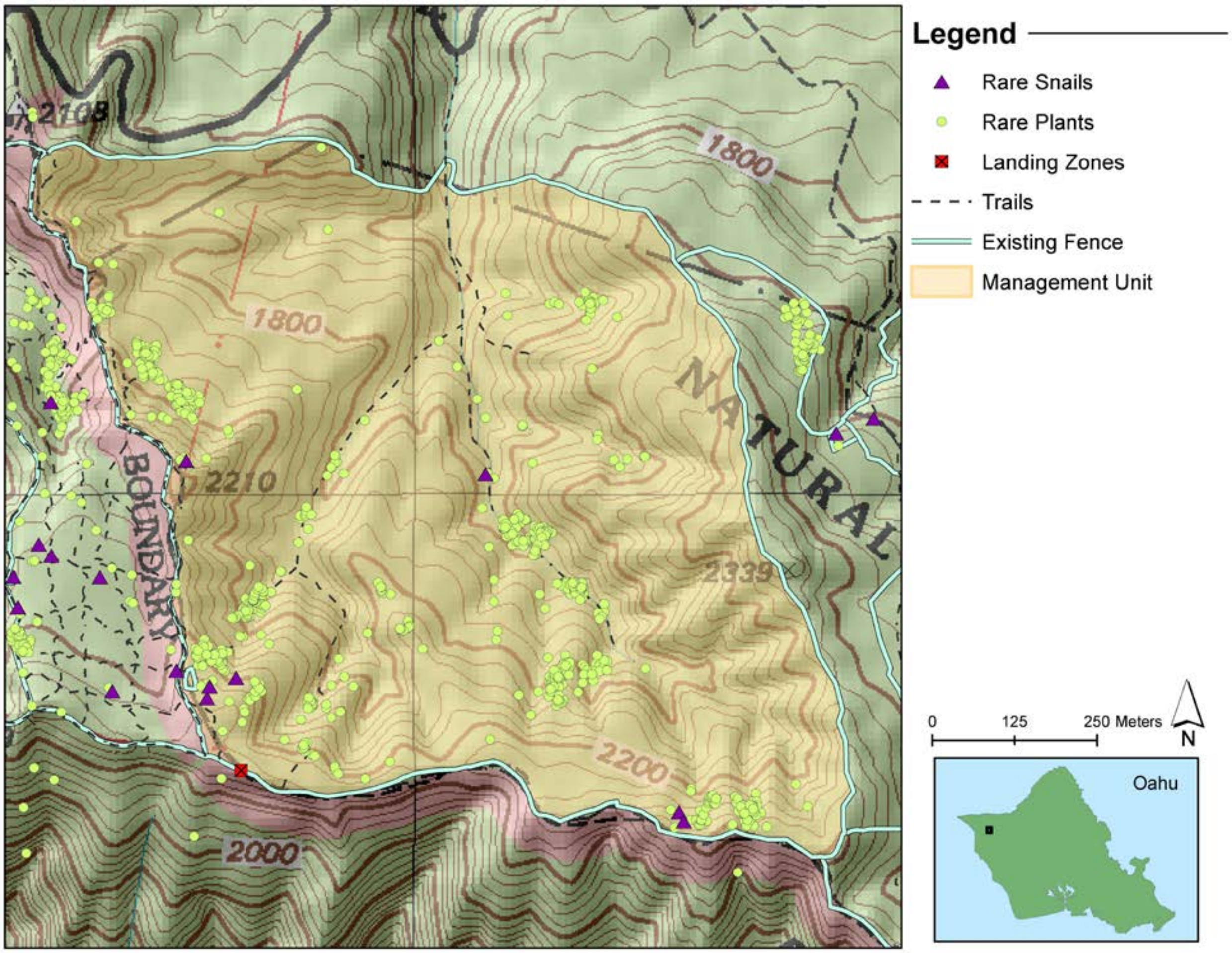
*Euphorbia herbstii*

*Kadua degeneri* subsp. *degeneri*

*Cyanea longiflora*

*Schiedea obovata*

**Locations of Rare Resources at Pahole**




**Threats to MIP/OIP MFS Taxa**

| Threat | Rare Taxa Affected | Management Strategy | Current Status, 2018 |
|---|---|---|---|
| Pigs | All | Fence | No animals within fence. |
| Weeds | All | Focus on rare taxa sites primarily, across MU secondarily | Regular maintenance required several times per year. Weeds are both an understory and canopy threat across whole MU. |
| Black Rat | *Achatinella mustelina*, *Cyanea grimesiana* subsp. *obatae*, *Euphorbia herbstii*, *Cyanea longiflora*, *Cyanea superba* subsp. *superba*, *Delissea waianaeensis* | Localized grids near select resources | Trap grids maintained by Native Ecosystems Protection and Management (NEPM). |
| Black twig borer (BTB) *Xylosandrus compactus* | *F. neowawraea*, *A. macrococcus* var. *macrococcus* | Monitor. Research new control methods. | Effective methods for control not available at this time. |
| Jackson's Chameleon | *Achatinella mustelina*, *Drosophila montgomeryi* | Predator-proof snail enclosure | No viable tools to control outside snail enclosure. |

**Threats to MIP/OIP MFS Taxa (Continued)**

| Threat | Rare Taxa Affected | Management Strategy | Current Status, 2018 |
|---|---|---|---|
| Slugs | *Cyanea grimesiana* subsp. *obatae*, *Euphorbia herbstii*, *Cyanea longiflora*, *Delissea waianaeensis*, *Schiedea nuttallii*, *Schiedea obovata* | Molluscicide treatment at chosen rare taxa sites. | FerroxxAQ, a molluscicide is applied every 6 weeks to control slugs. |
| Rosy Wolf Snail | *Achatinella mustelina* | Predator-proof snail enclosure | No viable tools to control outside snail enclosure. |
| Ant | Possble threat to all rare plant taxa. Ants known to farm Hemipterian pests | Survey rare taxa sites, and human entry point. Areas that have high risk of accidental ant introduction | Annual surveys conducted. |

## Management History

- 1981: Established as a NAR by the Governor's Executive Order 3098.
- 1989: First weeding begins by the State of Hawaii Division of Forestry and Wildlife (DOFAW).
- 1996: First recorded rare plant monitoring by OANRP.
- 1998: Pahole MU fence completed.
- 1998: Snail exclosure built.
- 1999: All pigs were removed by NARS staff.
- 2000: First outplanting in Pahole.
- 2003: Fire started in Makua reaches 150 m from the western portion of the MU.
- 2002: OANRP begins extensive weed control in addition to previous small scale efforts.
- 2006: Several small pigs breach the fence and were able to breed before detection.
- 2007-2008: OANRP partners with NARS to conduct herbicide trials on silky oak (*Grevillea robusta*).
- 2008: All pigs removed after breach in 2006. A total of 23 pigs were removed via snares.
- 2009: Rat, snail, and slug monitoring began as a part of the Kahanahaiki trap out study.
- 2012: Fence supplemented with skirting and Fickle Hill Deer Fence to prevent smaller piglets from breaching.
- 2013: DOFAW begins distribution of strawberry guava biocontrol agent, *Tectococcus ovatus*, a scale insect.
- 2014: OANRP conducts *D. waianaeensis* seed sow trial.
- 2017: Mokuleia fire burns within 1500 m north of MU.
- 2018: First *C. longiflora* outplating in Pahole.
- 2018 WCAs redrawn to include all of MU, and allow easier tracking of incidental weed control.

## Ungulate Control

Species: *Sus scrofa* (pigs)

Threat Level: High

Management Objectives:

- Maintain MU as ungulate free.
- Prevent ungulate ingress into exclosure.

Strategy and Control Methods:

- Exclusion of all ungulates from MU via large-scale fencing. The PAH-A fence was completed in 1998.
- Supplemented with skirting and Fickle Hill Deer Fence to prevent smaller piglets from breaching fence in 2012.
- Conduct quarterly fence checks.
- Note any pig sign while conducting day to day actions within fenced MU.
- If any pig activity is detected, work with the Ungulate Manger to implement hunting or snaring.

Discussion: There is a perimeter fence around this 215 acre MU with one major gulch crossing. The major threats to the perimeter fence include fallen trees and vandalism. There have been relatively few incidences of vandalism in the past; most of the fence damage is caused by fallen trees. At the gulch crossing there is a breakaway which is constructed in such a way to allow water to pass under without opening access to pigs. It also makes repairs to the stream section of the fence convenient if there is an extreme flash flooding event. Three sides of Pahole is protected by a shared fence from other MUs, Kahanahaiki, Kapuna, and Makua. Makua to the west, and to the south Kapuna are not ungulate free, control is ongoing at these sites. Kahanahaiki to the west of the MU has been ungulate free for many years. These fences adds extra protection to the Pahole MU; only leaving the north and east sides directly exposed to ungulate pressure.

Quarterly checks (including maintenance) of the fence’s integrity will be conducted, as well as monitoring for ungulate sign during the course of other field activities. Fences are also checked after extreme weather events. Special emphasis will be placed on monitoring the breakaway anytime there is an extreme amount of rainfall in the area. Given the moderate size of the fence, it is especially important to maintain unit as ungulate free. As with any large MU, it would take a great effort to remove ungulates once inside the unit.

# Weed Control

Weed Control actions are divided into 4 subcategories:

1) Vegetation Monitoring
2) Surveys
3) Incipient Taxa Control (Incipient Control Area - ICAs)
4) Ecosystem Management Weed Control and Restoration Actions (Weed Control Areas - WCAs)

These designations facilitate different aspects of MIP/OIP requirements.

## Vegetation Monitoring

Vegetation monitoring across Pahole was first completed by Patricia Welton, a Universtiy of Hawaii Graduate student. The State's Pahole NAR Management Plan (2016) summarizes this study, stating:

● Native Vegetation - Native plants are dominant and there is 60% or more of native tree canopy cover
● Mixed Native/Non-Native - Native and nonnative species are co-dominant
● Nonnative – Mixed native/nonnative associations as well as forests dominated by nonnative species.
Non-native species dominant in these areas include the following:

- Java Plum Forest
- Christmas Berry Forest
- Eucalyptus Forest
- Silk Oak Forest
- Koa Haole Thicket
- Guava – Strawberry Guava Forest
- Kukui Forest

In 2018, a student from the University of Hawaii began locating and monitoring the thirty year old plots to compare vegetation changes since the last reading. However, only a subset of plots within Pahole MU were located, and analyses of vegetation change within the MU using such a small sample size are dubious.

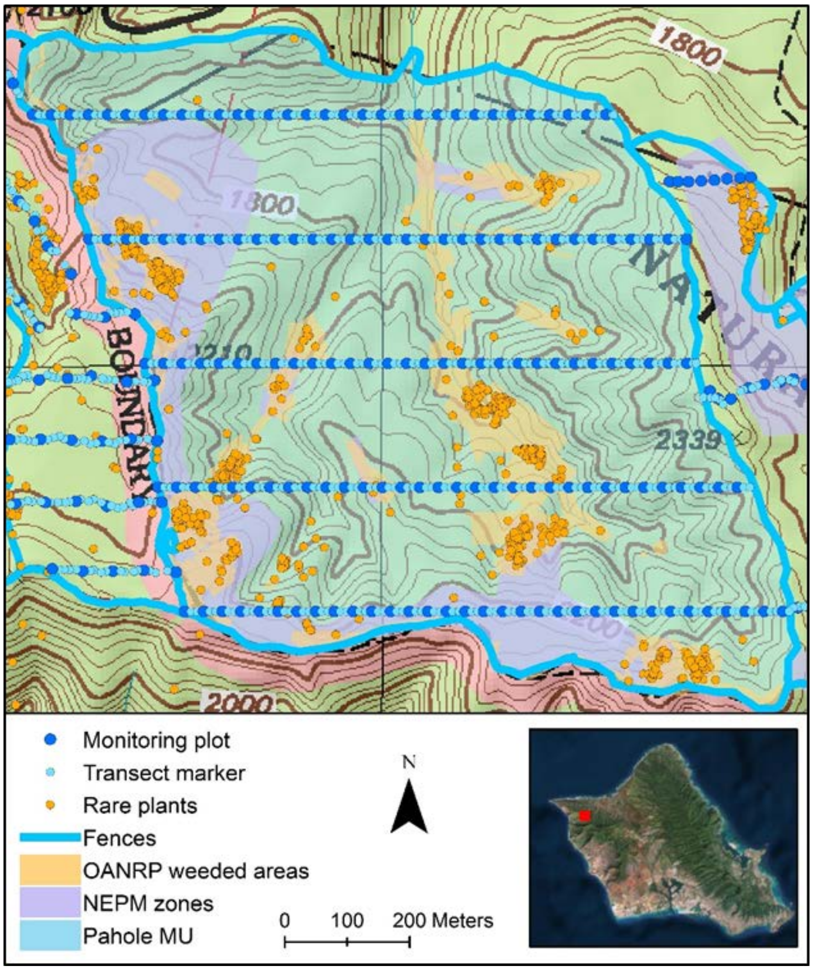
In 2018, the State approved OANRP plans to implement large scale MU-based vegetation monitoring. Belt-plot monitoring is slated to start in 2021 with follow-up readings every five years. With this method, permanent plots measuring 5 x 10 m are generally located at regular intervals along transects that are marked with flagging tape and metal tags every 10 m. Transects are placed at regular intervals. Areas too steep to monitor along transects are either diverted around or skipped. Transects would randomly traverse Native Ecosystems Protection and Management (NEPM) zones, OANRP managed areas, and areas that do not receive direct management (see map below).

Given the large size and diversity at Pahole MU, approximately 150 plots would be necessary to detect change with reasonable statistical power. Within plots, understory (0 – 2 m above ground level (AGL), including low branches from canopy species) and canopy (> 2 m AGL, including epiphytes) vegetation are recorded by percent cover for all species present. Percent cover categories are recorded in 10% intervals between 10 and 100%, and on finer intervals (0-1%, 1-5%, and 5-10%) between 0 and 10% cover. Understory recruitment (defined as seedlings or saplings < 2 m AGL) data for tree species may also be recorded. Only absolute cover changes ≥ 10% are recognized, with $\alpha = 0.05$. Analyses include either Wilcoxon's signed-rank test or Friedman's tests with Bonferroni adjusted post-hoc pairwise comparisons for cover and richness data, McNemar's tests for frequency data, and generalized linear modeling for the influence of weed control efforts (using shapefiles of areas weeded and restoration areas) on cover change as well as the influence of non-native cover change on changes in native cover, etc.

Belt-plot monitoring was chosen for Pahole because it would document vegetation percent cover, frequency, and species richness. It also allows for data comparison across multiple MUs, as this same method is used in other MUs.

The State has also inquired about doing small-scale vegetation monitoring to track changes in vegetation cover within Pahole NEPM zones. OANRP has offered to assist in demonstrating the point intercept method for NEPM staff. When small-scale vegetation monitoring of NEPM zones will begin has not been determined.

**Proposed transect and plot lines for belt-plot monitoring***




*Map does not represent final locations of transects or plots, which will be determined at a later time.

## Surveys

Potential Vectors: OANRP activity, hikers/hunters, pigs/goats, alien birds, wind, researchers, partner agencies.

Management Objective:

- Prevent the establishment of any new invasive alien plant or animal species through regular surveys along roads, landing zones, camp sites, fence lines, trails, and other high traffic areas.

Strategy and Control Methods:

- Note unusual, significant, or incipient alien taxa during the course of regular field work. Map and complete Target Species form to document sighting.
- Drive Mokuleia Access Trail (Pahole Road), from the bottom gate to the Nike site annually. GPS roads driven to document extent of survey in a given year. The OANRP Blue Team is responsible for this action, although use of the road is shared by many within and outside of the program.
- Survey one weed transects annually. This includes the access trail from the parking area to the Gulch 2/3 split.
- Quarterly surveys of the Nike site and Kahanahaiki overlook LZs (if used).
- Any significant alien taxa found will be researched and evaluated for distribution and life history. If found to pose a major threat, control will begin and tracked via ICAs.

Discussion:

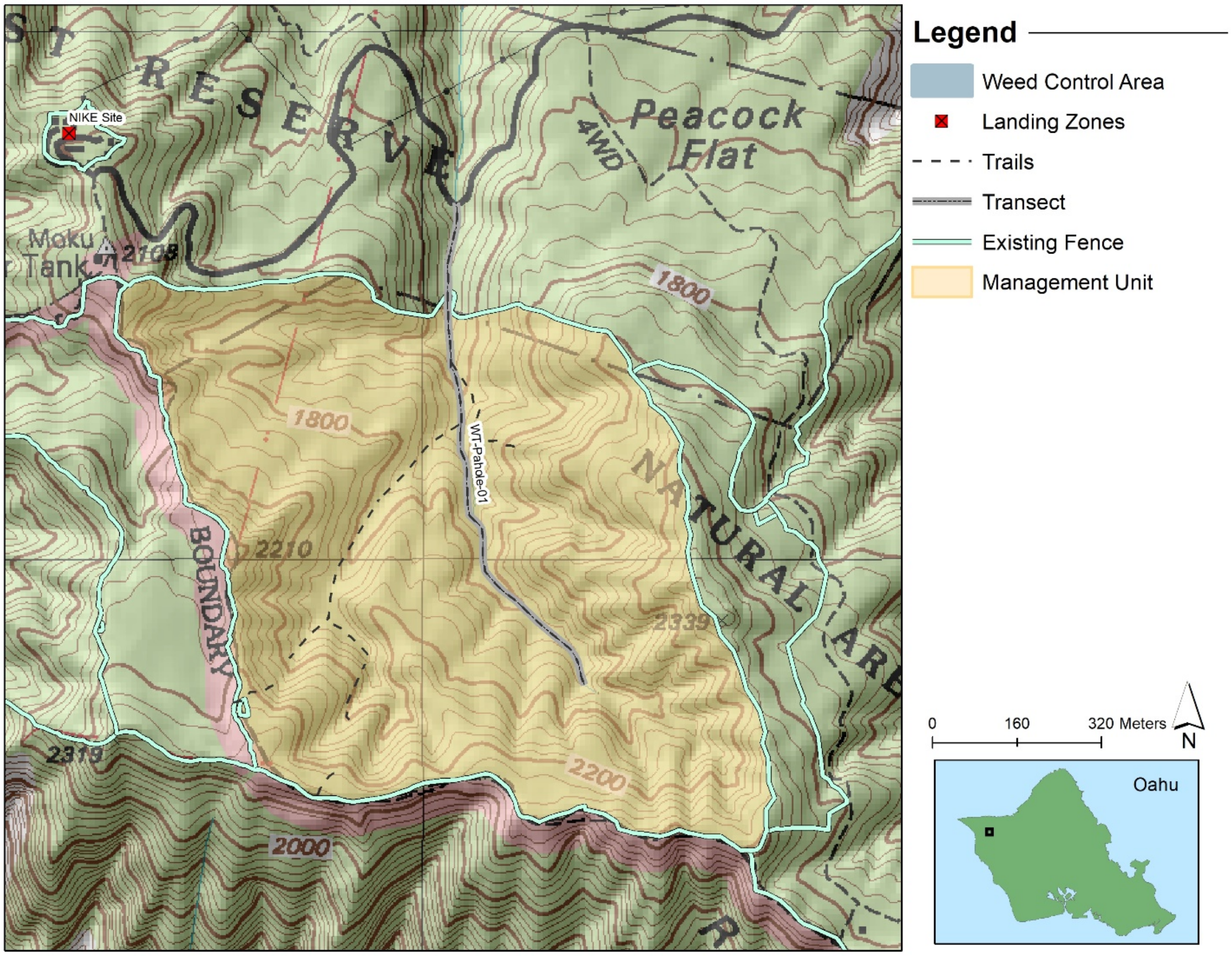
Surveys are designed to be the first line of defense in locating and identifying potential new weed species. Roads, landing zones, fence lines, and other highly trafficked areas are inventoried regularly to facilitate early detection and rapid response; Army roads and LZs are surveyed annually, non-Army roads are surveyed annually or biannually, while all other sites are surveyed quarterly or as they are used.

In Pahole, one road survey is conducted on the paved section of the Mokuleia Access Trail (Pahole Road). Although the OANRP Blue Team is responsible for conducting this survey, many use this road as a thoroughfare or for recreational activities (hiking, biking, exercising, etc.). For this reason, the possibility of spreading unwanted weeds near and/or into the unit is high. In addition to road surveys, the road is sprayed with herbicide as needed to maintain visibility around tight corners as well as keep unwanted weeds off the road to prevent them from spreading.

One weed transect survey is done annually, which covers the gulch bottom on the main access trail. Part of the survey starts outside the management unit and continues into the unit, which could help as a comparison as to what can be found inside versus outside the fence.

The Nike site is used on occasion as an LZ to access Ohikilolo, Makua, and other nearby LZs. The LZ will be surveyed once a quarter, if used. There are no camp sites in Pahole.

**Survey Locations Map**




## Incipient Taxa Control

All weed control geared towards eradication of a particular invasive weed is tracked via Incipient Control Areas, or ICAs. Each ICA is species-specific and geographically defined. One infestation may be divided into several ICAs or one ICA, depending on infestation size, topographical features, and land ownership. Some ICA species are incipient island-wide, and are a priority for ICA management whenever found. Others are locally incipient to the MU, but widespread elsewhere. In either case, the goal is eradication of the ICA. The goals, strategies, and techniques used vary between ICAs, depending on terrain, surrounding vegetation, target taxon, size of infestation, and a variety of other factors.

Management Objectives:

- Eradicate ICAs through regular and thorough monitoring and treatment. In the absence of any information about seed bank longevity for a particular species, eradication is defined as 10 years of consistent monitoring with no target plants found.
- Study seed bank longevity of ICA taxa, and revise eradication standards per taxon.
- Evaluate any invasive plant species newly discovered in MU, and determine whether ICA-level control is warranted. Factors to consider include distribution, invasiveness, location, infestation size, availability of control methods, resources, and funding.

Strategy and Control Methods:

- Species and ICAs are listed in the table below. History and strategy is discussed for each species.
- Monitor the progress of management efforts, and adjust visitation rates to allow staff to treat plants before they mature. Remember that one never finds 100% of all plants present.
- Use aggressive control techniques where possible. These include power spraying, applying pre-emergent herbicides, clearcutting, and frequent visits.

**Incipient Weed Photos**

*Tecoma capensis*

*Elephantopus mollis*

*Pterolepis glomerata*

**Summary of ICAs**

| Taxon | ICA Code | Control Discussion |
|---|---|---|
| *Albizia chinensis* | PaholeNoMU-AlbChi-01 | Commonly known as Chinese Albizia. Two trees first observed at this site near Peacock Flats gate on the mauka side of the road in July of 2009 and were controlled No plants have been observed since. Control technique: Clip and drip with 20% triclopyr and surfactant. Has not been seen since 2010. |
| *Angiopteris evecta* | Pahole-AngEve-01<br>Pahole-AngEve-02<br>Pahole-AngEve-03<br>Pahole-AngEve-04<br>Pahole-AngEve-05<br>Pahole-AngEve-06 | Commonly known as the giant fern/mules foot fern. *A. evecta* dominates wet gulches. Widespread outside MU, and only a few spots known in MU. Found growing near wet waterfalls and gulch bottoms in Gulches 5, 4, 3, and 2. Stipules from the frond bases can form new plants; caution should be taken to avoid controlling the plant in any way that encourages vegetative reproduction. Plants under the height of 10 cm are difficult to identify, but are of less concern given they take at least two years before becoming reproductive, and can be treated on subsequent visits when larger and more identifiable. Literature suggests that it takes many years for *A. evecta* to become mature. Visiting these ICA's once a year allows several chances to detect plants before they become mature and is acceptable to achieve eradication. Control technique: foliar with 10% triclopyr and water for small individuals, cut-stump with 20% triclopyr and surfactant for larger individuals. Application of 10-15 ml imazapyr to the top of brain and/or new crozier is also effective. |

**Summary of ICAs (Continued)**

| Taxon | ICA Code | Control Discussion |
|---|---|---|
| *Axonopus compressus* | Pahole-AxoCom-01 | Commonly known as carpet grass and is used for turf and pasture lands. Unusual to see in the forest setting, might have been an intentional planting. Medium size population located at the top of the Switchbacks near the water catchment and has recently been found in new areas along the trail. The population is recorded under the Kahanahaiki MU as an ICA. Recent control using a 2% concentration has shown little results. In the upcoming years we will be implementing new methods of control. New Control technique: Hand digging out, foliar spray with 0.58% Fusliade with added surfactant, if these techniques show little results a 1% foliar spray of Polaris will be used. |
| *Cryptostegia madagascariensis* | PaholeNoMU-CryMad-01 | Commonly known as rubber vine. A patch of 6 matures and 1 immature first found at this site along the Pahole Road, down in pasture lands below ranch gate on 7-16-09. More plants may be present on pasture land, but since they are far from the MU and access to private land may be difficult, control will be focused only along the road. Control technique: Clip and drip with 20% triclopyr and surfactant as needed to keep *C. madagascariensis* off of the road. |
| *Dicliptera chinensis* | Pahole-DicChi-01 | Three immature plants first found at this site in June of 2011 in Gulch 3 between the lower and middle populations of *Cyanea superba* subsp. *superba*. *D. chinensis* grows vegetatively, and does not spread easily. Plants have not been seen since 3-11-13, where a small 8x5 foot patch was controlled. Control technique: hand pull or foliar spray with 2%-5% glyphosate and water. |
| *Ehrharta stipoides* | Pahole-EhrSti-02 | Commonly known as weeping rice grass. Identification of this shade-loving grass can be difficult while the plant is immature. Ehrsti can also be easily mistaken for *Festuca bromoides*. Species present both in and outside of MU. Control needed to prevent greater spread of this species. Five ICAs have been successfully eradicated, in and outside of the MU. However, one ICA still remains inside the Pahole Snail Enclosure. Control technique: standard glyphosate foliar spray. |
| *Elephantopus mollis* | Pahole-EleMol-01 | Commonly known as soft elephant's foot. Aster from South America. Widespread in the Koolau mountain range, with very few locations in the Waianae range. 1 immature plant was found in the middle of the Kahanahaiki/Pahole ridge fence trail in August of 2016. Another individual was found on Maile flats near the chipper site around the same time. None have been found along the ridge trail since the original sighting. However, sightings of *E. mollis* at both locations within the same time frame could suggest future incursion. Staff must be vigilant to prevent spread in the MU. High priority to control to prevent further spread of this species throughout the Waianae range. Control technique: hand pull, or clip and drip with 20% triclopyr and surfactant. |
| *Pterolepis glomerata* | Pahole-PteGlo-01 | Commonly known as false meadowbeauty. Really aggressive weed that needs intense management and monitoring to eradicate. Widespread in the Koolau mountain range. Relatively few locations in the Waianae range. First found at this site along the Makua lookout trail. High priority to control to prevent further spread of this species throughout the Waianae range. As Pteglo is in the family Melastomataceae, the taxon does have a very persistent seed bank, so use of pre-emergent is necessary. Control technique: hand pull, or foliar application with 2% glyphosate and water. Sulfomet (pre-emergent) should also be applied to the site at a minimum of twice |

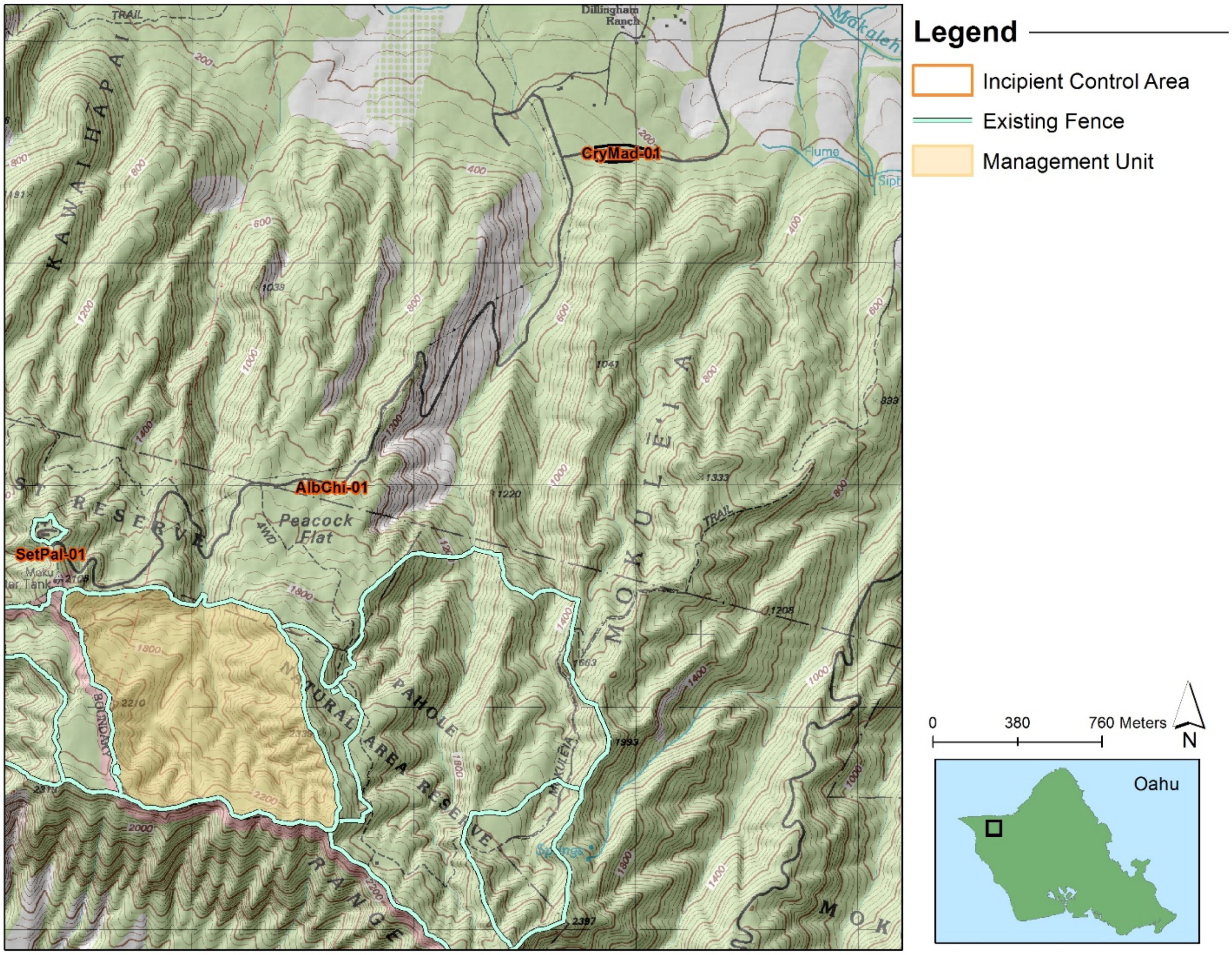
**Summary of ICAs (Continued)**

| Taxon | ICA Code | Control Discussion |
|---|---|---|
| | | per year, which may involve spraying bare ground. Control of surrounding weeds is essential to clear the search area and aid in detection. Effectively delimiting population and regular updating population area (occasional searching outside of known population) is critical in making sure populations don't expand unnoticed. |
| *Rhodomyrtus tomentosa* | Pahole-RhoTom-01 | Commonly known as downy rose myrtle. 1 mature plant was found along the rim on the Pahole fenceline in October of 2013 and has not been seen since. Taxa is widespread in the Kaneohe area, where it forms dense monocultures. Also highly invasive on Kauai. High priority to control to prevent further spread of this species throughout the Waianae range. Control technique: cut-stump with 20% triclopyr and surfactant. |
| *Setaria palmifolia* | Pahole-SetPal-01<br>PaholeNoMU-SetPal-01 | Commonly known as palm grass. 1 small seedling was found along the trail near the fenceline above SchNut.PAH-D switchbacks population in August of 2016 and has not been seen since. Small patch was found outside fence, very close to trailhead in June of 2010 and has not been seen since. *S. palmifolia* is a shade tolerant grass and that can form dense patches with dense root masses that can form mats. Control technique: handpull and remove plant material, or spray with glyphosate. |
| *Tecoma capensis* | Pahole-TecCap-01 | A prolifically growing vine, commonly known as Cape honeysuckle. *T. capensis* first found in February 2004 at this site along the south Kapuna/Pahole rim fenceline at the top of the ridge dividing gulch 2 and 3. *T. capensis* was last seen and controlled on 4-23-18. Potential for invasiveness has been observed elsewhere and is difficult to control. Staff suspect vegetative growth from roots left underground. Detection of small plants is also difficult in thick understory vegetation. Control technique: hand pull small individuals or clip and drip with 20% triclopyr and surfactant. Treat both ends if plant is stuck and growing up into a tree. A cocktail mixture of 1% aminopyralid, 2% triclopyr, and surfactant may also be used. Remove vegetative material from the field. |

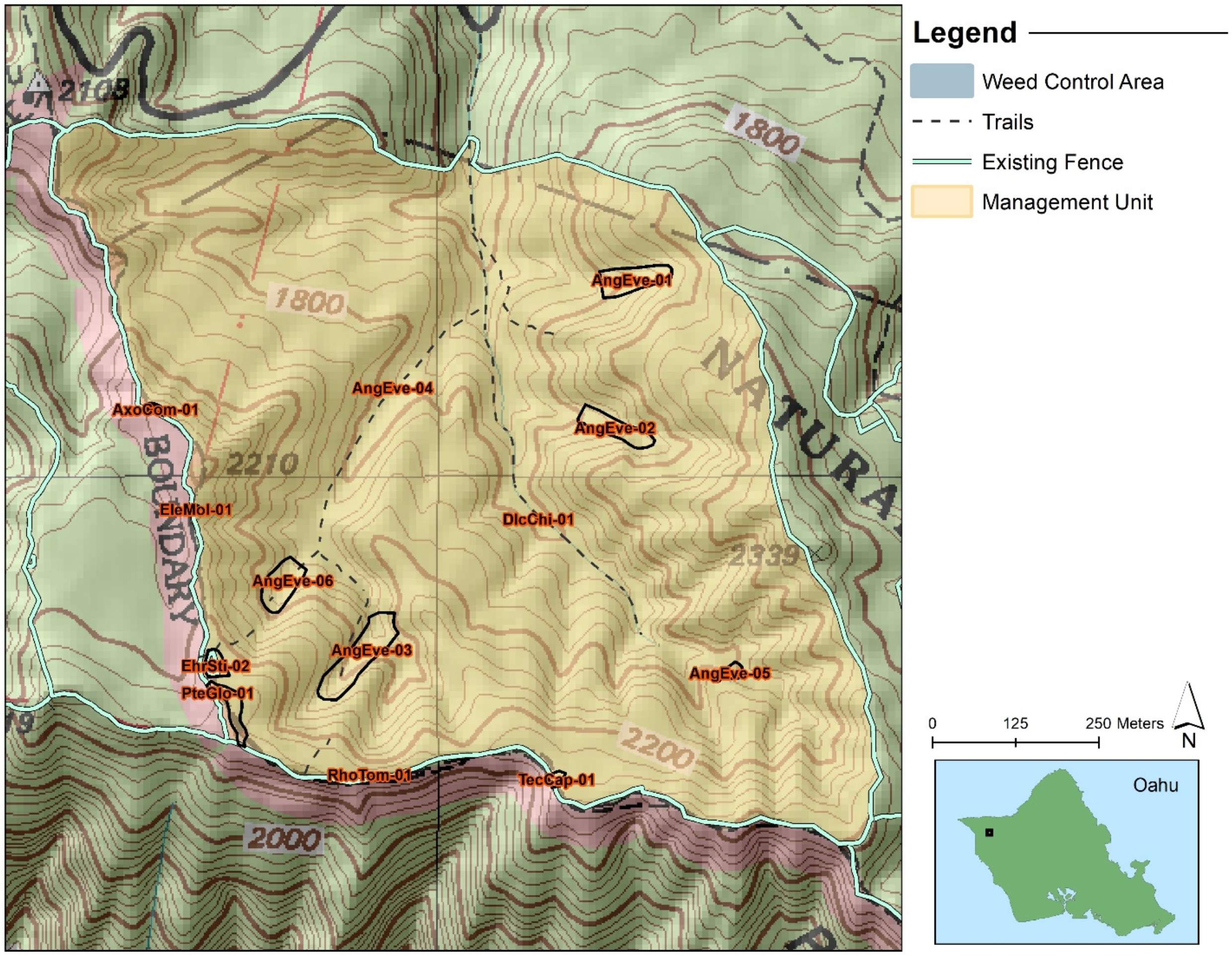
ICAs Eradicated at MU: *Ehrharta stipoides* (Pahole-EhrSti-01, Pahole-EhrSti-03, Pahole-EhrSti-04, Pahole-EhrSti-05; PaholeNoMU-EhrSti-01); *Rubus argutus* (MMR-RubArg-05)

ICAs Discontinued at MU: *Triumfetta semitriloba* (Pahole-TriSem-01 and Pahole-TriSem-02)

**PaholeNoMU Incipient Control Areas Map**



**Pahole Incipient Control Areas Map**




## Ecosystem Management Weed Control

All weed control geared towards general habitat improvement is tracked in geographic units called Weed Control areas, or WCAs. The goals, strategies, and techniques used vary between WCAs, depending on terrain, quality of native habitat, and presence or absence of rare taxa.

MIP Goals:

- Within 2m of rare taxa: 0% alien vegetation cover except where causes harm.
- Within 50m of rare taxa: 25% or less alien vegetation cover
- Throughout the remainder of the MU: 50% or less alien vegetation cover

Management Objectives:

- Work together with NEPM and NARS to define cohesive goals.
- Work towards making native canopy and understory dominant in rare plant areas, particularly reintroduction sites.
- Reduce grass cover in priority work areas.

- Reduce the frequency and cover of *S. campanulata* and *G. robusta*.

Discussion: During this revision of the ERMUP the WCAs were redrawn to cover the entire area of the MU. Previously the WCAs were divided into smaller sizes that just encompassed our rare taxa populations. There are three separate access points in Pahole, one is located at the Mokuleia Nike Missile Site, another is located at the bottom of the Pahole gulch on the Pahole road, and on occasion staff access the MU from the Kapuna trailhead. Three of the WCAs (mauka) are accessed from either the Nike Missile Site or the Kapuna trailhead. The rest are accessed from the Pahole road.

The vegetation in Pahole consists of weedy gulches (*P. cattleianum*, *C. hirta*, *R. rosifolius,* and non-native grasses) and intact native habitat on the ridges and North-facing mauka sections. Weed control in Pahole has mainly been around rare plant populations. Besides large scale *Toona ciliata* sweeps, and *G. robusta* trials by the State, as well as *Psidium cattleianum* removal by OANRP, there has been no major canopy management in Pahole, per NAR restrictions. However, in recent years staff have noticed large *Spathodea campanulata* in the gulches. If not controlled, rapid spreading and deep shading within the gulches can occur. *Spathodea campanulata* is also wind dispersed, which could lead to greater repercussions if mature seeding trees are left within the unit. Staff have also recognized large *G. robusta* on ridges where many rare plant populations exist.

Quantifying native/non-native species within Pahole has been difficult with no recent vegetation monitoring data. However, knowledge from staff on the ground has led management efforts where and when they are needed, mainly focusing around rare plant populations. Localized weed control will continue around rare plant populations until data from vegetation monitoring can be analyzed and management goals can be made. Vegetation monitoring is slated to start in 2021. NARS staff and volunteers have been working in small restoration areas within the management unit, mainly in Pahole-01. OANRP does not work in these restoration sites, however, habitat improvement efforts will help to work towards NARS management goals, as well as OANRP goals. There has been one restoration site along the Kahanahaiki/Pahole ridge trail near a *C. agrimonioides* var. *agrimonioides* outplanting site. A total of 20 plants (*A. koa, K. affinis* and *M. lessertiana*) were planted in a small area (366 $m^2$) in December 2017 and area currently doing well. There are no plans for other restoration work in Pahole, but OANRP is open to future restoration efforts.

The table below summarizes invasive weeds found at Pahole, excluding ICA species. While the list is by no means exhaustive, it includes the species targeted/prioritized for control. The distribution of each taxon is estimated as: Widespread (moderate to high densities of individuals, common across MU), Scattered (low densities across all or much of the MU), or Restricted (low or high densities, all in one discrete location).

**Summary of Target Taxa:**

| Taxa | Distribution | Notes |
|---|---|---|
| *Acacia mearnsii* | Restricted | Located on the border of Kahanahaiki and Pahole at the top of the Schwepps trail. The population is recorded under the Kahanahaiki MU as an ICA. On both sides of the trail there is only a minute amount. |
| *Achyranthes aspera* | Localized | Small population located in the lower section of the Pahole NAR. The objective is to keep it out of the Pahole MU by targeting this species when observed in WCAs. |
| *Blechnum appendiculatum* | Widespread | Groundcover found in wet areas and near rare plant populations. Spreading is vegetative, but can inhibit recruitment with thick clump formation below native plants. OANRP will control near rare plants to encourage recruitment. |

### Summary of Target Taxa (Continued)

| Taxa | Distribution | Notes |
|---|---|---|
| *Cenchrus clandestinus* | Restricted | Known from one location on state land near the NIKE site. Population is not spreading, no seed produced. OANRP will monitor to detect potential changes in behavior and work with State to determine level of control. |
| *Grevillea robusta* | Widespread | Not targeted by OANRP. NARS staff are currently treating large trees. Will continue communication with NARS staff to assess help needed. |
| *Montanoa hibiscifolia* | Widespread | Known from multiple locations across MU, and appears to be widespread. Will be a targeted during weed sweeps at all weed control areas and all occurrences will be GPSed. |
| *Passiflora suberosa* | Localized | Observed on fenceline border of Kahanahaiki and Pahole. NARS staff has observed an incursion of *P. suberosa* throughout the MU and recent vegetation monitoring in neighboring Kahanahaiki and Kapuna shows an increase in frequency and distribution. Vegetation monitoring in Pahole will help determine distribution and frequency. Always target species during weed control efforts, |
| *Rubus argutus* | Localized | One plant found on East rim of Pahole. Successful eradication at this site in May 2017 as an ICA (MMR-RubArg-05). Listed as a target since no longer considered an ICA. NARS staff have found more plants in their work areas and are actively controlling it. There is zero tolerance for this species within the NAR. |
| *Spathodea campanulata* | Localized | Found in gulch bottoms. Control during flowering season when large mature trees can be spotted from a far distance. |
| *Sphaeropteris cooperi* | Restricted | Small infestation along gulch bottom trail. One mature found on 3-4-10 within the MU, but many individuals are North of the Nike site, outside the MU. Control by cutting if found during weed sweeps or opportunistically. |
| *Tibouchina herbacea* | Restricted | One seedling was found by state employees. If found again, this species would be of serious concern and control would be high priority as an ICA. As a member of the family Melastomataceae, the seed bank would likely be extremely persistent. |
| *Zingiber zerumbet* | Restricted | One population along the trail to gulch 5, before SchKaa outplanting site. Used to be considered an ICA, but there is low priority for control and can be done opportunistically. |

Restoration activities are discussed in the notes section for each WCA. The table below contains specific notes on what native taxa and what type of stock may be appropriate for projects at Pahole. This is a lower priority MU for restoration actions. The state is mainly working on restoration in many of the sites OANRP works in.

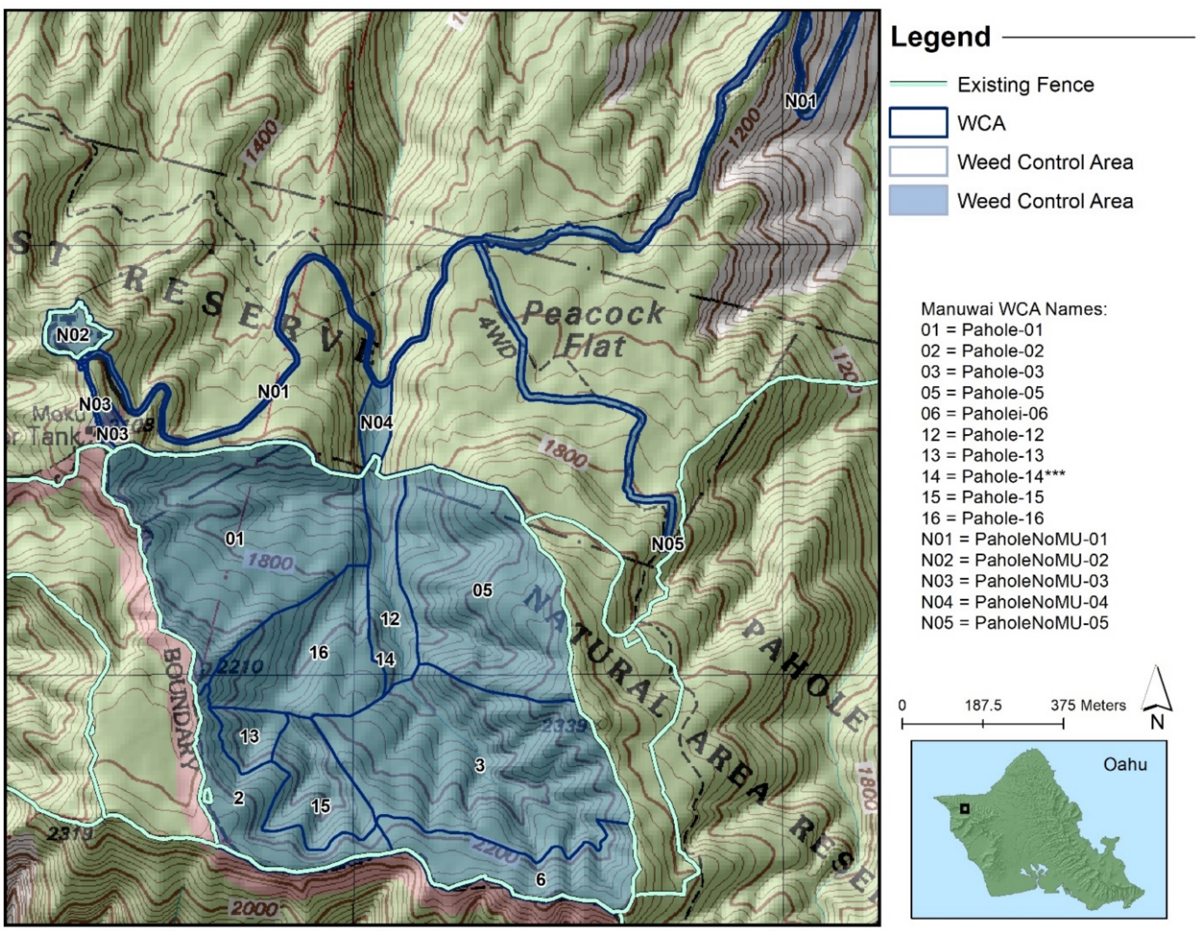
### Taxa Considerations for Restoration Actions:

| Native Taxon | Outplant? | Seedsow/ Division/ Transplant? | Notes |
|---|---|---|---|
| *Acacia koa* | Yes | Seedsow | Tree. Grow from seed. |
| *Bidens torta* | No | Seed sow | Herb. Easily grown via seed sows. |
| *Carex meyenii* | Yes | Seedsow/Division | Sedge. Grow from seed. Seed sows slow to germinate but effective. |
| *Dodonea visoca* | Yes | No | Small tree. Grow from seed. |

**Taxa Considerations for Restoration Actions (Continued)**

| Native Taxon | Outplant? | Seedsow/ Division/ Transplant? | Notes |
|---|---|---|---|
| *Hibiscus arnottianus* | Yes | No | Tree. Fast-growing. Grow from cuttings. |
| *Kadua affinis* | Yes | Seedsow | Small tree. Grow from seed. |
| *Metrosideros polymorpha* | Yes | No | Tree. Slow-growing. Grow from cuttings or seed. |
| *Microlepia strigosa* | Maybe | Division | Fern. Survives transplanting in mesic environments. |
| *Myrsine lessertiana* | Yes | No | Tree. Grow from cuttings or seed. |
| *Nestegis sandwicensis* | Yes | No | Tree. Grow from cuttings. |
| *Pipturus albidus* | Yes | Seedsow/Transplant | Small tree. Fast growing. Known to grow from seed sows. |
| *Pisonia* | Yes | Seedsow/Transplant | Tree. Fast growing. Easy to propagate. Some located just ouside of Kamaili Mauka. Know to grow from seed sows. |
| *Planchonella sandwicensis* | Yes | No | Tree. Grow from cuttings or seed. Slow growing. |
| *Psydrax odorata* | Yes | No | Tree. Grow from cuttings. |

**Weed Control Areas at Pahole**




***Pahole-14 encompasses the entire MU to track all trail and fence weed control actions.

**WCA Pahole-01 (Gulch 1)**

Veg Type: Mesic slope

MIP Goal: Less than 25% non-native cover

Targets: All weeds, focusing on *Schinus terebinthifolius*, *Psidium cattleianum*, *Montanoa hibiscifolia*, *R. rosifolius*, and *C. hirta*

Notes: This WCA encompases Gulch 1 which includes the Kahanahaiki/Pahole cross over on the North West of the MU to Puu 2210 and down the ridge to the gulch bottom. This is a large WCA, where priorities focus on understory and gradual control around rare plant taxa, grass control and canopy control. There is a large patch of *Microlepia strigosa* in the area encompassing the *Delissea waianaeensis* outplanting and controlling understory weeds may help this native understory expand. Habitat near the *Schiedea nuttallii* outplanting site is an intact native forest. Native canopy (*A. koa* and *M. polymorpha*) provides filtered light to support a thriving understory below (*S. nuttallii, Alyxia stellata, Kadua affinis, Asplenuim caudatum, Coprosma foliosa and Dianella sandwicensis*). Many areas along the rim just need periodic grass spray and minimal weeding of alien understory. OANRP should start *Blechnum appendiculatum* control in this area. It is better to attack before clumps get too large. If the population extends past an easy control threshold it is still possible to kill *B. appendiculatum* in 5 X 5 meter sections over time (a few years), reducing alien understory gradually.

**WCA Pahole-02 (Upper elevation Gulch 2)**

Veg Type: Mesic slope/ridge

MIP Goal: Less than 25% non-native cover

Targets: All weeds, focusing on *S. terebinthifolius*, *P. cattleianum*, *M. hibiscifolia*, *R. rosifolius*, and *C. hirta*.

Notes: This large WCA spans the north facing slope along the valley rim and includes the area from the Pahole Snail exclosure to the *Kadua degeneri* subsp. *degeneri* population. The area surrounding the large *Cenchrus agrimonioides* var. *agrimonioides* outplanting site is native dominated and will be maintained. However, the surrounding area will require further weeding, including periodic grass spray, *B. appendiculatum*, and *P. cattleianum* control. *K. degeneri* subsp. *degeneri*, *Cyanea longiflora*, and *Plantago princeps* var. *princeps* are located on the eastern side of this WCA. Although portions of the WCA are dominated by native understory, there is a concern of removing too much canopy, allowing non-native and invasive canopy to move in. To mitigate this concern, outplants of *Acacia koa* will be considered following any significant canopy removal actions.

**WCA Pahole-03 (Gulch 3 Eupher, Cyasup, Cenagragr)**

Veg Type: Mesic slope

MIP Goal: Less than 25% non-native cover

Targets: All weeds, focusing on *S. terebinthifolius*, *P. cattleianum*, *M. hibiscifolia*, *R. rosifolius*, and *C. hirta*.

Notes: This WCA spans the lower reaches of gulch 3, neighboring Pahole-06 which spans the higher elevations of gulch 3. The WCA includes the gulch bottom *Cyanea superba* subsp. *superba* outplants, as well as *Euphorbia herbstii* outplants. The overstory consists mainly of large *P. cattleianum* stands and in most areas of the gulch, little light is able to penetrate through to the gulch bottom. Groundcover in the gulch is partially comprised of native taxa such as *M. strigosa*, *Asplenium macrei*, and *A. kaulfussii*. Control of non-native understory and ground cover, such as *Rubus rosifolius* and *B. appendiculatum* will promote seedling recruitment, especially for *C. superba* subsp. *superba* and *E. herbstii*. *M. hibiscifolia* will be targeted wherever seen in the gulch. This WCA also includes ridge habitat that divides the major gulches. The ridge dividing Gulches 2 and 3 includes the in-situ population of *C. agrimonioides* var. *agrimonoides* among other native grasses such as *Panicum nephilophilum*. Non-native grasses are also on the ridge, including *Melinis minutiflora.* Control is implemented as necessary and careful care is taken to reduce impacts to the native grasses if spraying is needed. Directly downslope of the *C. agrimonioides* var. *agrimonoides* population is a large stand of *P. cattleianum*. This should be replaced slowly with *A. koa* as weeds are removed, so as not to let *P. cattleianum* continually encroach upon the wild population. Continuing down this ridge in a southern direction is the *D. falcata*-PAH-A population. Weed control will focus on the various rare taxa sites described here.

**WCA Pahole-05 (Gulch 4 and 5)**

Veg Type: Mesic Gulch

MIP Goal: Less than 25% non-native cover

Targets: All weeds, focusing on *S. terebinthifolius*, *P. cattleianum*, *R. rosifolius*, and *C. hirta*.

Notes: The rare taxa in this WCA include *Schiedea kaalae*, *C. agrimonioides* var. *agrimonoides* and *Cyanea grimesiana* subsp. *obatae*. *Phyllostegia kaalaensis* was reintroduced to gulch 4, but failed to maintain a population. In Gulch 5 there are *S. kaalae* and *C. grimesiana* subsp. *obatae* outplants in the gulch bottom. A small population of *Zingiber zerumet* is restricted to a small patch in Gulch 5. It is a target species and will be controlled as needed. In both Gulches 4 and 5 non-native taxa are the most dominant canopy species, including: *P. cattleainum*, *P. guajava*, *Aleurites molucanna* and *S. terebinthifolius.* The moist, dark gulch bottom is suitable habitat for *A. evecta*, other non-native ferns, and native ferns like *M. strigosa*. A mix of native and non-native shrubs exist in the gulch bottom including: *R. rosifolius*, *C. hirta*, *Buddleja asiatica*, and *Alyxia stellata*. Although there is a failed *P. kaalaensis* reintroduction in Gulch 4, other rare taxa can be found there, like *Cyrtandra dentata*. If *P. kaalaensis* is reintroduced to this site again, continual weeding of *R. rosifolius* and *B. appendiculatum* will be necessary, especially in the vicinity of the plants. It would be prudent to target the non-native understory and then gradually aim towards non-native canopy removal. The goal in this WCA is to improve habitat by gradually controlling weedy understory and canopy without shocking area with major changes in light levels, especially around rare plant populations.

The ridge dividing Gulches 4 and 5 has a reintroduced population of *C. agrimonioides* var. *agrimonoides*PAH-F. This is the only rare taxa in the immediate area, therefore the main focus of weeding is specific to this one population. Alien grasses are hand pulled near C. *agrimonioides* var. *agrimonoides* and grasses that are a safe distance away are sprayed. Continual weeding of *R. rosifolius* and *B. appendiculatum* is recommended. It would be prudent to target the non-native understory and then gradually work towards non-native canopy removal. Some of the canopy cover consists of non-natives, such as *P. cattleianum,* as well as native canopy, such as *A. koa*.

**WCA Pahole-06 (Upper elevation Gulch 3/Cyalon-A and I)**

Veg Type: Mesic slope

MIP Goal: Less than 25% non-native cover

Targets: All weeds, focusing on *P. cattleianum R. rosifolius*, and *C. hirta*.

Notes: This WCA stretches from the eastern side of Gulch 3 up to the Pahole rim. This WCA is extremely sensitive due to steep, wet banks with *Cyanea longiflora,* a primary managed IP taxa, recruitment. Due to the sensitivity of the habitat, it is recommended that activities in the area, such as weeding (*P. cattleianum*) and plant monitoring, be coupled with plant collection trips to minimize the number of visits to the site. There are several pockets of native forest patches. Additional rare taxa in the WCA include populations of *C. longiflora*, *C. dentata*, one population of *S. nuttalii*, and a small localized population of *Achatinella mustelina*. All of these plant populations are evenly dispersed among the WCA. The canopy consist of *M. polymorpha*, *A. koa*, *Cibotiumglaucum*, *A. platyphylum*, and the understory consists of *A.stellata* , *Dicranopteris linearis*, *Asplenium ssp.*, *Clidemia hirta*, and *B. appendiculatum*.

**WCA Pahole-12 (Gulch bottom/access trail)**

Veg Type: Mesic Gulch

MIP Goal: Less than 50% non-native cover

Targets: All weeds, focusing on *P. cattleianum*, *M. hibiscifolia*, *Toona ciliate*, *R. rosifolius*, *C. hirta*, and *Triumfetta semitriloba*.

Notes: The WCA spans the main gulch bottom. There are no rare taxa within this WCA, but this large drainage is the most commonly used corridor that leads to the five gulches in Pahole, each of which contains rare managed taxa. The moisture of this gulch environment allows for a lush, generally native filled understory consisting of native ferns. One of the goals is to focus our attention on *M. hibiscifolius* sweeps, as well as searching for other target weeds including *T. ciliata*, *Triumfetta semitriloba*, and *Passiflora edulis*, which became a potential threat a year ago. Due to the fact that this gulch is the main pathway used to access the other gulches, it is pertinent to halt any further transport of the previously mentioned weeds by prioritizing treatment along these high-use corridors.

**WCA Pahole-13 (Gulch 2 Eupher)**

Veg Type: Mesic Gulch

MIP Goal: Less than 25% non-native cover

Targets: All weeds, focusing on *P. cattleianum*, *M. hibiscifolia* and *C. hirta*.

Notes: *E. herbstii* PAH-F ismanaged within this WCA. *E. herbstii* growing in areas with open canopy or on slopes die more than plants with intermediate to closed canopies or in gulch bottoms, suggesting that drastic light changes are a concern in this WCA. Selective canopy control of *P. cattleianum* and *S. terebinthifolius* will be implemented to prevent major light changes around the *E. herbstii* population. Understory weeds such as *C. hirta*, *B. appendiculatum*, and *R. rosifolius* inhibit *E. herbstii* recruitment and frequent control is necessary. The bottom of Gulch 2 which includes Pahole-13 and Pahole-16 should be swept for *M. hibiscifolius*, *T. ciliata*, and *T. semitriloba* at least once a year.

**WCA Pahole-14 (Fencline/trail)**

Veg Type: Mesic Gulch

MIP Goal: Less than 50% non-native cover

Targets: All weeds, especially those encroaching or breaching the fence line, focusing on non-native grasses (*U. maxima* and *M. minutiflora*), *P. cattleianum*, and *T. semitriloba*.

Notes: WCA 14 encompasses the entire Pahole fence including the Hypalon. It is important to maintain and clear the fenceline in this area that spans from gulch to ridge top. Occasionally staff remove large fallen trees off the fence to maintain its integrity. Spraying grass and treating the thick invasive understory weeds will be done as needed in order to keep weeds at a manageable size and will keep the fence clear for maintenance checks.

**WCA Pahole-15 (Gulch 2 Cyalon-J)**

Veg Type: Mesic slope/ridge

MIP Goal: Less than 25% non-native cover

Targets: All weeds, focusing on *S. terebinthifolius*, *P. cattleianum*, and *A. moluccana*.

Notes: This WCA spans the back of Gulch 2 where terrain is very steep. Intensive weed effort to remove large *A. moluccana*, *P. cattleianum* and *S. terebinthifolius* cleared area for the most recent *C. longiflora* outplanting in Pahole. Selective removal of non-native trees, along with restoration efforts will be implemented. A mix of native and non-native understory occurs in this WCA. Lack of light in the gulch bottom encourages fern growth including *Angiopteris evecta*. Control is being implemented at this ICA (Pahole AngEve-03) to prevent plants from reaching maturity, as sweeps are done once per year.

**WCA Pahole-16 (Gulch 2 Fluneo)**

Veg Type: Mesic Gulch

MIP Goal: Less than 25% non-native cover

Targets: All weeds, focusing on *P. cattleianum*, *M. hibiscifolia* and non-native grasses (*Oplismenus hirtellus*, *Paspalum conjugatum*)

Notes: *Fluggea neowawraea* is the managed taxa within this WCA and the reintroduction site is in the bottom of Gulch 2. Aggressive canopy control in necessary, since *F. neowawraea* has high light level requirements. As canopy species are removed non-native grasses, such as *O. hirtellus* and *P.conjugatum* need to be controlled regularly. Other understory species of concern are *C. hirta, B. appendiculatum*, and *R. rosifolius*, which should be controlled regularly. The bottom of Gulch 2, which includes Pahole-13 and Pahole-16 should be swept for *M. hibiscifolius*, *T. ciliata*, and *T. semitriloba* at least once a year.

**WCA Pahole No MU-01 (Pahole Road)**

Veg Type: Mesic Forest

MIP Goal: N/A

Targets: Roadside weeds, focusing on *U. maxima*.

Notes: The goal of this WCA is to maintain the Pahole road and control/reduce of target weeds as a traffic safety issue. OANRP staff sprays grass and herbaceous weeds along the road from Peacock Flats gate to the ranch gate as needed. Often, a power sprayer and weed whackers are used. These actions are shared between teams. Maintenance and weed control on other parts of the road occurs occasionally. It is important to prevent spread of weeds on road, particularly since it is utilized by several organizations: OANRP, State, HECO (Hawaiian Electric Company), Verizon Wireless, and HPD (Hawaii Police Department), as well as public hunters, and hikers.

**WCA Pahole No MU-02 (Nike Site)**

Veg Type: Mesic Flat

MIP Goal: N/A

Targets: All weeds.

Notes: The goal of this WCA is to control weeds around the Nike site facility to prevent the spread of weeds to other areas. Weed control is focused around the LZ, OANRP greenhouses, the upper building at Nike, and anywhere else needed. Some common weeds found on these WCA sites include: *P. cattleianum*, *P. guajava*, *S. terebinthifolius*, *R. rosifolius*, *C. hirta*, *Leucaena leucocephala*, *M. minutiflora*, *U. maxima* and *Erigeron karvinskianus.* OANRP horticultural staff maintain this WCA with the help of the Green Team as needed

**WCA Pahole No MU-03 (Cenagragr Reintro Outside Fence)**

Veg Type: Mesic Slope

MIP Goal: Less than 25% non-native cover

Targets: All weeds, focusing on *P. cattleianum* and grasses (*M. minutiflora*, *U. maxima*)

Notes: This WCA is located from Pahole Road (Nike building gate) to the Kahanahaiki/Pahole trail crossover. The managed rare taxa here are reintroduced *C. agrimonioides* var. *agrimonioides* and *S. obovata* in a steep terrain habitat. The canopy is predominately *S. terebinthifolius*, and is very open. The area is an exposed ridge top, and therefore, not much ground cover is present. Target understory and gradual canopy removal. As canopy species are removed non-native grasses, such as *M. minutiflora* and *U. maxima* need to be controlled regularly. This WCA spans the main trail and maintenance will be as needed.

**WCA Pahole No MU-04 (Fig Gulch)**

Veg Type: Mesic Gulch

MIP Goal: Less than 50% non-native cover

Targets: All weeds, focusing on *M.* hibiscifolius, *T. semitriloba*, *P. cattleianum*, and *Achyranthes aspera*.

Notes: This WCA is located between the Pahole fence and the Pahole road. Any target species in this WCA should be killed including *M. hibiscifolius*, *T. semitriloba* and *A. aspera* to prevent these species from establishing and spreading into the MU. This area is fairly weedy with *M. hibiscifolia* and some *P. suberosa* intermixed along the slopes. The understory is comprised of mostly native taxa, *A. stellata* and *M. strigosa* and there are no rare taxa in the immediate area. Weed sweeps for *M. hibiscifolia* are on-going while conducting other MU actions and weed sweeps. Trail maintenance will be as needed for safe thoroughfare.

## Small Vertebrate Control

Species: *Rattus rattus* (Black rat), *Rattus exulans* (Polynesian rat), *Mus musculus* (House mouse), *Lophura leucomelanos* (Kalij Pheasant).

Threat Level: High threat from *Rattus spp.* to all members of the Campanulaceae including *Cyanea* & *Delissea* species. High threat to all *Schiedea* species. High for *A. mustelina.* Threat level unknown for *Lophura leucomelanos* (Kalij Phesant) on frugivory of Campanulaceae, but fruit consumption and physical stem damage have been documented on video.

Seasonality/Relevant Species Biology: OANRP manages rats seasonally or year-round, depending on whether the rare taxa require protection seasonally or year-round. For example, *Achatinella mustelina* are protected from predation year round with a small grid around the Pahole snail enclosure.

Management Objectives:

- Mitigate threat of vertebrate activity on managed plant and snail populations.

Strategy and Control Methods:

- Monitor rare plant (*C. superba* subsp. *superba, C. grimesiana*, *D. waianaeensis*, *E. herbstii*, *S. obovata*, *S. kaalae* and *S. nuttallii*.) populations, as well as other native species for evidence of rodent impacts.
- There are no immediate plans for a large scale trapping grid in Pahole. If rodent damage on rare taxa is observed, staff will deploy a rapid response grid of Good Nature A24 traps.
- There are no plans to mitigate the effects of frugivory by *Lophura leucomelanos* (Kalij Phesant) and other non-native birds at this time, however OANRP will continue to support research.

Discussion: Currently Goodnature A24 automatic rat traps are our greatest conservation tool for rodent control. The bait development of Goodnature A24's has vastly improved. The longevity has increased enough for OANRP staff to check once a quarter. Because of this new efficiency we may be able to expand protection to more areas for less cost. It would be worth evaluating if larger grids should be installed at some sites that have isolated or territory based grids.

There is a smaller grid deployed around the Pahole NAR tree snail exclosure which is maintained every four months by OSEPP (Oahu Snail Extinction Prevtion Program.). The exclosure is an older design constructed to keep out the predator snail *Euglandina rosea*, but not rodents. Plans are underway by the State to construct an updated version of the snail exclosure with rodent/predatory snail barriers in place.

Additional rat control/research is ongoing at the Kahanahaiki MU which is directly adjacent to the Pahole MU. Most current experiment in Kahanahaiki involved a trial with the rodent birth control product ContraPest, which could have overlapping effects into Pahole. Monitoring fruit fate of *C. superba* subsp. *superba* during the 2009-2010 fruiting season revealed a high rate of rat predation on fruits within the Pahole MU. We are considering dropping the status of *C. superba* subsp. *superba* in the Pahole to Kapuna PU when a new PU is established (Palikea) with a completed outplanting; therefore, rodent control is a low priority around this species. There are no immediate plans for a large scale trapping grid in Pahole.

Since 2016 research has been done by the Vertebrate Introductions and Novel Ecosystems (VINE) Hawaii project to examine [1] how the structure and dynamics of seed dispersal networks vary across ecological contexts, [2] how seed dispersal competence of non-native species varies across ecological contexts to influence ecosystem functioning, and [3] how ecosystem functioning is maintained across new spatial and temporal extents through non-native birds. As part of the project motion-detection cameras are set up in the field to record the types of non-native frugivores and the different species of plants they visit. One of the cameras had detected *Lophura leucomelanos* (Kalij Pheasant) frugivory on *Delissea waianaeensis* (PAH-C) while producing heavy damage to the plant. This was the first recorded threat of the Kalij on *D. waianaeensis*, currently the problem is being investigated for the feasibility of control in the future. However, the presence of *D. waianaeensis* seedlings in Pahole and in neighboring Kahanahaiki far from any known populations, could suggest that a frugivore is moving the seeds around. The VINE Hawaii project continues to collect data on non-native avian frugivores and study the viability of seeds through the avian digestive system.


Two rats consuming fruits from a population of *D. waianaeensis*

## Slug Control

Species: *Deroceras leave*, *Limax maximus*, *Veronicella cubensis*, *Meghimatium biliniatum*

Threat Level: High threat to all members of the Campanulaceae including *Cyanea* & *Delissea* species. High threat to all *Schiedea* species. Unknown threat to all other rare plant species, but could be a threat to *Euphorbia herbstii* seedlings.

Seasonality/Relevant Species Biology: Slugs are seasonally abundant during the wet season. In Pahole, slugs are present year round, though less active in the hottest months (July and August).

Management Objectives:

- Eradicate slugs locally to ensure germination and survivorship *C. grimesiana*, *D. waianaeensis*, *E. herbstii*, *S. obovata*, *S. kaalae*, and *S. nuttallii*.
- Ensure no rare snails are adversely impacted by slug control.
- Assess slug activity over time.
- Survey annually to ensure rare snails do not migrate into slug treatment areas.

Strategy and Control Methods:

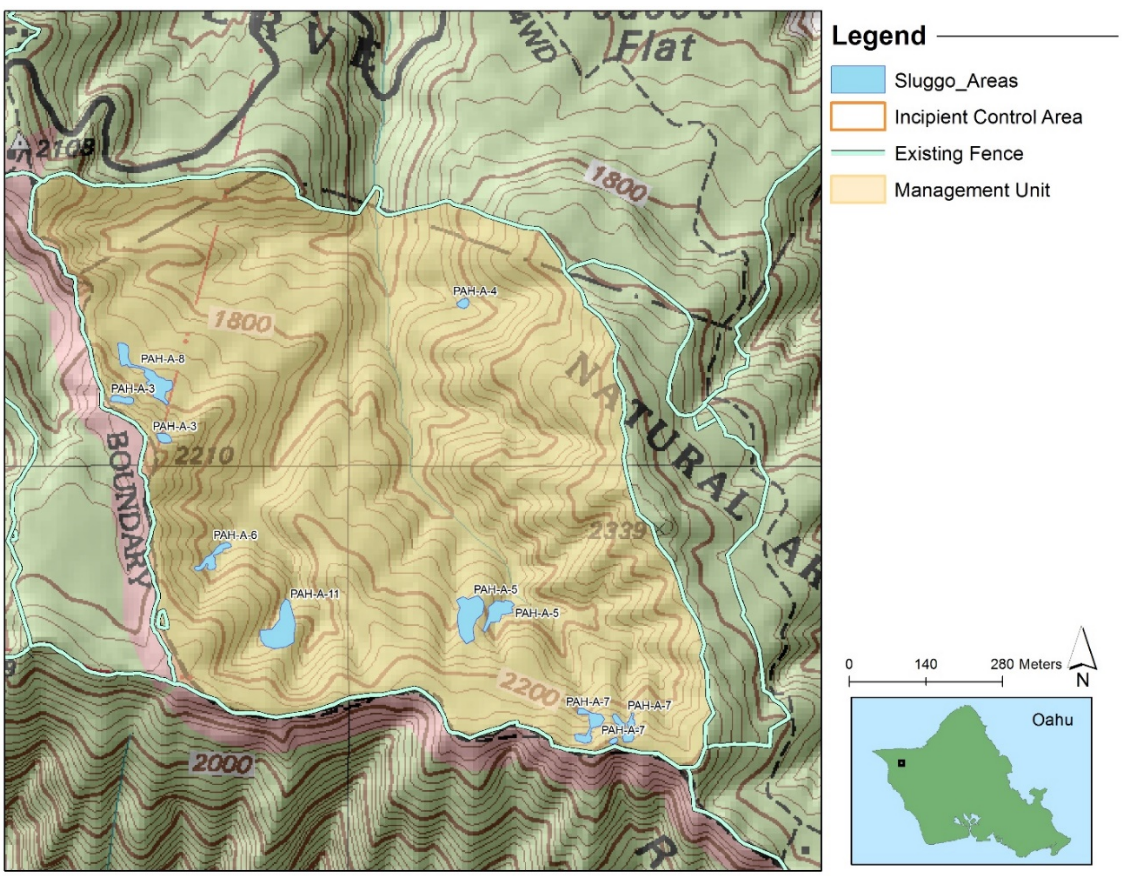
Slug Control Areas (SLCAs) have been delineated around rare taxa locations. These include not only the target plant but a buffer of 10 meters to kill slugs entering the rare plant vicinity. Apply FerroxxAQ every 6 weeks. A buffer of at least 5 meters from vulnerable plants is recommended. 10 meters is optimal.

- Prior to any control, day and nighttime surveys must be conducted in the proposed control area to ensure there are no rare snails are in the area.
- If rare snails are found in an established SLCA, treatment will be halted. Rare snails will be relocated to the MU snail enclosure. The site then will be resurveyed (day and night) to ensure no rare snails are present before treatment is resumed. Annual day and night surveys will be conducted at the SLCA for two years after the last rare snail sighting.
- Slug activity will be noted using baited pitfall traps set once a year in the wet season. Staff will also record and note any damage to target plants caused by slug feeding.

**Slug Control Area Locations Table**

| SLCA Code | Plant population reference codes | Date slug control began |
|---|---|---|
| PAH-A.2 | CyaSupSup.PAH-A | 2014-01-13/discontinued 2015-06-10 |
| PAH-A.3 | SchNut.PAH-D, SchNut.PAH-E and SchObo.PAH-E | 2014-01-13 |
| PAH-A.4 | CyaGriOba.PAH-D, SchKaa.PAH-C, SchKaa.PAH-A | 2015-09-16 |
| | | |
| PAH-A.5 | EupHer.PAH-R and EupHer.PAH-G | 2015-06-10 |
| PAH-A.6 | EupHer.PAH-F, EupHer.PAH-S and | 2015-06-10 |
| PAH-A.7 | CyaLong.PAH-I, CyaLong.PAH-A and SchNut.PAH-A | 2015-10-12 |
| PAH-A.8 | DelWai.PAH-C and CyaSub.PAH-B | 2017-09-26 |
| PAH-A.11 | CyaLong.PAH-J | 2018-03-11 |

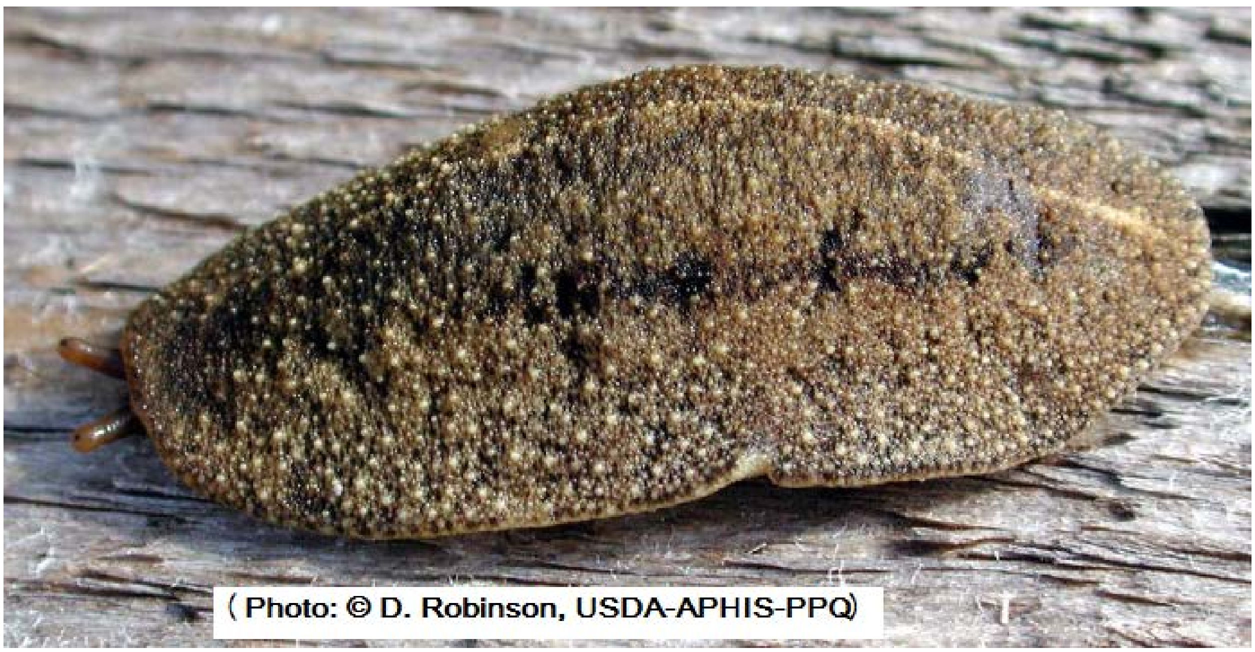
**Slug Management Map**



**Slug Photos**


*Deroceras laeve*, grey garden slug.
This is the most common slug in the MU.


*Limax maximus* (leopard slug) with eggs
This is the second most common slug in the MU.




*Veronicella cubensis* (Cuban slug). This slug is rare in the MU, it is restricted to the area above the road.

Discussion:

During annual rare plant monitoring, we will inspect plants for herbivory. If present, this will be noted. Indication that slugs are responsible includes the following: lower leaves closer to the ground are more damaged, slime is present, and leaf margins are consumed before the interior of the leaf (unless the midrib is resting on the ground while the margins are curled).

If slug herbivory is suspected, check for rare native snails within 20 meters of the rare plants before proceeding with a slug control program.

Sample slugs in the vicinity using baited beer traps. If the number of slugs captured per trap over two weeks exceeds one slug per trap, and, if no rare native snails are present, apply commence applying FerroxxAQ every 6 weeks year round.

Cyasupsup.PAH-A site is discontinued due to the designation of this population. It transitioned from a MFS population to GS. The new MFS for the

## Ant Control

Species: *Solenopsis genimata, S. papuana, Paratrechina bourbonica, Leptogenys falcigera.*

Threat Level: Low

Seasonality/Relevant Species Biology: Varies by species, but nest expansion is typically observed in late summer to early fall.

Management Objectives:

- Prevent spread of ant species into areas where not already established. Conduct annual surveys during the summer to determine what ant taxa are present in the MU.
- Detect incursions of new ant species prior to establishment.

Strategy and Control Methods:

- Sample ants at human entry points using the standard survey protocol (Plentovich and Krushelnycky 2009). Use samples to track changes in existing ant densities and to alert OANRP to any new introductions
- If incipient species are found and deemed to be a high threat and/or easily eradicated locally (<0.5 acre infestation), begin control.
- Sample ants at campsite, LZ, rare taxa sites, DZ, and fence lines to track changes in existing ant densities and to alert OANRP to any new introductions.
- Look for evidence of ant tending of aphids or scales on rare plants during annual rare plant monitoring.

**Ant Survey Site Table**

| **Site description** | **Reason for survey** |
|---|---|
| Hypalon Fence | Human entry point. High risk of accidental ant introduction |
| *Achatinella mustellina* snail exclosure | Human entry point. High risk of accidental ant introduction |

## Ant Photos


*S. papuana* or the thief ant is the most common ant in the MU.

Discussion: Ants have been documented to pose threats to a variety of resources, including native arthropods, plants (via farming of Hemipterian pests), and birds. It is therefore important to know their distribution and density in areas with conservation value. From 2008-2014 ants were sampled in high risk areas using the following method:

Vials are baited with SPAM, peanut butter and honey. We remove the caps and space vials along the edges of, or throughout, the area to be sampled. Vials are spaced at least 5 meters from each other. A minimum of 10 baited vials are deployed at each site, in a shaded area for at least 1 hour. Ant baiting takes place no earlier than 8:00 am in the morning no sampling occurs on rainy, blustery or cold days as both rain and low temperatures reduce ant activity. Ants collected in this manner are returned for later identification.

Standardized surveys have taken place in Pahole for 10 years. All species found listed at the beginning of this section.

## Black-Twig Borer (BTB) Control

Species: *Xylosandrus compactus*

Threat Level: High

Seasonality/Relevant Species Biology: Peaks have been observed from October-January

Management Objectives:

- During annual rare plant monitoring, look for signs of twig boring and damage at the rare plant populations commonly impacted by BTB (*Flueggea neowawraea*).

Strategy and Control Methods:

- If rare plant taxa that are monitored show any sign of boring, report to Rare Plant Manager immediately.
- If there is an urgency to collect any plant material (i.e. seed, cuttings, and saplings) for genetic storage, collect material.

Discussion: The current control method available for BTB involves the deployment of traps equipped with high-release ethanol bait. However, it is unclear whether this method reduces BTB damage to target plants. Therefore, this control method is not used to control BTB in the field. Since this control method is not effective, OANRP will continue to investigate other control methods. If there is a rare plant population threatened by BTB and there is an urgency to have the genetic material, OANRP staff will collect any plant material to prevent losing the plant founder altogether.

## Fire Control

Threat Level: Medium

Seasonality/Potential Ignition Sources: Fire may occur whenever vegetation is dry. Generally this happens in summer, but may occur at other times of the year, depending on variations in weather pattern. *Urochloa maxima* has a high fire index, and is the dominant vegetation nearby the western and southern side of this MU. In past fires have come close to the MU, both from fires set by the military, by arsonists along Farrington Hwy, or nearby farm lands.

Management Objectives:

- To prevent fire from burning any portion of the MU at any time.
- To prevent fire from damaging any rare taxa locations.

Strategy and Control Methods:

- Reduce fuel loads within the MU, along the road, and along the fenceline.
- If a fire occurs, conduct a post-fire survey, including mapping the perimeter of the fire and document damage via photos.

**Fire Photos**

2003 fire near Pahole NAR's western boundary

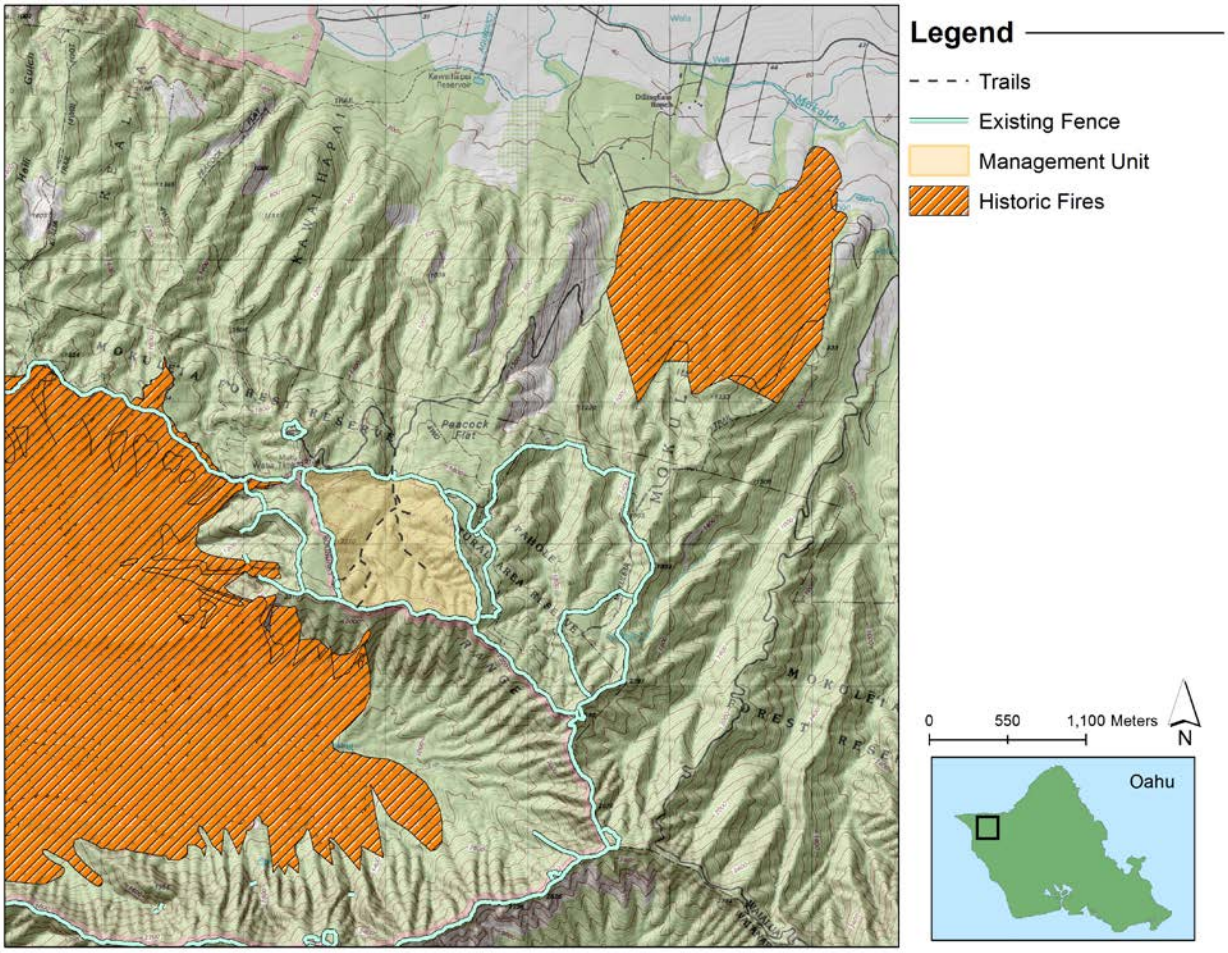
2017 fire near Pahole NAR's eastern boundary.

Discussion: The western and southern side of the Pahole MU falls into the MMR Action Area and is considered medium to high risk of fire due to the close proximity to Makua Valley where the fire threat is high, as well as, dry pasture lands to the north. In 2003, a prescribed burn got outside of the prescription area and got within 150m of the Pahole NAR's western boundary. Since early 2000's, the military has changed its vegetation suppression strategies, moving from prescribed burns to mowing/spraying most of the vegetation. There have been several fires in Makua since then that have started from arsonist from Farrington Highway. Though none of these fires reached the MU they still had potential to get into the management unit. Below the Pahole NAR are farm lands and grassy gulches. In 2017 a fire burned private and state land in Mokuleia, which was ignited by a farm vehicle on one of the agriculture lots. Though no taxa were impacted, it could have potentially got into Pahole gulch.

Fire prevention to this MU depends on fire measures put in place in Makua Valley, as well as, other surrounding land owners. As with all other fire prone MUs, the following preventative actions are important: fire prevention signage, trail and LZ maintenance, and reduction of grass and other fuel loads on ridges and fencelines.

The Biological Opinion, which is a re-initiation of the 1999 review by the U.S. Fish and Wildlife Service (FWS) of Army training in Makua, details several different options for reducing fire threat. Which options are required depends in part on the weapons/ munitions used during training. For now, OANRP will focus on maintaining good communication with the Wildland Fire Working Group to facilitate positive on-the-ground fire response in the event of another catastrophic Makua brushfire that could potentially threaten Pahole MU.

## Fire Management Map




Previous Fires near Pahole MU

# Action Table

The table below is a comprehensive list of threat control actions planned for the MU for the next five years. Actions are grouped by type; for example, Ungulate Control or Ant Control. Weed control actions are grouped into the following categories: General Survey, ICA code, or WCA code. Cells with **X** denote the quarters in which an action is scheduled. IP years run from October of one year through September of the next. Therefore, Quarter 4 (October-December) is listed first for each report year, followed by Quarter 1 (January-March), Quarter 2 (April-June), and Q3 (July-September). Species names are written as six-digit abbreviations, such as 'CenSet' instead of *Cenchrus setaceus*, for brevity.

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 5764 | Ant Monitoring | None | None | Sample ants at two human entry points where Gulch 2 intersects Hypalon fence and at the Achatinella mustellina snail exclosure. Monitoring protocol: place 10 open vials containing SPAM, peanut butter and honey throughout the area to be sampled. Close vials after one hour and place in freezer for ID. Do not sample on rainy days. | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |
| 7828 | Common Collections | None | None | ActionComments Obs/Collect common native plants for restoration use throughout Pahole MU. Collect from Pahole MU and/or appropriate nearby locations. General action for collections not specified for that year. Action includes monitoring phenology. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 3477 | Fence Monitor/ Maintenance | None | PAH-A | All fence monitoring and maintenance actions. Maintenance is defined as any minor repair work or that is LESS THAN 100m. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 7635 | Slug Control | CyaLong | PAH-A-11 | Gulch 2, CyaLong.PAH-J 2018. Vince already surveyed the area and it is clear of native snails so Sluggo may be used. Area needs to be mapped following outplanting. Based on the area he surveyed, 1.5 lbs. of FerroxxAQ should be applied every 6 weeks | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 5717 | Slug Control | SchNut | PAH-A-3 | Warning potential AchMus above and near SchNut.PAH-E. Apply 4 Lbs. of FerroxxAQ every 6 weeks at Pahole site 3 (SchNut.PAH-D, E). This is the area before the Pahole switchbacks on the trail to the makua overlook. You will need 4 lbs. of FerroxxAQ, 2 lbs are used on the Scheidea's on your left before the switchbacks, 2 are used on the SchNuts on the switchbacks | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6935 | Slug Control | SchKaa | PAH-A-4 | Gulch 5, Discontinue? Put 2 lbs. Sluggo at the CyaGriOba.PAH-D and and 1 lbs at the SchKaa.PAH-C. You will pass SchKaa.PAH-A on your way to site. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 5757 | Slug Control | EupHer | PAH-A-5 | Gulch 3, 4 Lbs. FerroxxAQ needed for this site which includes a mix of EupHer.PAH-R, EupHer.PAH-G | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 6938 | Slug Control | EupHer | PAH-A-6 | Gulch 2, EupHer.PAH-S, Sluggo related activities. Snail survet completed. Mapped for Sluggo and slugs sampled. Area recieves 3 lbs. Sluggo | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6939 | Slug Control | SchNut | PAH-A-7 | Sluggo: CyaLong.PAH-A and CyaLong.PAH-I, and SchNut.PAH-A 5 plants left. Amounts follow: CyaLon.PAH-A + SchNut.PAH-A mixed area recieves 7 lbs. of Sluggo. Follow the blue flags and apply sluggo at each orange and blue flagged "sluggo station" or as you recognize rare plants. Then use 3 lbs. of Sluggo at the Adjacent CyaLon.PAH-A site seperated by a small ridge. Follow the blue trail and the webbing to the plants. Finally, measure 7 lbs of Sluggo for the CyaLon PAH-I population. As with the previous populations, follow the blue flagged trail, webbing and apply sluggo at slug stations | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 6936 | Slug Control | DelWai | PAH-A-8 | DelWai.PAH-C, Sluggo related activities. Apply 7 lbs. of FerroxxAQ every 6 weeks at both DelWai and CyaSup plants. Surveyed for snails 2011-03-16, none found. 9/25/2017 Northwestern half of | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| | | | | population was mapped and GPSed. | | | | | | | | | | | | | | | | | | | | |
| 5016 | Weed Control | None | Pahole-01 | Control weeds across Cenagr, Schobo reintro zone every 6 months. Target understory, gradual canopy weed control. | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** |
| 5017 | Weed Control | None | Pahole-01 | Control weedy grasses across WCA every 6 months, as needed. Exercise care when spraying around rare taxa. | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | |
| 5018 | Weed Control | None | Pahole-01 | Control weeds across WCA annually. Focus around native forest patches. Target understory, Schter, Monhib, gradual canopy control. Avoid DOFAW TecOva release sites. Do not kill large Grerob; part of NARS trial. | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |
| 5950 | Weed Control | None | Pahole-01 | Control weeds across Schnut switchbacks reintro zone every 6 months. Target understory, gradual canopy weed control. | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** |
| 7491 | Weed Control | None | Pahole-01 | Control weeds across Schnut Puu 2210 reintro zone annually/as needed. Target understory, gradual canopy weed control. | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 959 | Weed Control | None | Pahole-01 | Control weeds around Delwai/Cyasup reintro zone every 6 months. Target understory weeds, gradual canopy weed control. Always target MonHib. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 5019 | Weed Control | None | Pahole-02 | Control weeds around SchObo, CyaGri, DelWai reintro zone every 6 months. Target understory weeds and gradual control of canopy weeds to prevent major light changes. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 5020 | Weed Control | None | Pahole-02 | Control weeds around native forest patches, across WCA, annually. Target Monhib, Trisem, select understory weeds and gradual removal of canopy weeds. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 5021 | Weed Control | None | Pahole-02 | Control weedy grasses across WCA every 6 months/year, as needed. Target Melmin, Pascon, Oplhir. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 7834 | Weed Control | None | Pahole-02 | Control weeds around KadDegDeg zone every annually. Time weed control before monitoring, if possible. Target understory weeds and gradual control of canopy weeds to prevent major light changes. Sensitive habitat, minimize traffic and disturbance. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 960 | Weed Control | None | Pahole-02 | Control weeds around Cenagr reintro zone every 6 months/year. Target understory and gradual control of canopy weeds. | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |
| 5022 | Weed Control | None | Pahole-03 | Control weedy grasses across CenAgr site on 2/3 ridge every 6 months/as needed. Target Melmin. Exercise care when working around Cenagr. | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |
| 5025 | Weed Control | None | Pahole-03 | Control weeds around EupHer reintro every 6 months. Target understory and gradual canopy weed control (prevent major light change). Control Bleapp right around Chaher. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 5026 | Weed Control | None | Pahole-03 | Control weeds around native forest patches, wild Akoko, sweeping across WCA every annually. Target canopy and select understory weeds. Target Monhib wherever found in gulch 3. GPS and flag locations of mature Monhib plants. Track number/reproductive status of Monhib treated. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 961 | Weed Control | None | Pahole-03 | Control weeds around Cenagr and nice forest patches on 2/3 ridge every 6 months/year. Target Monhib, understory and gradual control of canopy weeds (Psicat). Do not kill large Grerob; part of NARS trial. | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |
| 962 | Weed Control | None | Pahole-03 | Control weeds around Cyasup reintro (all three zones) every 6 months. Target understory and gradual canopy weed control (prevent major light change). Understory very weedy; selectively work around Cyasup plants. Target selected understory weeds for control across | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| | | | | zone. Target Bleapp right around Cyasup. | | | | | | | | | | | | | | | | | | | | |
| 3483 | Weed Control | None | Pahole-05 | Control weeds across Schkaa/Cyagri reintro zone in Gulch 5 every 6 months. Target understory weeds, especially weedy ferns. Conduct minimal canopy weeding to prevent light regime changes. Always treat MonHib and record #s treated. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 3484 | Weed Control | None | Pahole-05 | Control understory and canopy weeds around Cenagr reintro every 6 months/year. | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |
| 5027 | Weed Control | None | Pahole-05 | Sweep gulch at least once a year, focusing on significant weeds, particularly MonHib, TooCil, TriSem. Known MonHib hotspots in Gulch 4; GPS and flag locations of mature plants, and track number/reproductive status of plants treated. | X | | | | X | | | | X | | | | X | | | | X | | | |
| 7833 | Weed Control | None | Pahole-06 | Control weeds around native forest patches, across WCA, annually. Target Monhib, Trisem, select understory weeds and | | | X | | | | X | | | | X | | | | X | | | | X | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| | | | | gradual removal of canopy weeds. | | | | | | | | | | | | | | | | | | | | |
| 963 | Weed Control | None | Pahole-06 | Control weeds across CyaLon zone every 6 months/annually. Exercise extreme care when working around Cyalon, rare taxa; sensitive habitat. Pair with rare plant collection trips. Target understory and gradual canopy control, MonHib. Do not kill large Grerob; part of NARS trial. | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** |
| 5532 | Weed Control | None | Pahole-12 | Sweep gulch at least once a year, focusing on significant weeds, particularly MonHib, TooCil, TriSem. Maintain trail as needed. | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | |
| 5533 | Weed Control | None | Pahole-13 | Sweep gulch at least once a year, focusing on significant weeds, particularly MonHib, TooCil, TriSem. | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | |
| 5534 | Weed Control | None | Pahole-13 | Control weeds around EupHer.PAH-S every 6 months. Target understory and gradual canopy weed control (prevent major light change). Always target MonHib, TooCil, and TriSem in Pahole. | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 7799 | Weed Control | None | Pahole-15 | Control weeds around CyaLon.PAH-J reintro zone every 6 months. Target understory weeds and gradual control of canopy weeds to prevent major light changes. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 6215 | Weed Control | None | Pahole-16 | Conduct understory/canopy weed control around FluNeo/SchKaa reintroduction site every 3-6 months. FluNeo requires lots of sun. Control canopy weeds aggressively at site. Always target Trisem, Monhib in Pahole. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 6216 | Weed Control | None | Pahole-16 | Control weedy grasses across FluNeo reintro site, as needed. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 7798 | Weed Control | None | Pahole-16 | Sweep gulch at least once a year, focusing on significant weeds, particularly MonHib, TooCil, TriSem. | X | | | | X | | | | X | | | | X | | | | X | | | |
| 7832 | Weed Control | None | PaholeNo MU-02 | Control weeds on and around Nike LZ, as needed. Target grasses, EriKar, and any other weeds which shouldn't be spread to other locations. Monitor and remove tree hazards, as allowed by State Forestry. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 5010 | Weed Control | None | PaholeNo MU-03 | Control weeds around Schobo and Cenagr reintros every 6 months/year. Target understory weeds and limited canopy weed control. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 7801 | Weed Control | None | PaholeNo MU-03 | Spray grasses and other weeds along Kahanahaiki/Pahole access trail quarterly, or as needed. Note, this action only covers trail maintenance from the Pahole road to the first crossover. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 5535 | Weed Control | None | PaholeNo MU-04 | Control target weed species, particularly MonHib, TooCil, TriSem, annually. Maintain trail as needed. | X | | | | X | | | | X | | | | X | | | | X | | | |
| 5218 | Weed Control - Trails/Rds | None | Pahole-14 | Spray grasses along Kahanahaiki/Pahole fenceline quarterly, or as needed. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 5531 | Weed Control - Trails/Rds | None | Pahole-14 | Clear/maintain rat grid trails, access trails, and fencelines as needed. Intent = maintenance, NOT vegetation restoration. Remove downed trees, spray grass, treat thick understory, as needed. Target all MonHib seen | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| | | | | along fence at least 1x year. Target all Trisem seen along fence 1-2x year. Goal is to keep these weeds off fence and reduce likelihood of spreading them. | | | | | | | | | | | | | | | | | | | | |
| 965 | Weed Control - Trails/Rds | None | PaholeNo MU-01 | Control grass/herbaceous weeds along the Pahole road, from Peacock Flats gate to the Ranch gate quarterly/as needed. Use the power sprayer, weedwhack. Alternate this action between teams. Goal: maintain road, public safety, reduce weed spread. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 6208 | Weed: Incipient Control | AngEve | Pahole-AngEve-01 | Monitor/Control AngEve in back of gulch 5 every other year. Prevent any plants from reaching maturity. | | | | | | | X | | | | | | | | X | | | | | |
| 6481 | Weed: Incipient Control | AngEve | Pahole-AngEve-02 | Monitor/Control AngEve in back of gulch 4 every other year. Prevent any plants from reaching maturity. | | | | | | | X | | | | | | | | X | | | | | |
| 6999 | Weed: Incipient Control | AngEve | Pahole-AngEve-03 | Monitor/Control AngEve in back of gulch 2 every other year. Prevent any plants from reaching maturity. | | | | | | | X | | | | | | | | X | | | | | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 7369 | Weed: Incipient Control | AngEve | Pahole-AngEve-04 | Monitor/Control AngEve in mid part of gulch 2 every other year. Prevent any plants from reaching maturity. | | | | | | | X | | | | | | | | X | | | | | |
| 7469 | Weed: Incipient Control | AngEve | Pahole-AngEve-05 | Monitor/Control AngEve in gulch 3 every other year. Prevent any plants from reaching maturity. Wider surveys needed at this site. | | | | | | | X | | | | | | | | X | | | | | |
| 7802 | Weed: Incipient Control | AngEve | Pahole-AngEve-06 | Monitor/Control AngEve in gulch 2 EupHer reintro site annually, then every other year. Prevent any plants from reaching maturity. | | | X | | | | X | | | | | | | | X | | | | | |
| 2799 | Weed: Incipient Control | AxoCom | Pahole-AxoCom-01 | Monitor/control AxoCom at top of switchbacks quarterly/twice a year. Spray or remove via digging. Note, 1% glyphosate does not appear to be very effective (2018). | X | X | X | X | X | X | | X | | X | | X | | X | | X | | X | | X |
| 6180 | Weed: Incipient Control | DicChi | Pahole-DicChi-01 | Monitor/control DicChi at big rock site annually. Pick and remove from field any potentially mature fruit. Roots from veg matter. Use pre-emergent herbicide. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 3623 | Weed: Incipient Control | EhrSti | Pahole-EhrSti-02 | Monitor/control EhrSti at state snail jail quarterly, both inside and outside snail jail. Sweep entire ICA | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| | | | | each time. Pick and remove from field any potentially mature fruit. Use pre-emergent herbicide. This species is cryptic and can be difficult to id. | | | | | | | | | | | | | | | | | | | | |
| 7540 | Weed: Incipient Control | Elemol | Pahole-EleMol-01 | Monitor/treat at Pahole/Kahanahaiki ridge trail site, 2-4x year. Pick and remove from field any potentially mature fruit. | X | | X | | X | | X | | X | | X | | X | | | | | | | |
| 2797 | Weed: Incipient Control | PteGlo | Pahole-PteGlo-01 | Monitor/control Ptego at site south of state snail jail quarterly. Area was treated with Oust, a preemergent herbicide. Pick and remove from field any potentially mature fruit. Remove soil as feasible. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 6550 | Weed: Incipient Control | RhoTom | Pahole-RhoTom-01 | Monitor/control RhoTom at East rim fence site annually. Pick all fruit and remove from field. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 7319 | Weed: Incipient Control | SetPal | Pahole-SetPal-01 | Monitor/control SetPal at top of switchbacks near water catchment quarterly. Spray. Flag location to facilitate revisitation. Pick and remove from field any potentially mature fruit. | X | | X | | X | | X | | X | | X | | X | | | | | | | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| 2798 | Weed: Incipient Control | TecCap | Pahole-TecCap-01 | Monitor/control TecCap at East rim fence site by fence tag 84 every 6 months. Treat all roots with herbicide; majority of plants finding now appear to be resprouts from previous handpulling control efforts. | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | |
| 6261 | Weed: LZ Survey | None | LZ-MOKFR-189 | Survey Nike Upper LZ whenever used, not to exceed once per quarter. If not used, do not need to survey. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| 5958 | Weed: Transect Survey | None | WT-Pahole-01 | Survey Pahole gulch 3 access trail, from parking area on road, up to Chaher gulch split; annually. | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | |
| TBD | Vegetation Monitoring | None | None | Conduct belt plot monitoring. | | | | | | | | | | | | | | | **X** | | | | | |

# Ecosystem Restoration Management Plan

## MIP Year 15-19, Oct. 2018 – Sept. 2023

## MU: Manuwai, Manuwai No MU, Alaiheihe No MU

## Overall MIP Management Goals:

- Form a stable, native-dominated matrix of plant communities which support stable populations of IP taxa.
- Control fire and weed threats to support stable populations of IP taxa.

## Background Information

Location: Northern Waianae Mountains

Land Owner: State of Hawaii

Land Managers: Department of Land and Natural Resources (DLNR) – Natural Area Reserve System (NARS), DLNR – Land Division, DLNR – Forest Reserve, Army Natural Resource Program – Oahu (OANRP)

Acreage: 300 Acres

Elevation Range: 1000ft-3000ft

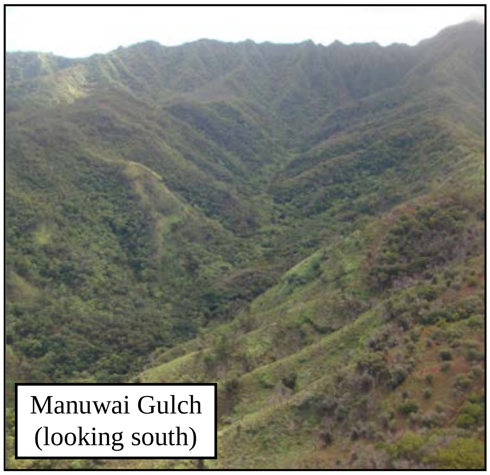
Description: Manuwai Gulch is located in the northern Waianae Mountains. Manuwai Gulch and a series of adjacent, parallel gulches are drainages off the side of Kamaohanui Ridge, which extends eastward from Kaala. The Manuwai Management Unit (MU) consists of the fenced upper half of Manuwai Gulch, and a side gulch that drains into Alaiheihe Gulch, formed off the dividing ridge between Manuwai and Alaiheihe Gulch. The gulch drains to the northeast. Most of the upper portion of the MU is within the Lower Kaala Natural Area Reserve (NAR); the rest is in the State Forest Reserve. There are four landowners, (Bob Cherry, Mike Pietsch, Bitsy Kelley, and the Kaukonahua Ranch), who allow us to access the MU via two roads, which leads to the west and east sides of the MU, through 'Flying R Ranch' that connects to a 4x4 contour dirt road managed by The State of Hawaii. There is no formal easement for use of the roads through 'Flying R Ranch', however the program will work towards establishing a Right of Entry in order for OANRP staff to continue using the private roads for access. Helicopter access to the MU is available. Helicopter operations usually begin flying from WLU LZ 155 (Bob Cherry's ranch) to the LZs located in the MU. However, if crews need to fly along the southern fenceline to access SBW LZ 55 (Kamaohanui) and/or SBW LZ 57 (Nalu's), AirMobile must be requested for the restricted air space 3000 ft. and above from the Army Range Control.

Much of Manuwai Gulch is steep, and some of these steep areas are not accessible on foot without safety ropes. The elevation gradient of the MU is dramatic, and the vegetation types within the MU span from Wet Forest to Lowland Dry Shrubland/Grassland. There are more than several *in situ* rare and endangered plant populations scattered throughout the MU, including *Melanthera tenuifolia* found on cliffs and steep areas, which require ropes to rappel to plants Overall, the MU is dominated by canopy weeds; however, there are some pockets of forest with high levels of native canopy.

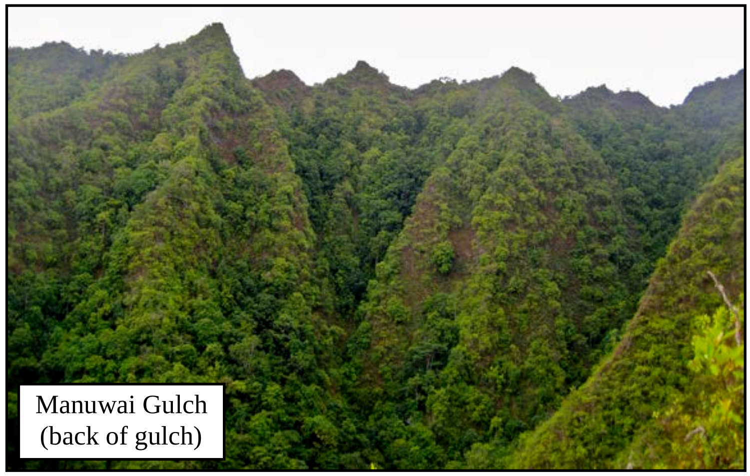
## Native Vegetation Types

| | Waianae Vegetation Types |
|---|---|
| Lowland Dry Shrubland/ Grassland | Canopy includes: *Erythrina sandwicensis*, *Myoporum sandwicense*, *Dodonaea viscosa*, *Santalum ellipticum*, and *Hibiscus brackenridgei* subsp. *mokuleianus.*<br><br>Understory includes: *Heteropogon contortus, Sida fallax*, *Eragrostis variabilis, Abutilon incanum*, *Leptecophylla tameiameiae*, and *Bidens* spp. |
| Dry forest | Canopy includes: *Diospyros* sp., *Myoporum sandwicense, Erythrina sandwicensis, Polyscias sandwicensis, Rauvolfia sandwicensis*, *Santalum ellipticum*, *Psydrax odorata, Nestegis sandwicensis* and *Myrsine lanaiensis*.<br><br>Understory includes: *Dodonaea viscosa, Sida fallax,* and *Bidens* spp. |
| Mesic mixed forest | Canopy includes: *Acacia koa*, *Metrosideros polymorpha, Nestegis sandwicensis, Diospyros* spp., *Planchonella sandwicensis*, *Charpentiera* spp., *Pisonia* spp., *Psychotria* spp., *Antidesma platyphylum*, *Bobea* spp. and *Santalum freycinetianum*.<br><br>Understory includes: *Alyxia stellata*, *Bidens torta, Coprosma* spp., and *Microlepia strigosa* |
| Mesic-Wet forest | Canopy includes: *Metrosideros polymorpha* var. *polymorpha*. Typical to see *Cheirodendron trigynum*, *Cibotium* spp., *Melicope* spp., *Antidesma platyphyllum*, and *Ilex anomala*.<br><br>Understory includes: *Cibotium chamissoi*, *Broussaisia arguta*, *Dianella sandwicensis*, and *Dubautia* spp. Less common subcanopy components of this zone include *Clermontia* spp. and *Cyanea* spp. |
| Wet forest | Canopy includes: *Metrosideros* spp., *Cheirodendron* spp., *Cibotium* spp., *Ilex anomala*, *Myrsine sandwicensis*, and *Perrottetia sandwicensis*.<br><br>Understory includes: Typically covered by a variety of ferns and moss; may include *Melicope* spp., *Cibotium chamissoi, Machaerina angustifolia*, *Myrsine sandwicensis, Nertera granadensis*, *Kadua centranthoides*, *Dryopteris rubiginosa*, *Perrottetia sandwicensis*, and *Broussaisia arguta*. |
| NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted. | |

**Terrain and Vegetation Types at Manuwai**



Manuwai Gulch (looking south)



Manuwai Gulch (back of gulch)

Lowland Dry Shrubland/Grassland

Dry Forest

Mesic Mixed

Mesic-Wet and Wet Forest

## MIP/OIP Rare Resources

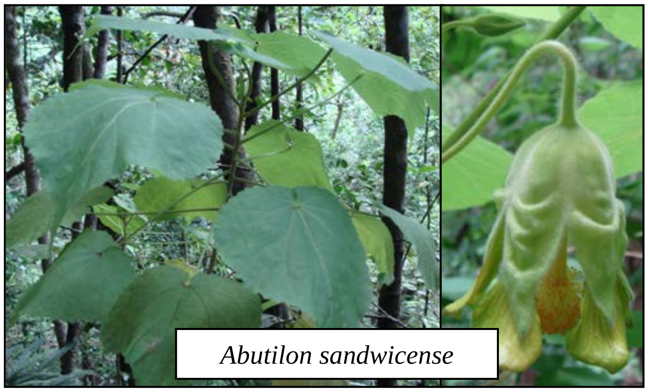
| Organism Type | Species | Pop. Ref. Code | Population Unit | Management Designation | Wild/ Reintroduction |
|---|---|---|---|---|---|
| Plant | *Abutilon sandwicense* | ANU-A, B, C, D, E, F, G, H, J | Kaawa to Puulu | MFS/GS | Wild |
| Plant | *Alectryon macrococcus* var. *macrococcus* | ANU-A, B*, C* & IHE-A, B, C | Alaiheihe and Manuwai | MFS/GS | Wild |
| Plant | *Cyanea superba* subsp. *superba* | ANU-A | Manuwai | MFS | Reintroduction |
| Plant | *Delissea waianaeensis* | ANU-A | Manuwai | MFS | Reintroduction |
| Plant | *Flueggea neowawraea* | ANU-A*, B, C | Manuwai | Manage Reintroduction for Stability | Both |
| Plant | *Kadua degeneri* subsp. *degeneri* | ANU-A, B & IHE-A, B, C, D | Alaiheihe and Manuwai | MFS | Both |
| Plant | *Hibiscus brackenridgei* subsp. *mokuleianus* | ANU-A | Kaimuhole and Palikea Gulch | MFS | Reintroduction |
| Plant | *Melanthera tenuifolia* | ANU-A, B | Manuwai | GS | Wild |
| Plant | *Neraudia angulata* var. *dentata* | ANU-A, ANU-B, ANU-C† | Manuwai | MFS | Both |
| Plant | *Nototrichium humile* | ANU-A | Manuwai | MFS | Reintroduction |
| Plant | *Phyllostegia kaalaensis* | ANU-B* | Manuwai | MFS | Reintroduction (failed) |
| Snail | *Achatinella mustelina* | ANU-A* | ESU-C | MFS | Extirpated |

MFS= Manage for Stability
GSC= Genetic Storage Collection
*= Population Dead
†=Reintroduction not yet done
ESU= Ecologically Significant Unit

## Other Rare Taxa at Manuwai MU

| Organism Type | Species | Status |
|---|---|---|
| Plant | *Bobea sandwicensis* | Endangered |
| Plant | *Chrysodracon forbseii* | Endangered |
| Plant | *Chrysodracon halapepe* | Vulnerable |
| Plant | *Colubrina oppositifolia* | Endangered |
| Plant | *Cyanea calycina* | Endangered |
| Plant | *Dubautia sherffiana* | Vulnerable |
| Plant | *Exocarpos gaudichaudii* | Rare |
| Plant | *Lobelia niihauensis* | Endangered |
| Plant | *Mezoneuron kavaiensis* | Endangered |
| Plant | *Pteralyxia macrocarpa* | Endangered |
| Plant | *Schiedea hookeri* | Endangered |
| Plant | *Strongylodon ruber* | Rare |
| Arthropod | *Drosophila flexipes* | Rare |
| Arthropod | *Drosophila obatai* | Endangered |
| Arthropod | *Drosophila paucicilia* | Rare |
| Arthropod | *Drosophila pilimana* | Rare |
| Arthropod | *Drosophila reynoldsiae* | Rare |
| Arthropod | *Drosophila turbata* | Rare |
| Bird | *Chasiempis ibidis* | Endangered |

**Rare Resources at Manuwai**



*Abutilon sandwicense*

*Kadua degeneri* subsp. *degeneri*

*Alectryon macrococcus* var. *macrococcus*

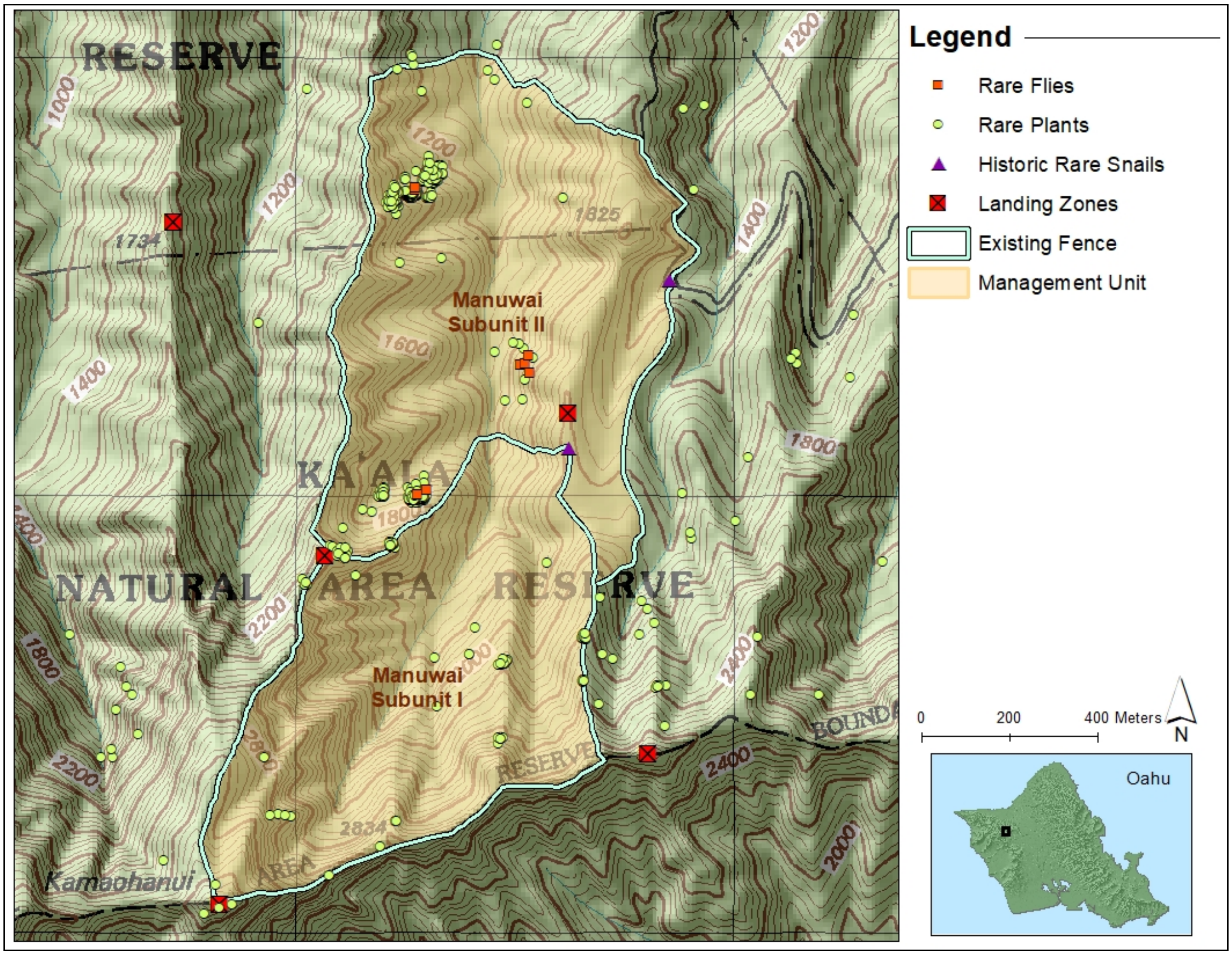
*Hibiscus brackenridgei* subsp. *mokuleianus*

*Neraudia angulata* var. *dentata*

*Flueggea neowawraea*

*Delissea waianaensis*

**Locations of Rare Resources at Manuwai**




**Threats to MIP/OIP MFS Taxa**

| Threat | Taxa Affected | Management Strategy | Current Status, 2018 |
|---|---|---|---|
| Pigs | All | Fence | MU fenced. No animals within fence. |
| Goats | All | Fence | MU fenced. No animals within fence. |
| Black Rat | *A. mustelina*, *A. macrococcus* var. *macrococcus*, *C. superba* subsp. *superba* *Delissea waianaeensis*, *F. neowawraea* | Localized trapping grids at chosen rare taxa sites. | One localized A24 trapping grid around *D. waianaeensis* population and another small scale A24 trapping grid at the *Drosophila obatai* monitoring site. |
| Slugs | *D. waianaeensis*, *N. angulata* var. *dentata*, *K. degeneri* subsp. *degeneri* | Localized control treatment with molluscicide at chosen rare taxa sites. | FerroxxAQ is applied around *D. waianaeensis* population quarterly. No evidence of slug damage to *N. angulata* var. *dentata* and *K. degeneri* subsp. *degeneri*. |
| Ground Birds | *Cyanea superba* subsp. *superba*, *D. waianaeensis* | No control currently. However, control to possibly be studied and developed. | *Pternistis erckelii* and *Lophura leucomelanos* are known to damage *D. waianaeensis* stems and eat leaves, fruit, and FerroxxAQ. Control should be investigated. |

**Threats to MIP/OIP MFS Taxa (Continued)**

| Threat | Taxa Affected | Management Strategy | Current Status, 2018 |
|---|---|---|---|
| Black Twig Borer | *A. macrococcus* var. *macrococcus*, *F. neowawraea*, *N. angulata* var. *dentata**, *Abutilon sandwicense* | Monitor and research new control methods. | There is no current effective control method. |
| Ants | *Drosophila obatai* | Survey high traffic and rare taxa sites annually. | *Anoplolepis gracilipes* are invading from below due to the increase in invasive scale insects. Localized control may be possible if they reach higher elevation sites. |
| Weeds | All | Focus on rare taxa sites primarily, across MU secondarily | Regular maintenance required several times per year. |
| Fire | All | Reduce grass cover on the southern edge of MU and participate in Wildland Fire groups. | Fuel pre-suppression via grass control, and rapid response and control of potentially threatening fires |
| Downy Mildew | *Phyllostegia kaalensis* | Monitor | No tools to control in field. Before the population completely failed, there were some plants observed with this mildew. Support ongoing research on this topic. |

*****Threat suspected. Field observation necessary.

## Management History

- 1986: Botanist Steve Perlman conducted surveys in area. Manuwai is noted as having patches of the rare forest type, Oahu Diverse Mesic Forest.
- 1990: Mount Kaala Natural Area Reserve Management Plan was written by the Natural Area Reserves System Program.
- 1999-2010: OANRP visited the historical rare plant populations, collected fruit from MIP species, and surveyed for new populations.
- 2000-2004: The goat removal program was established using snares for ungulate control along SBW border east of Kamaohanui in order to keep goats from breaching the fenced MU.
- 2000-2006: Annual or semi-annual hunts for goats were conducted in the general Lower Kaala NAR region.
- 2007: In August, a fire catastrophic wildfire burnt the ridges below the MU. Many rare taxa were affected. The most significant taxon affected was the *H. brackenridgei* subsp. *mokuleianus*. The fire destroyed about 90% of the total number of *H. brackenridgei* subsp. *mokuleianus* on Oahu.
- 2010: Initial vegetation monitoring across MU was conducted.
- 2011: MU fence completed.
- 2011: First discovery of *Pterolepis glomerata* was found on the east fenceline along the ridge. *P. glomerata* was most likely introduced via fence material, which was stored in the Koolaus and used to fence this MU.
- 2011-2012: Ungulate eradication began via snaring.

- 2013: Ungulate sign decreased significantly, however few pigs and goats were caught during this year.
- 2013: *D. waianaeensis* (ANU-A), *C. superba* subsp. *superba* (ANU-A), *P. kaalaensis (*ANU-A), *N. angulata* var. *dentata* (ANU-B), *F. neowawraea* (ANU-B and ANU-C) were reintroduced.
- 2013: *K. degeneri* subsp. *degeneri* are reintroduced in two locations. One on the east fenceline (IHE-D) and the other along the interior fenceline on the West side of the MU (ANU-B).
- 2013: *H. brackenridgei* subsp. *mokuleianus* (ANU-A) plants from the wild populations that were located in the gulches, which burnt in 2007, were reintroduced in the south-west portion of the MU. This was the first *H. brackenridgei* subsp. *mokuleianus* reintroduction into a forested gulch habitat in order to reduce the likelihood that *H. brackenridgei* subsp. *mokuleianus* would be destroyed again by a fire.
- 2014: Fence was deemed ungulate free.
- 2014: *P. glomerata* first discovered on the Kamaohanui LZ.
- IPA/Targeted taxa sweeps for select canopy weeds on landscape scale begun in walkable potions of MU.
- 2014: Another reintroduction of *N. angulata* var. *dentata* occurred.
- 2015: Portion of fence in gulch bottom blew out due to flood. Fence was repaired and no pig sign was detected in the MU.
- 2015: *P. glomerata* first discovered during a fence check from Kamaohanui LZ along the west side of the MU.
- 2016: Fence crossing the gulch bottom was replaced with hypalon material allowing water to flow better, which should prevent fence from being blown out again after heavy rains.
- 2016: The 2$^{nd}$ monitoring of the vegetation belt plots was conducted.
- 2017: *Chromolaena odorata* found at the perimeter/interior fenceline crossing.
- 2017: *P. glomerata* first discovered on the east fenceline further away from existing known *P. glomerata* site also located on the east fenceline.
- March 2017: Fresh pig sign was found during a *C. odorata* survey. Snares were set.
- August 2017: One pig was successfully removed using snares. No ungulate sign was observed following the captured ungulate.
- September 2017: Fickle fencing was added to fenceline on the East side close to access road where pig activity on the outside of the fence seems to be high.
- June 2018: *Schizachyrium condensatum* first detected in the MU by OANRP staff conducting an IPA sweep for Target Canopy Species.
- 2018: Although one pig was removed in 2017 and the fence was assumed to be pig-free, recent pig activity was found in the main gulch of the MU. Snaring will continue until the MU is pig-free. Additionally, OANRP staff will need to investigate how pigs are continuing to breach the fence.
- 2018: Fickle fencing will be installed along the fenceline to cover the entire east and west side of the MU.
- 2019: West Access Road survey will be established.

## Ungulate Control

Species: *Sus scrofa* (pigs), *Capra hircus* (goats)

Threat Level:

- *Sus scrofa:* High
- *Capra hircus*: High

Management Objectives:

- Maintain the Subunit I/II enclosures as ungulate free.

Strategy and Control Methods:

- Remove pigs from Subunit II with hunts and traps, and Subunit I with hunts, traps and snares as needed if pig sign is detected in the fence.
- Supplement existing fence with fickle fence.
- Conduct fence checks quarterly around entire MU, including strategic section along entire southern ridge.
- Monitor for ungulate sign while conducting other management actions in the fence.
- Check fences especially gulch crossings and hypalon after heavy rains and/or severe weather.

Discussion: There are several sections of the fence that are 'strategically' fenced, where natural barriers and geography (cliffs and pinnacle rocks) are used instead of actual fences to prevent pig ingress. There is a break in fencing around a large rock section on the western fenceline. Also, the majority of the southern edge of the MU is not fenced (strategic), since the topography along this ridge is extremely steep, and pigs and goats are not expected to be able to traverse. Additionally, Lihue (the forested gulches behind Schofield Barracks West Range) is fenced but pigs are still present. There are already very few pigs remaining in Lihue, so the chances of ingress are very low. Currently, control is ongoing in Lihue. However, special attention will be given to the strategic portions of the fence during fence checks to ensure that the barriers are effective in keeping ungulates out of the MU. Occasionally, goats from the ranch below the MU make it up to the fence and get caught between the holes in the fencing panels. The lower sections of the fence that cross the gulches are at high risk of getting washed out after heavy rainfall. This has happened a few times, however flow mitigation has been since put in place using a hypalon and a baffle in these gulch bottoms. In 2017, pig sign was discovered in the Subunit II. Snaring and trapping resumed until the pig was caught. OANRP staff speculate that the hogwire and fence panels used have large enough gaps to allow a small pig to fit through. Since then, the pig has been caught, no new pig sign has been seen, and fickle wire has been added along the fence towards the bottom (east side) where there is high pig traffic. OANRP plans to install fickle along the Alaiheihe side and any sections with panel gaps exposed to low ground within the next year.

# Weed Control

Weed Control actions are divided into 4 subcategories:

1) Vegetation Monitoring
2) Surveys
3) Incipient Taxa Control (Incipient Control Area - ICAs)
4) Ecosystem Management Weed Control (Weed Control Areas - WCAs)

These designations facilitate different aspects of MIP/OIP requirements.

**Vegetation Monitoring**

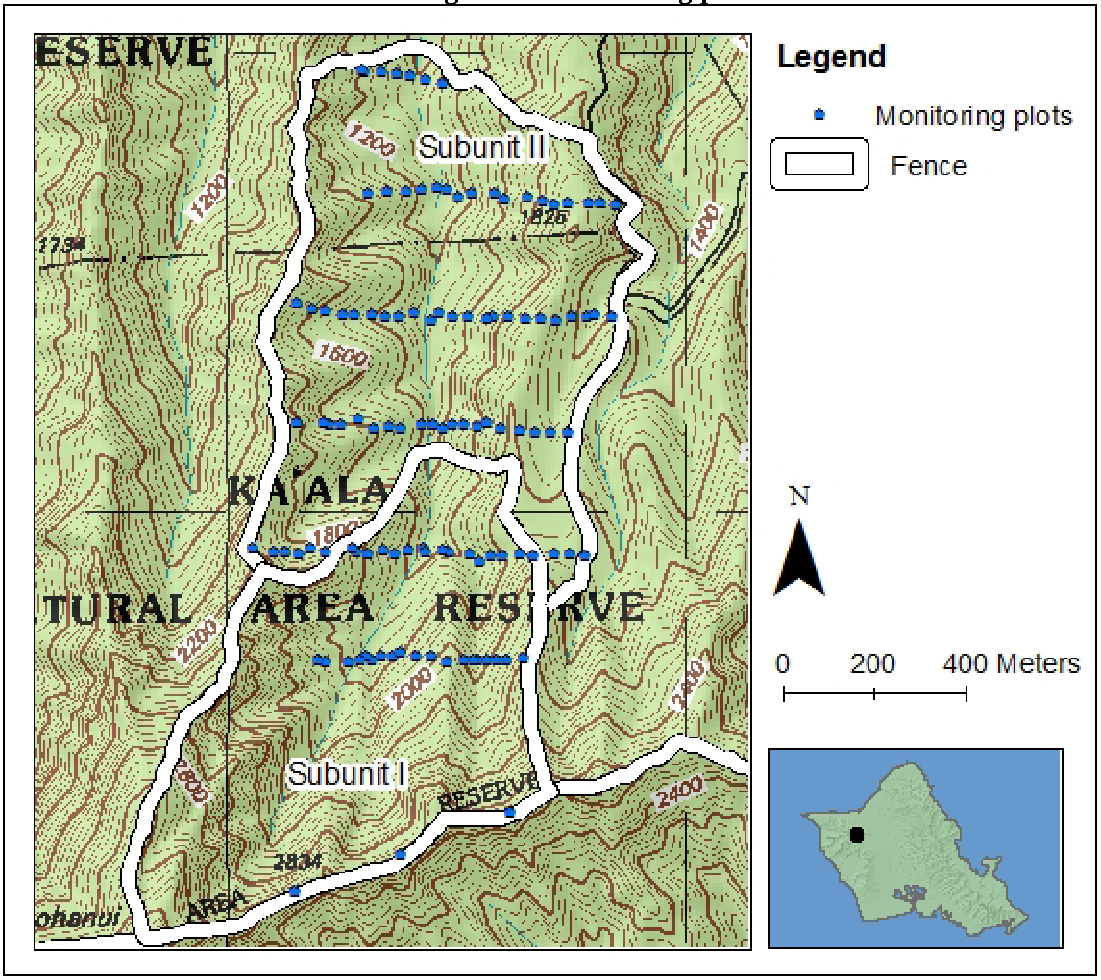
Background:

Vegetation monitoring occurs on a five-year interval at Manuwai MU in association with MIP/OIP requirements for long term monitoring of vegetation composition and change over time (OANRP 2008). The primary objective of MU monitoring is to assess if the percent cover of non-native plant species is less than 50% across the MU, or is decreasing towards that threshold requirement. The secondary objective is to assess if native cover is greater than 50% across the MU, or is increasing towards that threshold recommendation (OANRP 2016).

Methods:

Monitoring was conducted in 2011 (OANRP 2011) and 2016 (OANRP 2016) in 114 plots generally located every 40 m along transects. Transects were located in accessible areas (much of the higher elevations in Subunit I are too steep to access), spaced approximately 250 m apart. Vegetation was recorded by percent cover for all non-native and native species present. Summary percent cover by vegetation type (shrub, fern, grass/sedge) in the understory, overall summary percent cover of non-native and native vegetation in the understory and canopy, and bare ground (non-vegetated < 25 cm AGL), were also documented.

**Manuwai MU vegetation monitoring plot locations**




Summary results:

Management objectives were not met for vegetation percent cover for Manuwai MU in either year, as native cover was low, and non-native cover was high.

**Median cover (%) of vegetation in plots at Manuwai MU from 2011 to 2016.**

| | 2011 | 2016 |
|---|---|---|
| Native understory | 7.50 | 3.00 |
| Non-native understory | 55.00 | 65.00 |
| Native canopy | 15.00 | 15.00 |
| Non-native canopy | 75.00 | 85.00 |

There were a number of noteworthy significant differences in the 2016 data as compared with 2011, including:

- Increase in non-native understory and canopy cover
- Increase in non-native understory and canopy richness
- Increase in frequency for non-native species:
    - *Adiantum hispidulum* (understory)

  - *Clidemia hirta* (understory)
  - *Passiflora suberosa* (understory)
  - *Toona ciliata* (canopy)
- Increase in percent cover for non-native species:
  - *A. hispidulum* (understory)
  - *Blechnum appendiculatum* (understory)
  - *C. hirta* (understory)
  - *Oplismenus hirtellus* (understory)
  - *P. cattleianum* (canopy)
- Decrease in percent cover for non-native species:
  - *P. cattleianum* (understory)
  - *Grevillea robusta* (canopy)
- Decrease in percent cover for native species:
  - *Alyxia stellata* (understory)
  - *Psydrax odorata* (understory)
  - *Diospyros sandwicensis* (canopy)
- Percent cover change in weeded plots:
  - Decrease in native understory and *G. robusta* (canopy)
  - Increase in non-native understory
- Percent cover change in unweeded plots:
  - Decrease in native understory
  - Increase non-native canopy and *T. ciliata* (canopy)

Most of the vegetation change that occurred between 2011 and 2016 indicated worsening conditions, with increases in non-native cover, richness and frequency, and declines in some native taxon cover. Given the high level of non-native canopy cover in the MU, management goals of < 50% cover may be unrealistic across the MU. Refinement of management goals to apply specifically to prioritized areas (those with greater potential for restoration) within the MU may result in goals that are more likely to be successfully accomplished. Manuwai MU is challenging to manage, given access limitations during inclement weather, and difficulties associated with working in very steep terrain.

Impacts of weeding efforts were primarily attributed to IPA control of *G. robusta* and *T. ciliata*. These efforts were effective for reduction of canopy *G. robusta* within weeded areas. The pervasiveness of *T. ciliata* throughout the MU presents a considerable management challenge. The significant increase in canopy *T. ciliata*, as well as non-native canopy cover in general, in plots outside, but not inside, weeded areas suggest IPA efforts may be preventing canopy cover increases for that taxon and for non-native cover in general within treated areas. *T. ciliata* frequency increase in the canopy may be explained in part by vertical growth of individuals that were in the understory in 2011, but reached the canopy by 2016. Because IPA efforts focus on larger individuals in efforts to minimize primary seed sources, the continued presence of smaller individuals within the canopy is to be expected. The increase in non-native understory cover in weeded plots may have been a response to the creation of light gaps in the canopy resulting from IPA treatment. The decline in native understory cover in weeded areas had a similar pattern in unweeded areas, and was not likely influenced by IPA efforts.

Natural resource management staff anecdotally observed increased cover of *Urochloa maxima* in Subunit II within the last year, and expressed concerns that IPA control efforts may exacerbate the problem. Though the frequency of this taxon was too low for statistical analyses, it did appear in more plots in 2016 (in 14% of plots) than in 2011 (in 11% of plots), and cover increased in over half of the plots in which it was observed in 2011, while none had reduced cover.

Recommendations:

Based on the results of vegetation monitoring, a number of recommendations were made with the goal of making progress towards meeting management objectives:

- designate prioritized areas for management
- refine management goals to focus on prioritized areas
- more aggressive weed control paired with restoration efforts in prioritized areas
- target uncommon weeds when seen (particularly target taxa)
- continue IPA efforts within areas already treated, as *T. ciliata* and *G. robusta* grow to the targeted size/stage, and expand efforts into new areas, including higher elevations with more native cover
- monitoring of understory change in direct association with IPA treatments (via a separate monitoring regime) may be done to better understand its impact on native and non-native understory cover
- continued discussion and assessment of costs associated with worsening understory conditions resulting from the creation of light gaps associated with large scale IPA canopy removal vs. benefits of controlling IPA target taxa
- aerial spraying of *U. maxima* as possible

## Surveys

Potential Vectors: OANRP staff, State Biologists, ungulates, non-native birds, wind.

Survey Locations: Landing zones, fencelines, access roads, and high potential traffic areas.

Management Objective:
- Prevent the establishment of any new invasive alien plant species through regular surveys along roads, landing zones, camp sites, fencelines, trails, and other high traffic areas (as applicable).

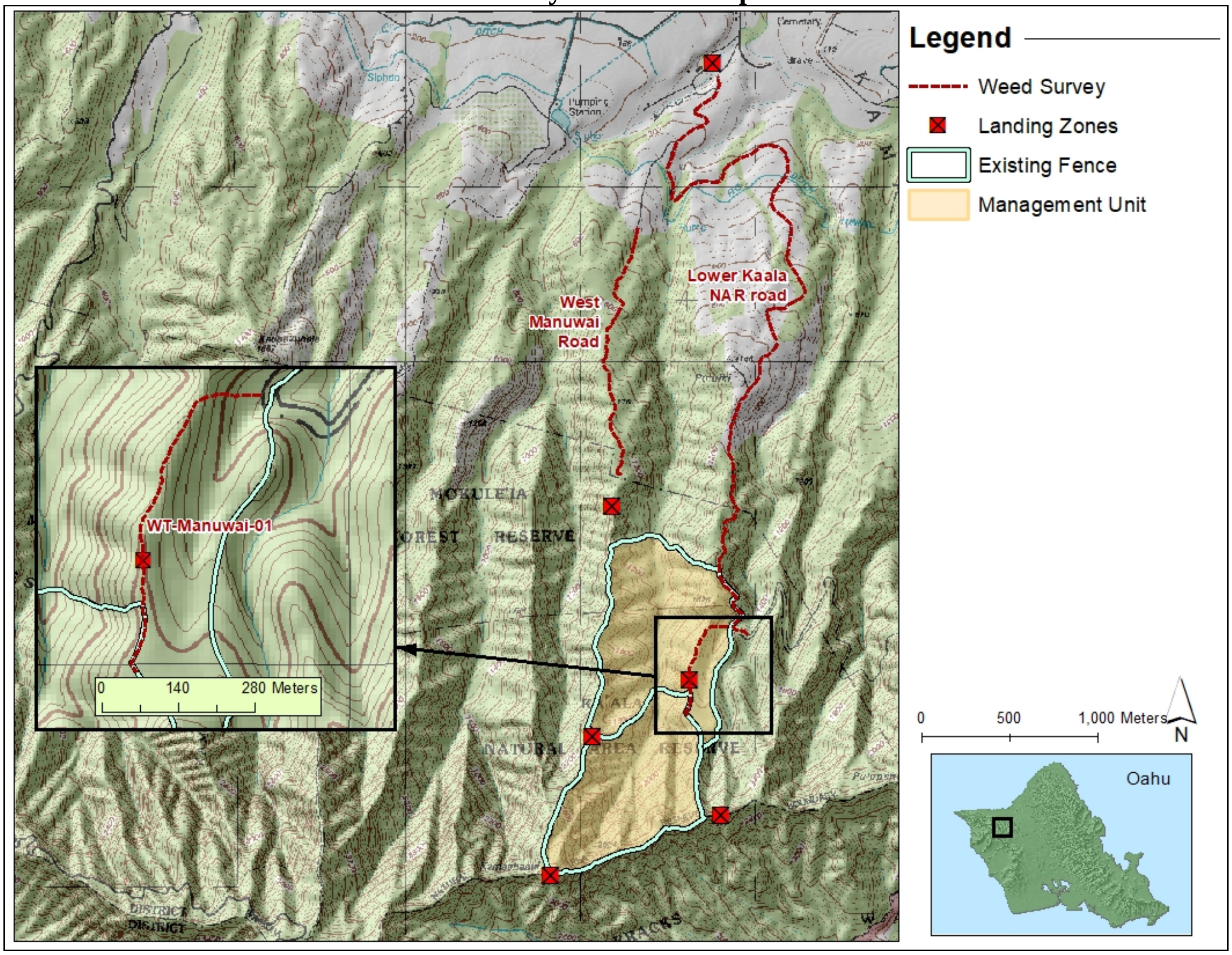
Strategy and Control Methods:
- Quarterly surveys of LZs (East Ridge camp, MelTen, Spider Camp, Nalu's, Kamaohanui, & Bob Cherry's; if used).
- Surveys of access roads (Lower Kaala NAR and West access road) every other year.
- Quarterly surveys of campsites (East ridge camp & Spider camp; if used).
- Note unusual, significant or incipient alien taxa during the course of regular field work, particularly when walking the fence line.
- Survey high traffic areas (weed Transect on East Side) annually.
- Any significant alien taxa found will be researched and evaluated for distribution and life history. If found to pose a major threat, control will begin and will be tracked via Incipient Control Areas (ICAs).

Discussion:

Surveys are designed to be the first line of defense in locating and identifying potential new weed species. Roads, landing zones, fence lines, and other highly trafficked areas are inventoried regularly to facilitate early detection and rapid response; Army roads and LZs are surveyed annually, non-Army roads are surveyed annually or biannually, while all other sites are surveyed quarterly or as they are used.

In Manuwai, LZs are surveyed when used, and the Lower Kaala NAR Road and the West Access Road are surveyed every other year. The Weed Transect runs along the main access trail from the parking spot on the road over the saddle and into the gulch bottom; it is surveyed annually. OANRP will consider installing additional surveys in other high traffic areas, however, incidental observations during regular field management are also important to document new ICAs.

**Survey Locations Map**




## Incipient Taxa Control

All weed control geared towards eradication of a particular invasive weed is tracked via Incipient Control Areas, or ICAs. Each ICA is species-specific and geographically defined. One infestation may be divided into several ICAs or one ICA, depending on infestation size, topographical features, and land ownership. Some ICA species are incipient island-wide, and are a priority for ICA management whenever found. Others are locally incipient to the MU, but widespread elsewhere. In either case, the goal is eradication of the ICA. The goals, strategies, and techniques used vary between ICAs, depending on terrain, surrounding vegetation, target taxon, size of infestation, and a variety of other factors.

Management Objectives:

- Eradicate ICAs through regular and thorough monitoring and treatment. In the absence of any information about seed bank longevity for a particular species, eradication is defined as 10 years of consistent monitoring with no target plants found.
- Study seed bank longevity of ICA taxa, and revise eradication standards per taxon.

- Evaluate any invasive plant species newly discovered in MU, and determine whether ICA-level control is warranted. Factors to consider include distribution, invasiveness, location and infestation size, availability of control methods, resources, and funding.

Strategy and Control Methods:

- Species and ICAs are listed in the table below. History and strategy is discussed for each species.
- Monitor the progress of management efforts, and adjust visitation rates to allow staff to treat plants before they mature. Remember that one never finds 100% of all plants present.
- Use aggressive control techniques where possible. These include power spraying, applying pre-emergent herbicides, clearcutting, aerial spraying, and frequent visits.

**Summary of ICAs**

| Taxon | ICA Code | Control Discussion |
|---|---|---|
| *Chromolaena odorata* | Manuwai-ChrOdo-01 | This highly invasive shrub is a major target at KTA and SBW. When an immature plant was discovered in 2017 along a highly trafficked fenceline, staff conducted 200m buffer surveys around the site, and re-swept areas were the Ecosystem Restoration team went in the MU prior to the first discovery. The spread of *C. odorata* in this MU was likely introduced by the Ecosystem Restoration team because of their frequent work in *C. odorata* infested areas (KTA), the timing of their work trips between KTA and Manuwai, the size and estimated age of the plants found, and that Blue team does not work in any other *C. odorata* areas. OANRP staff are confident that there is only one location of this taxon at Manuwai at this time. *C. odorata* seeds last at least 3 years in soil, and further seed bank longevity testing is underway. Staff have monitored this site regularly, with no plants found since 2017. This ICA is a high priority. Re-survey buffer areas every 5 years. Since the first *C. odorata* discovery in the MU, OANRP are now required to use dedicated *C. odorata* gear when checking *C. odorata* ICAs elsewhere. However, this *C. odorata* gear is not required in this MU for conducting the buffer sweeps or checking the existing ICA, to reduce the likelihood of spreading *C. odorata* further in Manuwai. |
| *Caesalpinia decapetala* | Manuwai-CaeDec-01 | One population known from bottom of gulch on north end. Staff should be confident about identifying between *Caesalpinia bonduc* and *C. decapetala*, since there has been misidentification in the past. Last *C. decapetala* in this ICA seen 2014. This ICA is now monitored once a year until 2024. |
| *Dietes iridioides* | Manuwai-DieIri-01 | One population known along the east fenceline. Staff have been controlling and monitoring this site quarterly. Spend more effort surveying infestation area to determine the extent of ICA. OANRP staff have controlled this ICA by foliar application using Ranger Pro and a pre-emergent mixture. However, this technique has not been effective in reducing the numbers of *D. iridioides*. OANRP will to evaluate more effective weed techniques by testing a 0.75% Polaris foliar spray. |
| *Pterolepis glomerata* | Manuwai-PteGlo-01 | Located along the East fenceline. This ICA is treated quarterly. However, a significant expansion of the search area of PteGlo-01 occurred when significant numbers were discovered on the south facing slope below the Manuwai Camp LZ found this year 2018. Given the presence of *P. glomerata* on the LKN road (although not widespread on the road itself) and likelihood of spread by ungulate activity, reevaluation of control intensity and scope may be required. |
| | Manuwai-PteGlo-02 | This population was found on Kamaohanui LZ. The ICA is checked and/or treated quarterly. Last PteGlo found was August 2017. |
| | Manuwai-PteGlo-03 | This ICA is located on the West fenceline near MelTen LZ. The ICA is checked and/or treated quarterly. *P. glomerata* last found at this ICA back in 2015, when *P. glomerata* was first discovered. |

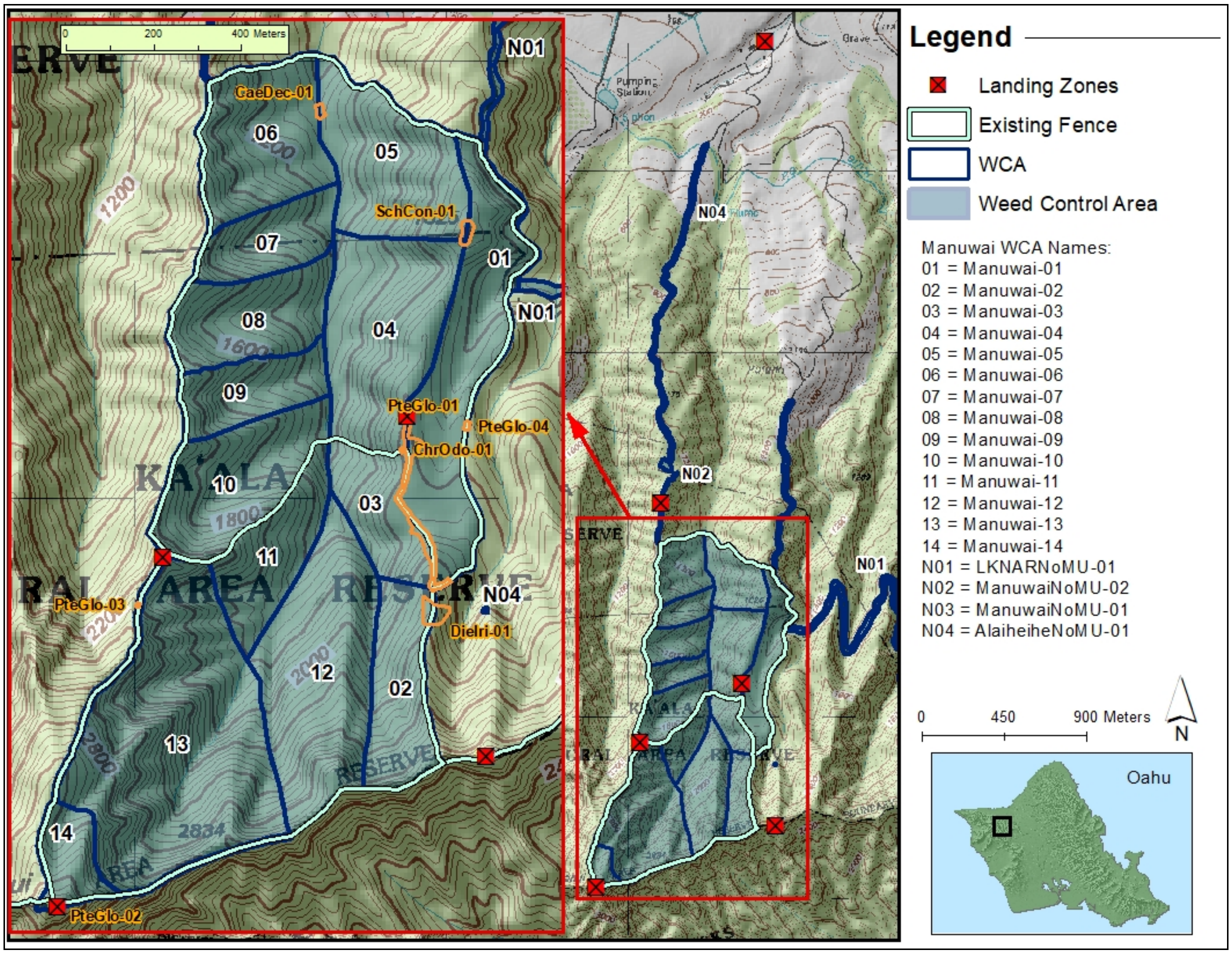
## Summary of ICAs (Continued)

| Taxon | ICA Code | Control Discussion |
|---|---|---|
| | Manuwai-PteGlo-04 | This ICA exists outside the fence along the Alaiheihe side of the fenceline. The ICA is checked and/or treated quarterly. In addition, OANRP plans to dig up and bag soil from this ICA to prevent the seed bank from spreading by soil erosion and pigs. |
| *Schizachyrium condensatum* | Manuwai-SchCon-01 | First detected by OANRP staff in 2018 during an IPA sweep in the bottom of the MU. Few mature plants and immature plants were found. OANRP needs surveys to determine the ICA's extent and begin control. *S. condensatum* was likely introduced from contaminated gear from SBE via Ecorestoration team, but still looking at vector pathways. This is only the third location found on Oahu, so this ICA is a high priority for control. |

## Incipient Weed Photos


The two immature *C. odorata* found March 2, 2017 at Manuwai.

**Incipient and Weed Control Areas at Manuwai**




## Ecosystem Management Weed Control

All weed control geared towards general habitat improvement is tracked in geographic units called Weed Control areas, or WCAs. The goals, strategies, and techniques used vary between WCAs, depending on terrain, quality of native habitat, and presence or absence of rare taxa.

MIP Goals:

- Within 2 m of rare taxa: 0% alien vegetation cover.
- Within 50 m of rare taxa: 25% or less alien vegetation cover.
- Throughout the remainder of the MU: 50% or less alien vegetation cover.

Management Objectives:

- Reach 50% or less alien canopy cover across the MU in the next 5 years.
- In WCAs within 50 m of rare taxa, work towards achieving 25% or less alien vegetation cover in understory and canopy.

Discussion: The entire Manuwai MU was broken up into WCAs to ease data tracking. Due to the high level of non-native cover in much of the MU and patchiness of native canopy pockets, large scale weed sweeps targeting large mature *Toona ciliata* occurs in WCAs not close to managed rare taxa. By targeting large mature *T. ciliata*, OANRP's goal is to reduce the reproducing tree numbers in the MU. Sweeps in the northern most WCAs of the MU are reduced due to the concern of creating too much of a light gap for grass to grow. These sweeps will be repeated in 5-10 years. OANRP also plans to remove select species across the entire MU (see 'MU targets in summary of Target Taxa table' below). This list was selected based on distribution levels of taxa seen during vegetation monitoring, and also based on known characteristics of the taxa. For example, *Schefflera actinophylla* was chosen as a MU wide target because it had a relatively low distribution throughout the MU making it feasible to control. Furthermore, most of the individuals seen were immature, and if the taxon can be treated across the MU before it becomes reproductive, there is a far greater chance to control it.

In addition to MU-wide weed targets, OANRP will also conduct smaller scale, localized, intensive control around areas with high levels of native canopy, and most especially around wild sites of rare taxa. Weed efforts in Manuwai-06 and Manuwai-10 are focused around rare taxa. Canopy weed control should be cleared in advance of plant reintroductions so as not to disrupt rare plants after they are already in the ground. Understory weeds will be controlled continually as needed. Rare plant reintroductions should avoid large patches of *Blechnum appendiculatum*. It is however, feasible to effectively remove smaller patches of this weed and it should be targeted in all rare plant zones. Additionally, *B. appendiculatum* herbicide trials demonstrated that using 10% Garlon4 spray mix is an effective herbicide to control larger patches of this weedy fern (OANRP 2015).

The WCAs along Kamaohanui Ridge as well as some others are very steep. Ground-based weed control will be difficult or impossible in these areas and in most cases control may only be achieved via methods such as aerial ball sprays or Herbicide Ballistic Technology (still in development). Aerial surveys of these areas is still needed to document distribution of priority weeds.

The table below summarizes invasive weeds found at Manuwai, excluding ICA species. While the list is by no means exhaustive, it includes the species targeted/prioritized for control. The distribution of each taxon is estimated as: Widespread (moderate to high densities of individuals, common across MU), Scattered (low densities across all or much of the MU), or Restricted (low or high densities, all in one discrete location). WCA control refers to only targeting taxa during scheduled WCA weeding around rare taxa.

**Summary of Target Taxa:**

| Taxa | Distribution | Notes |
|---|---|---|
| *Acacia confusa* | Widespread | Widespread on ridges. Target during weed control sweeps in priority WCAs. Cut and apply Garlon4 20%. |
| *Begonia vitifolia* | Scattered | Treat during WCA control around rare taxa. |
| *Blechnum appendiculatum* | Widespread | Widespread and often forming dense patches around rare plant taxa. Known to inhibit rare plant recruitment. Effective control by 10 % Garlon4 foliar application. |
| *Clidemia hirta* | Widespread | Widespread and often forming dense patches throughout the MU. *Clidemia* is best treated by using the clip-and-drip method (cutting stump and applying Garlon4 herbicide). |
| *Clusia rosea* | Scattered | Noted from Lower Kaala NAR. Not detected during MU monitoring or initial surveys. If found, will treat as a WCA target. Effective control by IPA coupled with 100% Ranger Pro. |
| *Coffea arabica* | Widespread | Treat during WCA control. Forms dense stands. Effective control using IPA method coupled with 100% Polaris or cut-stump/basal coupled with 20% Garlon4. |
| *Cupressus lusitanica* | Scattered | Treat as MU target. Not documented as being highly invasive in Hawaii, but staff have noted related species spreading in other areas. |
| *Ficus microphylla* | Scattered | Treat during WCA weed control sweeps. IPA control method coupled with 100% Ranger Pro. |

**Summary of Target Taxa (Continued)**

| Taxa | Distribution | Notes |
|---|---|---|
| *Fraxinus uhdei* | Unknown | Noted from Lower Kaala NAR. Not detected during MU monitoring or initial surveys. If found, will treat as WCA target. *F. uhdei* is best treated by using the girdle method and applying 20% Garlon4. |
| *Juniperus bermudiana* | Scattered | Treat as MU target. Determine if present; easily confused with *C. lusitanica* |
| *Lophospermum erubescens* | Unknown | Treat as MU target. Distribution in the MU is unknown. GPS any plants found. Evaluate effective treatment methods. |
| *Melaleuca quinquenervia* | Unknown | Treat as MU target. None found during vegetation monitoring, but known from MU. Has potential to spread quickly in appropriate habitat, especially at upper elevations. Effective control by IPA coupled with 100% Milestone or Polaris. |
| *Melia azedarach* | Scattered | Target during weed control sweeps in priority WCAs. Effective control using cut stump coupled with 20% Garlon4 application. |
| *Montanoa hibiscifolia* | Widespread | Target during weed control sweeps in priority WCAs. Seed is wind dispersed. *M. hibiscifolia* is known to inhabit shady areas and has the potential to become a dominant specie in both the understory and canopy. Thus, making it a priority for control. |
| *Psidium cattleianum* | Widespread | Widespread and often forming dense patches throughout the MU. Control in rare plant zones and native forest patches. |
| *Urochloa maxima* | Widespread | Important to strategically treat patches of *U. maxima* for fire suppression (see fire section). Target in WCAs as needed by foliar spray. Priority to control along the fencelines and in the rare plant zones. |
| *Roystonia regia* | Restricted | Only a few individuals known. Treat as MU target. |
| *Rubus argutus* | Restricted | Target in new locations. Frequent retreatment is often required for control of this species. Use effective control measures such as digging out tubers and coupled with 40% Garlon4. Only known from the first 100 m of the fenceline from Kamaohanui LZ. |
| *Schefflera actinophylla* | Widespread | Immature plants are somewhat widespread through MU, and there are not many mature individuals. Treat as MU wide target (treat all known immature individuals throughout the MU at one time), and then control as needed in WCAs. Know to be ecosystem altering, fast growing, fruits prolifically, and disperses widely via birds. Effective IPA treatment known. |
| *Schinus terebinthifolius* | Widespread | Target during weed control sweeps in priority WCAs. Best treatment is either cut-stump or basal method coupled with 20% Garlon4. |
| *Spathodea campanulata* | Scattered | Several individuals throughout MU. High concentrations in Subunit II. Treat as MU target, then control as needed in WCAs. Effective IPA treatment known. |
| *Syzygium cumini* | Widespread | Target in WCAs during weed control around rare taxa using IPA method and 100% Milestone application. |
| *Toona ciliata* | Widespread | Target in WCAs. There are high levels of this weed in the MU; it occurred in the overstory in 44% of vegetation survey plots, and 48% in the understory in survey plots. The tree is fast growing, and mature trees readily produce lots of offspring nearby. Where possible, target small stands entirely where possible around rare IP taxa. Target large trees during WCA sweeps to decrease reproducing trees in MU. Small trees can be controlled using cut-stump and 20% Garlon4 application. Larger trees are effectively controlled using IPA method. |
| *Trema orientalis* | Scattered | Treat as MU target. Many large mature trees seen during vegetation surveys and visual surveys from ridges. Canopy is broad. Several trees are on slopes inaccessible on foot and will require remote or aerial control technologies. |
| *Triumphetta semitrilobata* | Scattered | Target during weed sweeps in high priority WCAs, and target along trails, LZs, and campsites. *Triumphetta* is best treated by using the clip-and-drip method (cutting stump and applying Garlon4 herbicide). |

**WCA: Manuwai-01 (Alaiheihe fork)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 50% alien cover (no rare taxa in WCA).

Targets: *Schinus terebinthifolius, Syzygium cumini, Toona ciliata, Psidium cattleianum,* and *Coffea arabica*.

Notes: The terrain in this WCA is not as steep as most of the other WCAs in the MU and has slopes with large stands of native dominated forest including areas with *Acacia koa* canopy, stands of *Diospyros sandwicensis* and a nice short stature shrub forest of *Leptecophylla tameiameiae, Metrosideros tremuloides,* and *Dodonea viscosa.* It encompasses a side gulch that drains into Alaiheihe Gulch. There are no known rare resources in this WCA, however the native dominated mixed-mesic forest in this gulch would be worthwhile to weed by the Ecosystem restoration team. The Ecosystem restoration team sweeps for Target Canopy Species, such as large fruiting *T. ciliata* and/or any other uncommon alien plant species, every 3-5 years. This WCA was swept multiple times in 2017 and a couple times in 2018.

**WCA: Manuwai-02 (Upper East slope/East Fenceline)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: *T. ciliata*, *Clidemia hirta*, and *Blechnum appendiculatum*.

Notes: This WCA contains the *K. degeneri* subsp. *degeneri* IHE-D reintroduction and a section of the East fenceline. These two areas are prioritized for Blue team weeding efforts. The WCA shares some of the native dominated forest aforementioned in WCA 1 but is considerably steeper, so much of the WCA is difficult to access. Weed removal along the interior fenceline is also a high priority to avoid vegetation overgrowth and reducing fuel loads along the fenceline. Ecosystem restoration team sweeps in accessible areas for Target Canopy Species, such as large fruiting *T. ciliata* and/or any other uncommon alien plant species, every 3-5 years. In extremely steep terrain, this WCA could be another site to use aerial tools to treat weeds.

**WCA: Manuwai-03 (Mideast slope)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 50% alien cover (no rare taxa in WCA).

Targets: *S. terebinthifolius*, *S. cumini*, *T. ciliata*, *P. cattleianum*, and *C. arabica*.

Notes: There was a population of *Alectryon macrococcus* var. *macrococcus* known from this WCA, however it is now extant. Unless rare plants or suitable habitat for rare plant reintroductions are found, no regular weed control will take place in this WCA. The Ecosystem restoration team sweeps in accessible areas for Target Canopy Species, such as large fruiting *T. ciliata* and/or any other uncommon alien plant species, every 3-5 years. Part of this WCA has been swept from 2015 to 2017.

**WCA: Manuwai-04 (Kauila slope/Interior fenceline)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: *Aleurites moluccanus*, *S. terebinthifolius*, *S. cumini*, *T. ciliata*, *P. cattleianum*, and *C. arabica*.

Notes: This WCA has several current and historic rare plant populations. Two populations of *Abutilon sandwicense* are present. Only *A. sandwicense* are managed by OANRP. This WCA also contains endangered *Mezoneuron kavaiense* and *Colubrina oppositifolia*, OANRP will coordinate with the Oahu Plant Extinction Prevention Program and the Division of Forestry and Wildlife (DOFAW) for weeding efforts and *Chrysodracon* spp. Reintroductions (for *Drosophila obatai*) in this area. The majority of these rare plants occur across a mostly native, *Diospyros sandwicensis* dominated slope. Blue team control efforts will be focused across this slope and around MIP rare plant species as needed to maintain low levels of alien cover directly around those populations. Blue team is also responsible for weed removal along the interior fenceline is also a high priority. While, the Ecosystem restoration team sweeps this WCA for early removal of Target Canopy Species, such as large *T. ciliata* and/or any other uncommon alien plant species every 3-5 years. This WCA was swept for Target Canopy Species multiple times already (four times in 2014 and once in 2018).

**WCA: Manuwai-05 (Lower East Manuwai gulch/Fenceline)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.\

Targets: *S. terebinthifolius, S. cumini*, *T. ciliata*, *P. cattleianum, U. maxima*, and *C. arabica* in the understory.

Notes: This WCA has several steep, grassy ridges and is largely degraded. There are a few rare plant populations in some of the shallow gulches. Blue team weed control efforts will be focused around IP rare plant species as needed to maintain low levels of alien cover directly around those populations and controlling grass around IP taxa and along the fenceline. The Ecosystem restoration team sweeps for Target Canopy Species, such as large *T. ciliata* and/or any other uncommon alien plant species, every 3-5 years in the walkable areas. These IPA sweeps have begun (2015-2016) in a portion of the WCA. The high fuel load, relative dryness, and possible access by recreational hikers/hunters makes it a likely entry point for fire should one occur. Fuel load control is a high priority along the fenceline. There are high levels of *U. maxima* throughout the WCA that will be cleared directly around rare plants in any reintroduction established in this WCA. Aerial or on the ground *U. maxima* control along the northern edge of this WCA (fenceline) will also be evaluated to facilitate fence checks, and may serve as a potential fire break, Possibility of aerial spray for fuel load reduction should be evaluated for grass patches inside and outside of the fence. Ground surveys must be conducted to determine rare plant locations to minimize aerial spray impacts.

**WCA: Manuwai-06 (Lower West Manuwai gulch/Fenceline)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: *S. terebinthifolius, S. cumini*, *T. ciliata*, *P. cattleianum, U. maxima*, and *C. arabica*.

Notes: This WCA contains several rare plant reintroductions along with several *in situ* rare plant populations. There are high levels of *U. maxima* in the northern half of this WCA. The 2007 Waialua fire burned the northern edge of this WCA and *U. maxima* has filled in all the burned area. The southern-most gulch of this WCA had a population of *Neraudia angulata*. There is also a sizeable stand of *C. oppositifolia* on the ridge that divides along the fenceline. Currently, this WCA still contains a few wild *N. angulata* and *Abutilon sandwicense* plants. However, from recent reintroductions, this WCA has outplanted *N. angulata* var. *dentata*, *Hibiscus brackenridgei* subsp. *mokuleianus*, *Flueggea neowawraea*, and *Nototrichium humile* sites in two separate small gullies. Weeding efforts around the reintroduction areas are one of the highest priorities in this WCA for the Blue team. Another priority for the Blue team is to maintain *U. maxima* along the North fenceline to facilitate fence checks and create a fuel break. Again, aerial spray of large grassy slopes adjacent to the unit should be evaluated to reduce risk of fire ingress given the large amounts of rare and endangered taxa in the WCA. The Ecosystem restoration team sweeps for Target Canopy Species, such as large fruiting *T. ciliata* and/or any other uncommon alien plant species, every 3-5 years. This WCA has been swept once by the Ecosystem restoration team in 2017.

**WCA: Manuwai-07 (Abutilon gulch)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: *S. terebinthifolius*, *S. cumini*, *T. ciliata*, *P. cattleianum*, and *C. arabica*.

Notes: The boundaries of this WCA run from the fence line down two ridges, and surround one large gulch. There is a small population of *A. sandwicense* in this WCA. Blue team weed control will focus around the *A. sandwicense* at least once a year when it is also scheduled to monitor this population. Ecorestoration sweeps for Target Canopy Species, such as large *T. ciliata* and/or any other uncommon alien plant species, every 3-5 years. WCA has been swept once by the Ecosystem restoration team in 2016.

**WCA: Manuwai-08 (West slope- North)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 50% alien cover (no rare taxa in WCA).

Targets: *S. terebinthifolius*, *S. cumini*, *T. ciliata*, *Grevillea robusta*, *P. cattleianum*, and *C. arabica*.

Notes: The boundaries of this WCA run from the fence line down two ridges, and surround one large gulch. These ridges are mostly native mid-slope, but are thick with coffee closer to the gulch. Ecosystem restoration team sweeps for Target Canopy Species, such as large *T. ciliata*, and/or any other uncommon alien plant species every 3-5 years. This WCA was swept in 2016.

**WCA: Manuwai-09 (West slope- South)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 50% alien cover (no rare taxa in WCA).

Targets: *S. terebinthifolius*, *S. cumini*, *T. ciliata*, *G. robusta*, *P. cattleianum*, and *C. arabica*.

Notes: The boundaries of this WCA run from the fence line down two ridges, and surround one large gulch. At mid-slope these ridges are mostly native, but are thick with coffee closer to the gulch. The Ecosystem restoration team sweeps for Target Canopy Species such as large *T. ciliata*, and/or any other uncommon alien plant species every 3-5 years. The first of IPA sweep in this WCA was conducted in 2016.

**WCA: Manuwai-10 (MelTen gulch/KadDegDeg reintro)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: *S. terebinthifolius*, *S. cumini*, *T. ciliata*, *G. robusta*, *C. hirta*, *U. maxima*, *Melinis minutiflora*, *P. cattleianum*, and *C. arabica*.

Notes: This WCA has high levels of native cover and is a high priority for weeding since rare taxa are present. There are side gulches with *Pisonia sp.*, and *Cyanea angustifolia* scattered throughout the upper regions. There is also large population of *Melanthra tenuifolia* on and around the cliff that forms at the back of the gulch in the WCA. Along the elevation gradient of the gulch there is suitable habitat for rare plants, and the terrain is not as steep as in other parts of the MU and is more manageable from that perspective, making this WCA a prime site for rare plant reintroductions. Blue team weeding efforts are mainly focused around the IP plant taxa. There are rare plant reintroductions within this gulch including *Delissea waianaeensis*, *Cyanea superba* subsp. *superba*, and *F. neowawraea*. Also present in this WCA, there is a *K. degeneri* subsp. *degeneri* (ANU-B) reintroduction site along the interior fenceline on the ridge. This *K. degeneri* subsp. *degeneri* population is shared between this WCA and Manuwai-11. Weed control in this WCA began as site preparation for reintroductions, and since has been conducted to reduce non-native cover around these rare plant populations. This WCA is also high priority for the Ecosystem restoration team to remove any Target Canopy Species, such as large *T. ciliata*, and/or any other uncommon alien plant species every 3-5 years. These sweeps were already conducted from 2014-2015. Restoration efforts by planting common native plant species is a consideration for this WCA around the *D. waianaeensis*, *C. superba* subsp. *superba*, and *F. neowawraea* populations in order to reduce weeding efforts and improve native habitat around the reintroduction zone. However, restoration efforts overall in the Manuwai MU is a lower priority since the habitat is highly degraded making it difficult to commit to restoration efforts for the next 5 years. OANRP plans to revisit restoration actions after MIP Year 19 for the revised Manuwai MU Plan.

**WCA: Manuwai-11 (Midwest Slope/KadDegDeg reintro)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: *S. terebinthifolius, S. cumini, P. cattleianum, T. ciliata, C. Arabica, C. hirta, U. maxima, M. minutiflora*, and *Paspalam conjugatum*.

Notes: This WCA shares the native forest in WCA 10 along the ridgeline interior fence and has patches of native forests. Blue team is responsible for controlling weeds especially alien grasses around the reintroduction site. It is worthwhile to not only weed around the *K. degeneri* subsp. *degeneri* (ANU-B) plants, but also nearby native forest patches in order to extend the suitable habitat for more rare plant reintroductions in the future. The Blue team also maintains weeds such as *C. hirta*, *U. maxima*, and *M. minutiflora* along the interior fence. The other parts of this WCA is quite steep and therefore less management will take place in those areas. The Ecosystem restoration team sweeps in accessible areas for Target Canopy Species, such as large *T. ciliata* and/or any other uncommon alien plant species, every 3-5 years. There has been a few sweeps for canopy target species between 2014 and 2016.

**WCA: Manuwai-12 (*Kadua*/Central ridge)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: *S. terebinthifolius, S. cumini, T. ciliata, G. robusta, U. maxima, Melinis minutiflora, P. cattleianum, Ageratina riparia, C. hirta*, and *C. arabica*.

Notes: The boundaries of this WCA run down two drainages, and encompass a ridge with a MFS population of *K. degeneri* subsp. *degeneri* (ANU-A). Weed control will be conducted mostly around these rare plants. There are also other rare plants on the slopes of the ridge including: *A. macrococcus* var. *macrococcus, Bobea sandwichensis, F. neowawraea, Pteralyxia macrocarpa, Dubautia sherffiana*, and *Schiedea hookeri*. This is a large WCA, and the southern edge of this WCA is very steep and largely inaccessible. If remote weed control technologies are developed, this would be a WCA where they could be used. The Ecosystem restoration team sweeps in accessible areas for Target Canopy Species, such as large *T. ciliata* and/or any other uncommon alien plant species, every 3-5 years. This WCA was swept once in 2016 and once in 2018.

**WCA: Manuwai-13 (Manuwai cliffs)**

Vegetation Type: Mesic Ridge

MIP Goal: Less than 50% alien cover (no rare taxa in WCA).

Targets: *S. terebinthifolius, S. cumini, T. ciliata, P. cattleianum,* and *C. arabica*.

Notes: This WCA encompasses the cliffs abutting Kamaohanui ridge. The terrain is very steep, or vertical and is mostly inaccessible. Control in this area will be limited to accessible rare taxa and target weed species sites. This is a large WCA, and the southern edge of this WCA is very steep and largely inaccessible. If remote/aerial weed control technologies are developed, they could be used to control Target Canopy Species.

**WCA: Manuwai-14 (Kamaohanui and fence)**

Vegetation Type: Wet Forest

MIP Goal: Less than 50% alien cover (no rare taxa in WCA).

Targets: *S. terebinthifolius, S. cumini, T. ciliata, P. cattleianum,* and *C. arabica*.

Notes: This WCA includes the highest elevations in the MU and is mostly a mesic forest. Since this WCA has extremely steep areas, remote weed control technologies will be required for control of MU wide target species. However, the Ecosystem restoration team will sweep in accessible areas for Target Canopy Species, such as large *T. ciliata* and/or any other uncommon alien plant species, every 3-5 years. This is the only WCA with *Rubus argutus* located on the Kamaohanui LZ and down the fenceline ~100m, so the Blue team will continue to monitor this population. If *R. argutus* continues to spread or is found in new locations in the MU, Blue team will take immediate action to control this plant species, since it is known to form dense thickets where it is found elsewhere.

**WCA: ManuwaiNoMU-01 (Spider Camp Road)**

Vegetation Type: N/A

MIP Goal: N/A

Targets: *U. maxima*

Notes: This WCA was created to control grass and other weed species to keep the road clear and accessible for vehicles. Controlling grass also reduces the fuel load below the MU and provides access for fire-fighters responding to a fire.

**WCA: ManuwaiNoMU-02 (Manuwai West LZ)**

Vegetation Type: N/A

MIP Goal: N/A

Targets: *U. maxima*

Notes: This WCA was created to control grass and other weed species to keep the trail and LZ clear for use. Controlling grass also reduces the fuel load in the MU.

**WCA: LKNARNoMU-01 (Lower Kaala NAR Access Road)**

Vegetation Type: N/A

MIP Goal: N/A

Targets: *U. maxima*

Notes: This WCA was created to control grass and other weed species to keep the road clear and accessible for vehicles. Controlling grass also reduces the fuel load below the MU and provides access for fire-fighters responding to a fire.

**WCA: AlaiheiheNoMU-01 (KadDeg IHE-C)**

Vegetation Type: Mesic

MIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: *S. terebinthifolius, S. cumini*, *T. ciliata*, *G. robusta*, *U. maxima*, *M. minutiflora, P. cattleianum,*

*A. riparia*, *C. hirta*, and *C. arabica*.

Notes: This WCA encompasses the wild *K. degeneri* subsp. *degeneri* site outside of the MU fence in Alaiheihe. There are stands of *Metrosideros polymorpha*, *D. sandwicensis*, *D. viscosa*, *Psychotria hathewayi*. Weeding efforts will only coincide with the scheduled *K. degeneri* subsp. *degeneri* monitoring action, since this population is maintained for genetic storage collection.

## Small Vertebrate Control

Species: *Rattus rattus* (Black rat), *Rattus exulans* (Polynesian rat), *Mus musculus* (House mouse), *Pternistis erckelii* (Erckel's francolin), *Lophura leucomelanos* (Kalij Pheasant).

Threat Level: High for *Rattus* spp. on *Cyanea superba* subsp. *superba*, and *Delissea waianaeensis*, moderate on *Chrysodracon* spp. Unknown for *M. musculus*, *P. erckelii*, and *L. leucomelanos*.

Seasonality/Relevant Species Biology: Spikes in rodent population are often observed in other MUs following the fruiting season (about twice a year) of *Psidium catteleianum*, then followed by a return to normal activity levels. It is assumed rodent activity follows similar patterns. *P. erckelii* and *L. leucomelanos* numbers are unknown in the MU, however these ground birds remain threats to rare plant IP taxa since there has been recent observations in other MUs of damage and fruit predation caused by these birds.

Management Objectives:

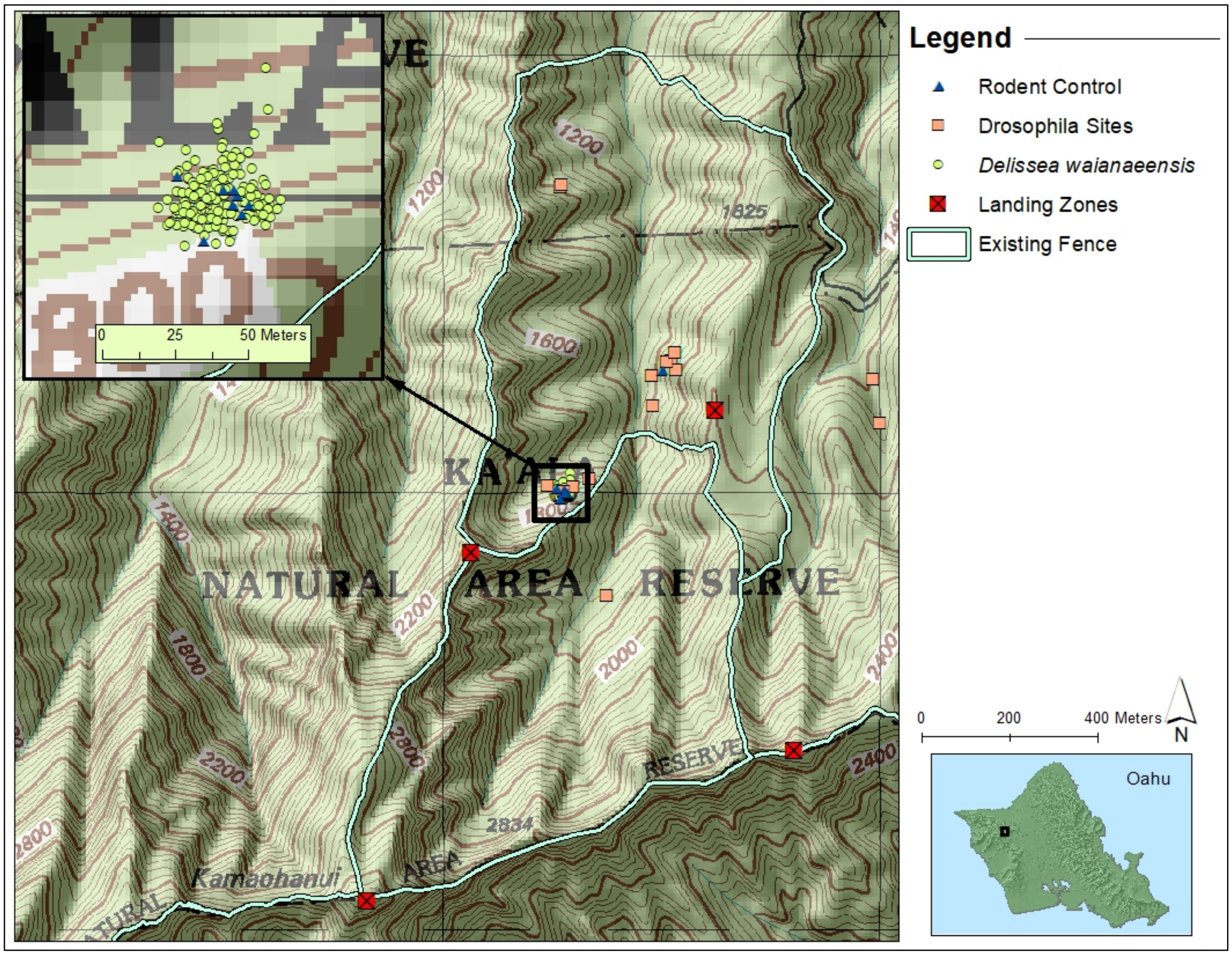
- Limit rodent predation on *D. waianaeensis* plants and *C. halapepe* seeds.
- Mitigate threat of rodent activity on managed plants. IP goal is having 10% rat activity or less.
- Monitor rare plant IP taxa populations, that do not have rodent control, for rodent damage; promptly initiate control if damage is noted.
    - Rare plant IP taxa not receiving rodent control- *C. superba* subsp. *superba*, *Kadua degeneri* subsp. *degeneri*, *Hibiscus brackenridgei* subsp. *mokuleianus*, *Neraudia angulata* var. *dentata*, *Abutilon sandwicense*, *Flueggea neowawraea*, and *Nototrichium humile*.

- Monitor rare plant IP taxa for damage from *P. erckelii* and *L. leucomelanos*.

Strategy and Control Methods:

- Control rodents annually around *D. waianaeensis* plants and *C. halapepe* seeds using a small localized A24 trapping grid.

**Small Vertebrate Management Map**




Discussion: Due to the difficulty of accessing this MU and steep terrain, the only rodent control currently maintained by OANRP staff are around the *D. waianaeensis* reintroduced plants and *C. halapepe* plants to protect the seeds. These rare taxa are protected annually. However, if other rare plant IP taxa are impacted by rodents, OANRP may extend their rodent control efforts in this MU using newly developed rodent traps. OANRP has adopted new models of GoodNature A24 traps and automatic lure pump baits have shown high success in limiting rodent predation on rare taxa in other MUs. OANRP will plan to expand the existing trapping grid to the *C. superba* subsp. *superba* if plants mature. OANRP staff currently checks A24s every 4 months. If damage to rare IP plant taxa from ground birds are observed, OANRP will have to acquire permits to manage these birds and investigate control methods.

## Slug Control

Species: *Deroceras laeve* and *Limax maximus*

Threat Level: Low, due to low counts of slugs in this MU. If slug activity rises, slugs could threaten *Delissea waianaeensis* and *Cyanea superba* subsp. *superba*

Seasonality/Relevant Species Biology: Slugs are seasonally abundant during the wet season. We know that in some areas slugs are abundant even during the dry season (for example, West Makaleha and Palikea). In those areas, dry season application of molluscicide is needed. However, slug were only detected three times over two years of sampling. Therefore we can assume slug numbers in this MU are low.

Management Objectives:

- Control slugs locally to ensure germination and survivorship of *D. waianaeensis*.
- During annual rare plant monitoring, look for seedling recruitment and slug herbivory.

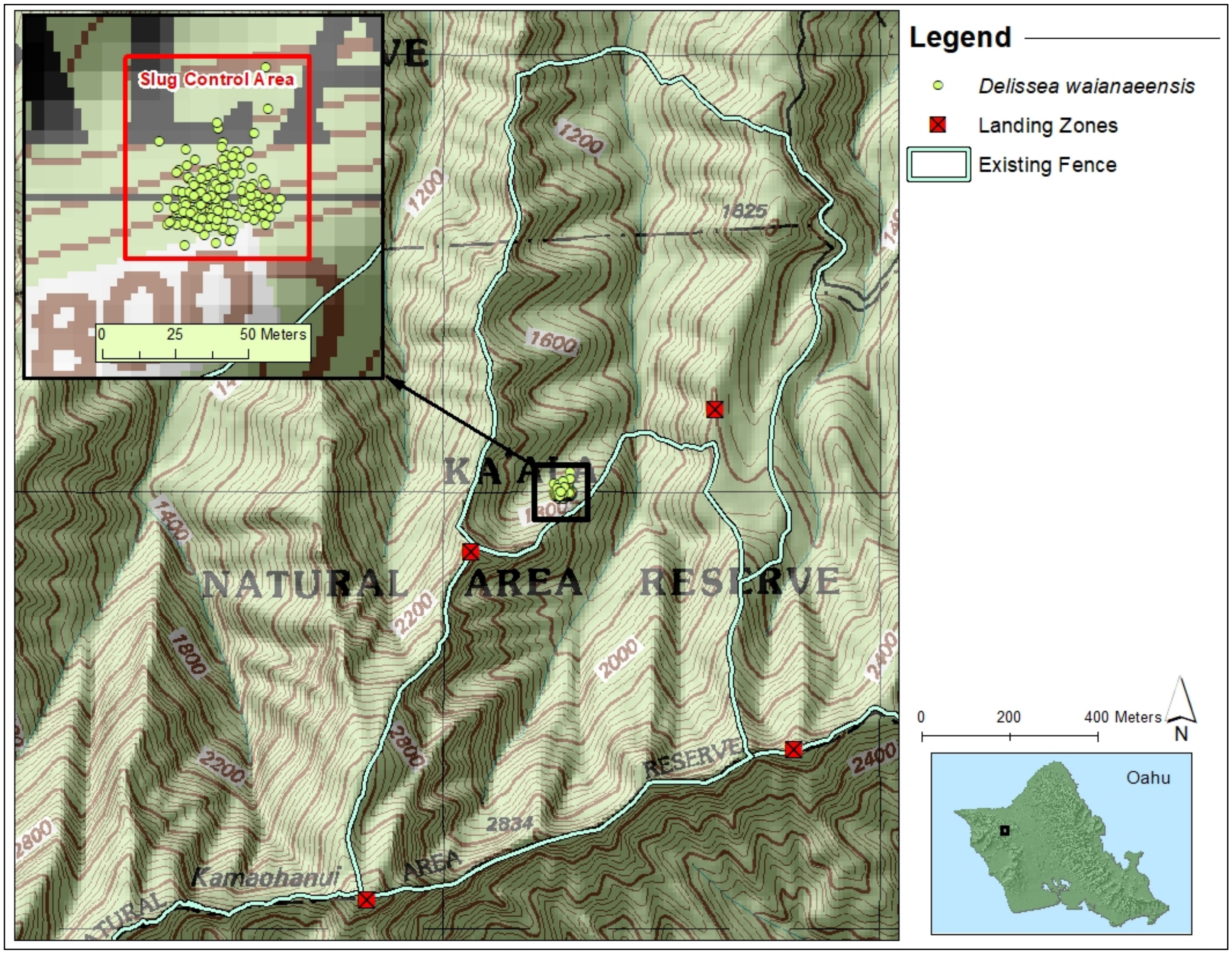
Strategy and Control Methods:

- Slug Control Areas (SLCAs) around rare taxa locations have been surveyed and cleared of native snails
- FerroxxAQ once a quarter is applied to the SLCA. FerroxxAQ is not applied within 20 m of known populations of native snails.
- If new sites for rare plant reintroductions are chosen outside of the existing SLCAs, areas will be searched thoroughly by an experienced malacologists for slug densities and native snails during the day and at least one night prior to application of FerroxxAQ.

**Slug Control Area Locations Table**

| SLCA Code | Plant population reference codes | Date slug control begun |
|---|---|---|
| ANU-A-1 | DelWai ANU-A | 2012 January |

## Slug Management Map




Discussion: During annual rare plant monitoring, OANRP staff will inspect plants for herbivory. If present, this will be noted. Indications of slug damage includes the following: lower leaves closer to the ground are more damaged than upper leaves, slime is present, and leaf margins are consumed before the interior of the leaf (unless the midrib is resting on the ground while the margins are curled).

If slug herbivory is suspected and rare native snails are not present in an area, then molluscicide may be applied. FerroxxAQ should be applied at label rates every 6 weeks However, since this MU is often difficult to access via 4x4 roads and slug counts are already low, FerroxxAQ application is scheduled for once a quarter instead of the 6 week interval that is required elsewhere. If molluscicide is applied, then some weeds, like *Clidemia hirta*, may flourish, so more weeding should be planned if treatments take place.

Currently, slugs are managed only around the *D. waianaeensis*. However, SLCA may expand into the nearby *C. superba* subsp. *superba* reintroduction site when plants mature. OANRP staff will continue to monitor this rare plants and conduct slug sampling annually.

# Ant Control

Species: *Anoplolepis gracilipes*

Threat Level: High for endangered *Drosophila*.

Seasonality/Relevant Species Biology: Varies by species, but nest expansion is typically observed in late summer to early fall.

Management Objectives:

- Prevent spread of ant species into areas where they are not already established. Conduct annual surveys during the summer to determine what ant taxa are present in the MU.
- Implement control if incipient, high-risk species are found or if needed for *Drosophila* conservation.
- Detect incursions of new ant species prior to establishment.

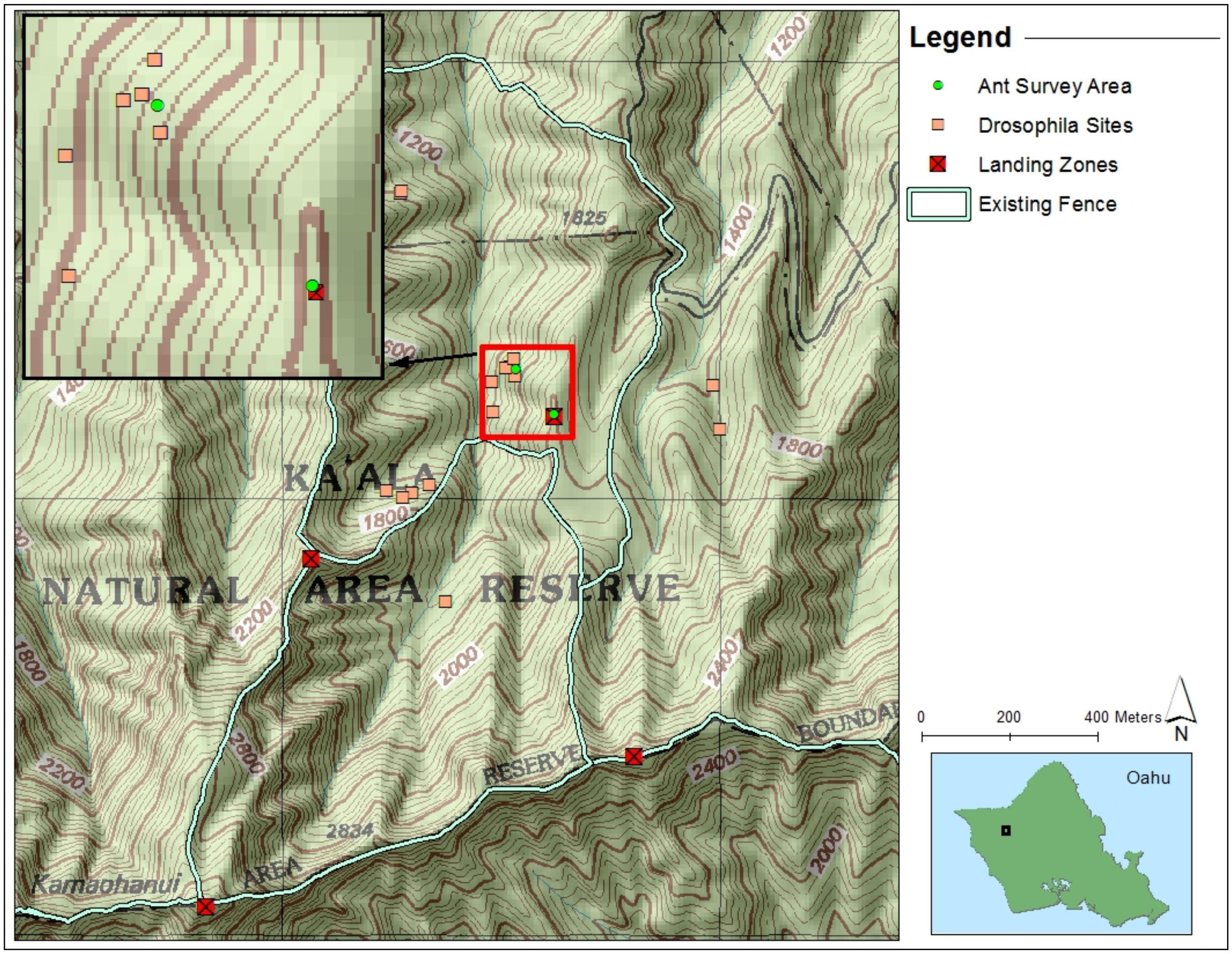
Strategy and Control Methods:

- Sample ants at human entry points using the standard survey protocol (Plentovich and Krushelnycky 2009) and *Drosophila* sites a minimum of once a year (see table below). Use samples to track changes in existing ant densities and to alert OANRP to any new introductions.
- If incipient species are found and deemed to be a high threat and/or easily eradicated locally (<3 acre infestation), begin control.
- Sample ants at campsite, LZ and Drosophila sites.
- Partner with the DOFAW to survey and manage any *S. papuana* (if found) around *D. obatai* populations.

**Ant Survey Site Table**

| **Site description** | **Reason for survey** |
|---|---|
| East ridge camp site | High risk of accidental ant introduction |
| Halapepe *Drosophila* area | *Drosophila* are sensitive to high ant abundance |

**Ant Management Map**




Discussion: Ant sampling has never been conducted in this MU previously. However, during *Drosophila* monitoring by the program's entomologist, *A. gracilipes* was detected. There is concern about this ant species invading higher elevations, however there currently is no effective control method for this type of species. *A. gracilipes* is present in the gulch near *Drosophila* monitoring sites and may need to coordinate with DOFAW to control if this species moves to higher elevations. Another ant specie *Solenopsis papuana* is a known threat to Drosophila populations. If present, this species would be locally controlled using Amdro (registered for forest use). Unlike *A. gracilipes, S. papuana* is an aggressive ant specie that is known to reduce *Drosophila* survival by 58% (Krushelnycky *et al*. 2017).

Surveying for ants will continue during *Drosophila* monitoring. In addition, annual formal ant surveys at high traffic areas, i.e., east ridge camp and Halapepe *Drosophila* site, where D. obatai (IP rare taxon369) occurs, will be conducted to determine what ant species occur if any. If S. *papuana* is found during these surveys, Amdro will be used to control this species. OANRP will partner with DOFAW on managing ants around and *D. obatai* sites.

## Black-Twig Borer (BTB) Control

Species: *Xylosandrus compactus*

Threat Level: High

Seasonality/Relevant Species Biology: Peaks in BTB activity have been observed from October-January

Management Objectives:

- During annual rare plant monitoring, look for signs of twig boring and damage at the rare plant populations commonly impacted by BTB (*Abutilon sandwicense* and *Flueggea neowawraea*).

Strategy and Control Methods:

- If rare plant taxa that are monitored show any sign of boring, report to Rare Plant Manager immediately.
- If there is an urgency to collect any plant material (i.e. seed, cuttings, and saplings) for genetic storage, collect material.

**BTB Photos**

Photos of BTB damage (arrows) on *Abutilon sandwicense*.

Discussion: The current control method available for BTB involves the deployment of traps equipped with high-release ethanol bait. However, it is unclear whether this method reduces BTB damage to target plants. Therefore, this control method is not used to control BTB in the field. Since this control method is not effective, OANRP will continue to investigate other control methods. If there is a rare plant population threatened by BTB and there is an urgency to secure its genetic material, OANRP staff will collect any plant material to prevent losing the plant founder altogether.

## Fire Control

Threat Level: High

Seasonality/Potential Ignition Sources: Fire may occur whenever vegetation is dry. Generally this happens in summer, but may occur at other times of the year, depending on variations in weather pattern. *Urochloa maxima* has a high fire index, and is the dominant vegetation across the MU. This site has burned in the past by arsonists along Farrington Hwy.

Management Objectives:

- To prevent fire from burning any portion of the MU at any time.
- To prevent fire from damaging any IP rare taxa locations.

Strategy and Control Methods:

- Reduce fuel loads by grass control along the fenceline and access roads.
- If a fire occurs, conduct a post-fire survey, including mapping the perimeter of the fire and document damage via photos. If possible, rehabilitate burned areas within the fuel break with native species.
- Establish a fuel break corridor along the north fenceline, possibly via aerial spray outside the fence.

**Fire Management Map**

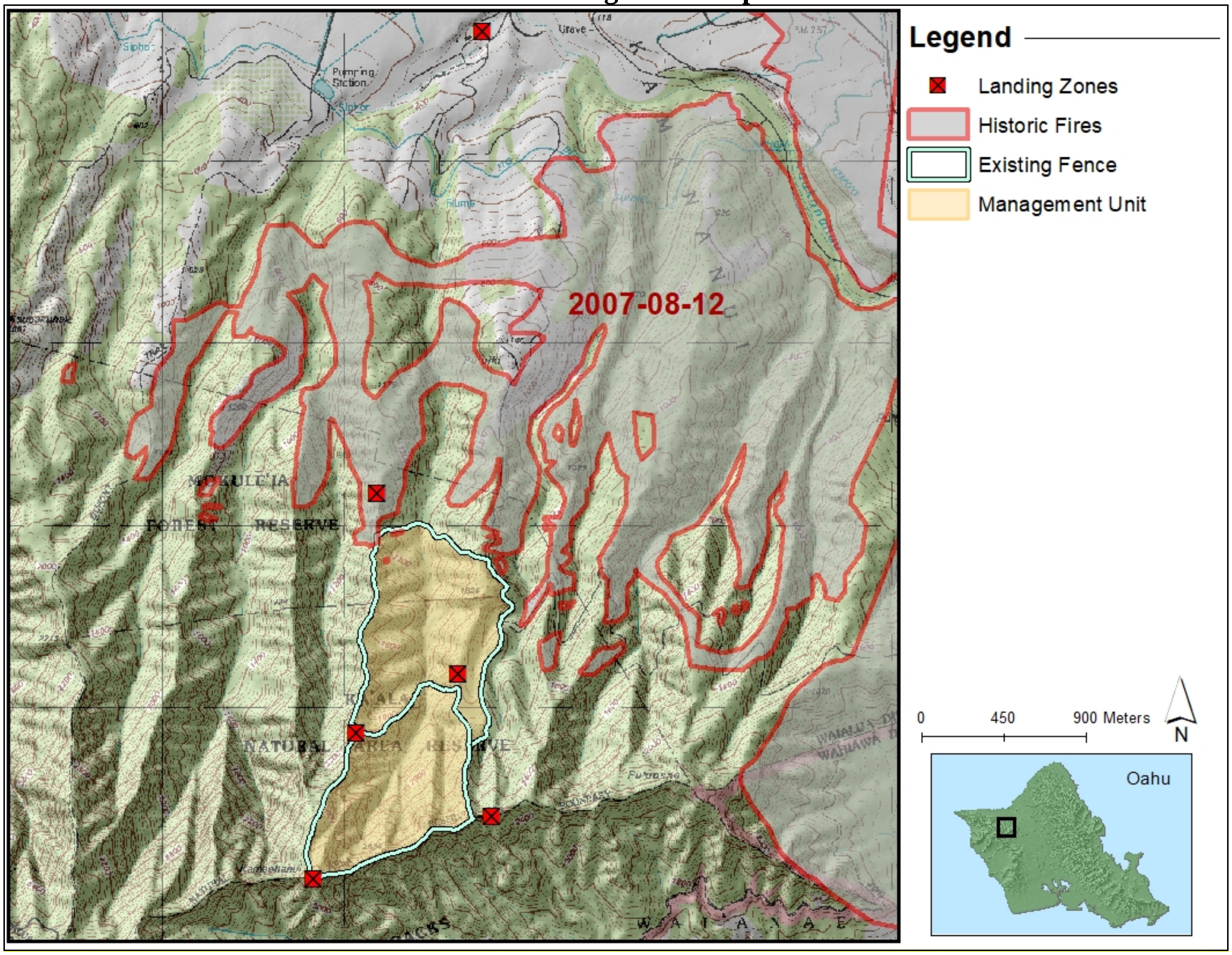
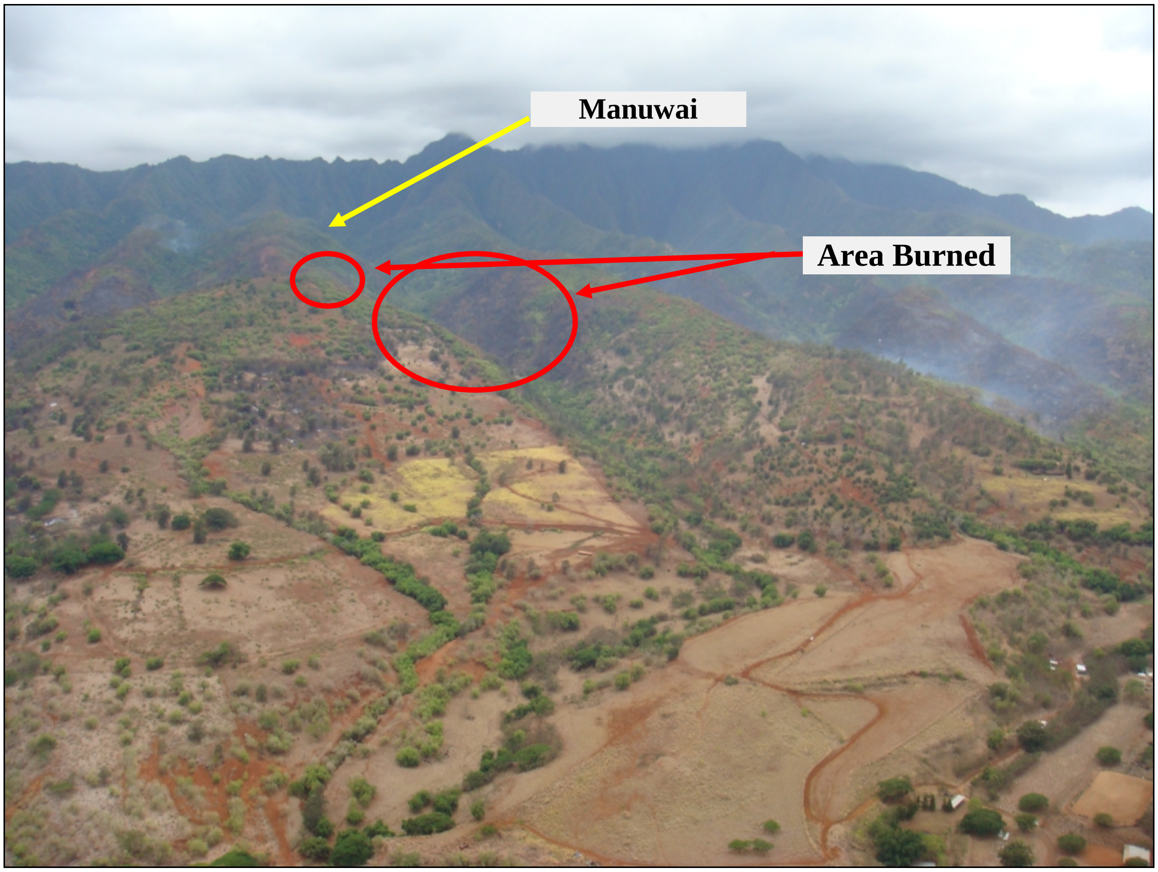


**Photo of area burned in Manuwai Gulch in 2007 fire**




Discussion: In 2007, a fire started in Waialua, crossed Kaukonahua Road and burned through ranch land, to State Forest Reserve and Natural Area Reserve Land. OANRP staff and other knowledgeable resource managers guided helicopter water drops to priority areas around natural resources for eight days as the fire burned. Prior to 2007, no fires had burned through this area in at least 50 years. The southernmost gulches below the Manuwai MU was burned and many rare plant taxa, including *Hibiscus brackenridgei* subsp. *mokuleianus, C. oppositifoli, Abutilon sandwicense*, *Bobea sandwicensis*, *Bonamia menziesii, Eugenia koolauensis*, *Euphorbia haeleeleana*, *Nototrichium humile*, *and Schiedea hookeri*. The most impacted rare plant taxa were the wild *H. brackenridgei* subsp. *mokuleianus* populations, which accounted for about 90% of all *H. brackenridgei* subsp. *mokuleianus* on Oahu. No rare plants were affected in the fenced Manuwai MU, the fire reached as close as 100 meters to known rare plant populations. However, there is evidence that it burned into the *C. oppositifolia* stand at the northwest corner of the fence. The burned area quickly filled back in with *Urochloa maximus,* which serves as a large fuel load at the bottom of the MU.

Since the 2007 fire, OANRP began to contract discing of grass growing in fallow fields along Kaukonahua Road until 2014 when a new land owner purchased this area. This creates a wider and continuous fire break at the site where the fire jumped the road in 2007. OANRP plans to meet with the new landowner of the roadside grass fields to re-new the contract and resume discing the grass. Efficient grass spraying techniques such as using helicopters with spray booms and ball sprayers will be investigated. This technique could be useful to create a fuel break at the bottom of the MU or in other strategic locations. Currently, OANRP staff manage fuel loads along the access roads, northern fencelines, and around managed rare plant taxa sites in the MU. It is also important to maintain roads and LZs for fire access and as fire escape routes. The help of OANRP staff and other knowledgeable resource managers to direct helicopter water drops to priority areas around natural resources is key in dealing with fires across the area. Additionally, it will be important to work with DOFAW to develop a fire management plan for the entire Mokuleia Forest Reserve and Lower Kaala NAR. One of the land owners Kaukonahua Ranch, who acquired land adjacent to the forestry area in 2017, has incorporated fire mitigation in their development plan. This plan includes controlling grass and *Eucalyptus* spp. and planting native dry-forest plants.

# Action Table

The table below is a comprehensive list of threat control actions planned for the MU for the next five years. Actions are grouped by type; for example, Ungulate Control or Ant Control. Weed control actions are grouped into the following categories: General Survey, ICA, or WCA code. Cells filled with **X** denote the quarters in which an action is scheduled. IP years run from October of one year through September of the next. Therefore, Quarter 4 (October-December) is listed first for each report year, followed by Quarter 1 (January-March), Quarter 2 (April-June), and Q3 (July-September). Species names are written as six-digit abbreviations, such as ‘CenSet’ instead of *Cenchrus setaceus*, for brevity.

| **Action ID** | **Action Type** | **Taxon Code** | **Action Site Code** | **Actions** | **MIP Year 15 Oct 2018-Sept2019** | | | | **MIP Year 16 Oct 2019-Sept2020** | | | | **MIP Year 17 Oct 2020-Sept2021** | | | | **MIP Year 18 Oct 2021-Sept2022** | | | | **MIP Year 19 Oct 2022-Sept2023** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| 7803 | Ant Monitoring | None | ANU-A | Sample ants using peanut butter and syrup at LZ and at Drosophila site, 10 baits at each site, leave for 1 hour (can leave longer but a minimum of 1 hour). Note weather. Avoid sampling on rainy cold days. If baits are left in the sunshine, place them in the shade under vegetation | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |
| 7709 | Collections | ErySan | | Collect Erythrina sandwicensis (Wiliwili): Collect/monitor fruit for use in restoration projects in Manuwai and Seed Zone: OA-3. Action includes monitoring phenology of common native species. | **X** | | | | | | | | | | | | | | | | | | | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 3325 | Fence | None | ANU-A | All fence monitoring and maintenance actions. Maintenance is defined as any minor repair work or that is LESS THAN 100m. This action also includes clearing fenceline of excess vegetation. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 4569 | Fence | None | ANU-B | All fence monitoring and maintenance actions. Maintenance is defined as any minor repair work or that is LESS THAN 100m. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 4497 | Fire- Photo point monitor | | None | Take Photopoints across LKN/road region. Was 1x/yr, but now 1x/5yrs, or if a big fire occurs. | | | | | | | | | | | | | | | | | | | | |
| 6942 | Predator Control-RP | DelWai | ANU-A | Seasonal trapping around fruiting period. | X | X | | X | X | X | | X | X | X | | X | X | X | | X | X | X | | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| 7292 | Slug Control | DelWai | ANU-A-1 | 4 lbs. of FerroxxAQ at DelWai ANU-A population as possible. No native snails are present in the area. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 6076 | Weed Control | None | Manuwai-01 | Control weeds across rare plant zone, and high quality lama-band annually. [EcoRest team able to assist with this action]. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 6078 | Weed Control | None | Manuwai-02 | Control weeds around isolated rare plant populations as needed. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 6085 | Weed Control | None | Manuwai-03 | Conduct weed control around rare plant reintroductions (Cyasup, Delwai), 2-4x per year. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 6087 | Weed Control | None | Manuwai-03 | Conduct weed control around KadDegDeg.ANU-B reintroduction, 1-2x per year. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |

**Action Table (Continued)**

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6089 | Weed Control | None | Manuwai-04 | Weed throughout KadDegDeg.ANU-A population and suitable habitat along ridge, annually. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 6090 | Weed Control | None | Manuwai-04 | Evaluate feasibility of controlling target species on the ground (area is very steep). Species include: GreRob, CupLus, JunBer, MelQui, RoyReg, SchAct, SpaCam, TreOri. Where not possible, aerially identify locations of targets. Control with remote control technologies if determined appropriate control for those targets. Complete control by MIP Year 11. | | | | | | | | | | | X | | | | | | | | | |
| 6092 | Weed Control | None | Manuwai-04 | Maintain LZ and fenceline as needed, 1-2x per year. Control weeds across accessible portion of WCA near LZ | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6218 | Weed Control | None | Manuwai-04 | Conduct understory/canopy weed control around Fluneo reintroduction site every 3-6 months. Goal is to manage Fluneo, which requires lots of sun. Control canopy weeds aggressively at site | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 6219 | Weed Control | None | Manuwai-04 | Conduct weed control around NerAng/NotHum/FluNeo reintro zone; prepare and maintain sites. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 6220 | Weed Control | None | Manuwai-05 | Conduct weed control around HibBramok reintroduction; prepare and maintain sites. Includes grass control. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 6221 | Weed Control | None | Manuwai-05 | Control weeds, especially grasses, along fenceline, as needed (minimum annually). This WCA is closest to unmanaged grass lands and is at high risk from fire. | X | | X | X | | | X | X | | | X | X | | | X | X | | | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6990 | Weed Control | None | Manuwai-06 | Control weeds, especially grasses, along fenceline, as needed. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 6991 | Weed Control | None | Manuwai-06 | Control weeds along fenceline and trail, as needed. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 7490 | Weed Control | None | Manuwai-06 | Control weeds, especially grasses, along fenceline, as needed (minimum annually). This WCA is closest to unmanaged grass lands and is at high risk from fire. | | | X | X | | | X | X | | | X | X | | | X | X | | | X | X |
| 7550 | Weed Control | None | Manuwai-07 | Conduct weed control around KadDegDeg.ANU-B reintroduction, 1-2x per year. | | | X | X | | | X | X | | | X | X | | | X | X | | | X | X |
| 7552 | Weed Control | None | Manuwai-10 | Conduct sweeps across lama dominated slopes and ridge shared with WCA 10. | X | | | | X | | | | X | | | | X | | | | | | | |
| 7560 | Weed Control | None | Manuwai-10 | Conduct weed control around KadDegDeg.IHE-D reintroduction, 1-2x per year. | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| 7804 | Weed Control | None | Manuwai-10 | Control weeds around AbuSan ANU-F & J. Target understory weeds, and select canopy weed removal. AbuSan respond well to light gaps. Partner weed control with rare plant monitoring, as feasible. | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |
| 7805 | Weed Control | None | Manuwai-10 | Control weeds around AbuSan ANU-C. Target understory weeds, and select canopy weed removal. AbuSan respond well to light gaps. Partner weed control with rare plant monitoring, as feasible. | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6691 | Weed Control | None | Manuwai-11 | Conduct target species weed control across WCA, in native forest patches in walkable areas; once every 10 years. Species include but not limited to: GreRob, TooCil, CupLus, JunBer, MelQui, RoyReg, SchAct, SpaCam, TreOri. For Toocil, only treat trees >6" diameter. | | | | | | | | | | | | | | | | | | | X | |
| 6694 | Weed Control | None | Manuwai-11 | Conduct target species weed control across WCA, in walkable areas; once every 10 years. Species include but not limited to: GreRob, CupLus, JunBer, MelQui, RoyReg, SchAct, SpaCam, TreOri. For Toocil, only treat trees >6" diameter. | | | | | | | | | | | | | | | | | | | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 7096 | Weed Control | None | Manuwai-12 | Conduct target species weed control across WCA, in native forest patches in walkable areas; once every 10 years. Species include but not limited to: GreRob, CupLus, JunBer, MelQui, RoyReg, SchAct, SpaCam, TreOri. For Toocil, only treat trees >6" diameter. | X | | | | | | | | | | | | | | | | | | | |
| 7601 | Weed Control | None | Manuwai-13 | Control weeds in and around native forest patches, particularly high quality lama-band; annually. Target both canopy and understory weeds. Take extra care around rare taxa. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 7742 | Weed Control | None | Manuwai-14 | Control weeds in and around native forest patches, particularly high quality lama-band; annually. Target both canopy and understory weeds. | | | X | | | | X | | | | X | | | | X | | | | X | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 4043 | Weed Control | None | LKNARNo MU-01 | Control grass/herbaceous weeds along the LKN contour road, 1-2x per year or as needed. Use the power sprayer, weedwhack. Goal: maintain road, safety, reduce weed spread. Coordinate with State. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 6445 | Weed Control | None | LKNARNo MU-01 | Control EhrSti on eastern end of road. | | X | | | | X | | | | X | | | | X | | | | X | | |
| 7046 | Weed Control | None | ManuwaiNo MU-01 | Maintain road to spider camp, as needed. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 7047 | Weed Control | None | ManuwaiNo MU-02 | Maintain ridge trail and Manuwai West LZ (165), clear weeds as needed. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 6068 | Weed: Incipient Control | CaeDec | Manuwai-CaeDec-01 | Monitor/control Caesalpinia decapetala in the bottom of the gulch in Subunit I every 6 months/annually. Pick and remove from field any potentially mature fruit. | | | X | | | | X | | | | X | | | | X | | | | X | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| 7419 | Weed: Incipient Control | ChrOdo | Manuwai-ChrOdo-01 | Sweep/treat ICA, 2-4x year. Pick and remove from field any potentially viable fruit. Check known hotspots and treat with Oust every 3-6 months. | **X** | **X** | **X** | **X** | **X** | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** |
| 7539 | Weed: Incipient Control/ Survey | ChrOdo | Manuwai-ChrOdo-01 | Survey greater area around known locations for ChrOdo, define boundaries of infestation, identify core areas, areas with scattered plants, & any outliers. Sweep designated appropriate habitat. Re-survey in 3-5 years. | | | | | | | | | | | | | | | | **X** | **X** | **X** | **X** | |
| 7418 | Weed: Incipient Control/ Survey | ChrOdo | Manuwai-ChrOdo-01 | Survey greater area around known locations possible for ChrOdo, define boundaries of infestation, identify core areas, areas with scattered plants, and any outliers. Sweep designated appropriate habitat. Re-survey in 3-5 | | | | | | | | | | | | | | | | **X** | **X** | **X** | **X** | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| | | | | years. | | | | | | | | | | | | | | | | | | | | |
| 5921 | Weed: Incipient Control | PteGlo | Manuwai-PteGlo-01 | Monitor/control Pteglo along east Manuwai ridge between LZ and Alaiheihe fence juction, quarterly. Survey/sweep whole ICA along fenceline. Target Hotspot 1A for intensive treatment, including area off fence. Flag plant locations to guide future efforts. Pick and remove from field any fruit. Use preemergent herbicide to exhaust seedbank. Consider removing soil in select locations. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 6536 | Weed: Incipient Control | PteGlo | Manuwai-PteGlo-02 | Monitor/control Pteglo at Kamaohanui LZ quarterly. Pick and remove from field any potentially mature fruit. Use preemergent herbicide to exhaust seedbank. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| | | | | Remove soil as feasible. | | | | | | | | | | | | | | | | | | | | |
| 7274 | Weed: Incipient Control | PteGlo | Manuwai-PteGlo-03 | Monitor/control Pteglo at West Fence site quarterly. Always look for PteGlo when conducting fence checks. Pick and remove from field any fruit. Use preemergent herbicide to exhaust seedbank. Remove soil as feasible. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 7542 | Weed: Incipient Control | PteGlo | Manuwai-PteGlo-04 | Monitor/control Pteglo at Alaiheihe Fence site quarterly. Always look for PteGlo when conducting fence checks. Pick and remove from field any fruit. Use preemergent herbicide to exhaust seedbank. Remove soil as feasible. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 7809 | Weed: Incipient Control | SchCon | Manuwai-SchCon-01 | Monitor/control SchCon at Puu 1825 spot quarterly, or/to every 6 months as numbers decrease. Pick and remove from field any fruit. Use preemergent. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 7808 | Weed: Incipient Control/ Survey | SchCon | Manuwai-SchCon-01 | Survey extent of SchCon infestation in Manuwai around Puu 1825, and in any appropriate habitat. Refine ICA boundaries as needed. Track areas swept in Weed_Survey_Polygon. Coordinate efforts with Blue Team. | X | X | | | | | | | | | | | | | | | | | | |
| 6520 | Weed: Survey | LopEru | | Map all known locations of Lophospermum erubescens (formerly Maurandya antirrihiniflora), create map of infestation. Use to decide how and if to control. | | | | | | | X | | | | | | | | | | | | | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 5994 | Weed: Survey | None | | Collect samples of unknown Pinus and Cupressus (pine and juniper) taxa along road. Need male and female cones and pictures of bark to make positive ID. Submit to Bishop. Evaluate for control. | | X | | | | | | | | | | | | | | | | | | |
| 5181 | Weed: LZ Survey | None | LZ-CHERRY-155 | Survey Cherry's Ranch LZ whenever used, not to exceed once per quarter. If not used, do not need to survey. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 2864 | Weed: LZ Survey | None | LZ-SBW-055 | Survey Kamaohanui LZ (55) whenever used, not to exceed once per quarter. If not used, do not need to survey. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 4395 | Weed: LZ Survey | None | LZ-SBW-057 | Survey Nalu's LZ whenever used, not to exceed once per quarter. If not used, do not need to survey. This does not include Fencing team visits (they have separate | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

**Action Table (Continued)**

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| | | | | action). | | | | | | | | | | | | | | | | | | | | |
| 7171 | Weed: LZ Survey | None | LZ-Manuwai-209 | Survey Manuwai MelTen LZ (209) whenever used, not to exceed once per quarter. If not used, do not need to survey. | | | | | | | | | | | | | | | | | | | | |
| 6065 | Weed: Other Survey | None | | Survey Campsite on east ridge whenever used, not to exceed once per quarter. If not used, do not need to survey. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| 6067 | Weed: Transect Survey | None | WT-Manuwai-01 | Survey Manuwai upper access trail from fence gate at parking spot, up slope to ridge, and up the crest to the subunit 1/2 fence corner that heads down into gulch, and beyond to camp, ending at fence tag B-447. Survey annually. | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 4294 | Weed-Road Survey | None | RS-LKN-01 | Survey road from gate at top of Bob Cherry's ranch as far as can survey along LKN road. Also survey Western Access Road to parking spot to complete this survey. Survey every other year. | | X | | | | | | | | X | | | | | | | | X | | |
| 7154 | Weed: Survey | None | | Conduct aerial survey of canopy weeds in Manuwai, to guide IPA efforts. As needed. | | | X | | | | | | | | | | | | | | | | | |
| 5638 | Vegetation Monitoring | None | | | | | | | | | | | | X | | | | | | | | | | |

# Ecosystem Restoration Management Plan

## MIP Year 15-19, Oct. 2018 – Sept. 2023

## MU: Opaeula Lower I

### Overall MIP Management Goals:

- Form a stable, native-dominated matrix of plant communities which support stable populations of IP taxa.
- Control weed threats to support stable populations of IP taxa.

## Background Information

Location: Northern Koolau Mountains

Land Owner: Kamehameha Schools, U.S. Army Garrison – Hawaii (Army) lease

Land Managers: Army Natural Resource Program - Oahu (OANRP)

Acreage: 16-acres

Elevation Range: 1,920 ft. – 2,260 ft.

Description: Opaeula Lower is a 16-acre management unit (MU) located in the northern Koolau Mountain Range, on the island of Oahu. This MU is in the back of a side gulch off of Opaeula stream. Opaeula Lower is a part of the Kawailoa Training Area (KLOA) and is currently leased by the Army from Kamehameha Schools. The annual precipitation averages 3,816 millimeters (mm) (Giambelluca 2013) and elevation ranges between 1,920-2,260 feet. Because of the unique topography and the amount of precipitation in Opaeula Lower, there is one pond with year-round standing water and another pond that is seasonal. The plant community is classified as a montane wet forest. The vegetation is thick/dense and comprised of a mixture of native and introduced species, however it is predominately native. Many slopes are uluhe (*Dicranopteris linearis*) dominated. For a mid-elevation area in the Koolau Mountain Range, this MU has extremely unique native forest patches that have tall koa (*Acacia koa*) and ohia (*Metrosideros* spp.) trees. The Opaeula Lower MU can be accessed via the Peahinaia trail, however due to the length of the trail, OANRP uses helicopters to access the MU for management. Due to lack of military training in KLOA, OANRP is no longer required to manage Tier 2 or 3 taxa. However, these taxa and other rare taxa in Opaeula Lower benefit from ecosystem management for Tier 1 taxa across the MU.

**Native Vegetation Types**

| Koolau Vegetation Types | |
|---|---|
| Wet forest | Canopy includes: *Acacia koa*, *Metrosideros* spp., *Syzygium sandwicense*, *Cheirodendron* spp., *Cibotium* spp., *Ilex anomala*, *Psychotria* spp., *Myrsine* sp., and *Melicope* spp.<br><br>Understory includes: *Dicranopteris linearis*, *Freycinetia arborea*, *Alyxia stellata*, *Dianella sandwicensis*, *Melicope* spp., *Psychotria* spp., *Cibotium chamissoi*, *Machaerina angustifolia*, and *Broussaisia arguta*. |
| | NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted. |

## Terrain and Vegetation Types at Opaeula Lower

Top row- Typical vegetation at Opaeula Lower.
Bottom left- the larger of the two ponds in Opaeula Lower.
Bottom right- *Gardenia mannii* on Puu Melicope.

**MIP/OIP Rare Resources Opaeula Lower**

| Organism Type | Species | Pop. Ref. Code | Population Units | Management Designation | Wild/ Reintroduction |
|---|---|---|---|---|---|
| Plant | *Cyrtandra dentata* | OPA-F | Opaeula | MFS /T1 | Wild |
| Plant | *Gardenia mannii* | OPA-A, B, OPA-T, PAA-K | Lower Peahinaia | MFS/T1 GSC/T1 | Wild and Reintroduction |
| Plant | *Melicope lydgatei* | OPA-D*, E*, F, M, PAA-L | Kawaiiki and Opaeula | MFS/T2 | Wild |
| Plant | *Myrsine juddii* | PAA-H | Kaukonahua to Kamananui-Koloa | T2 | Wild |
| Plant | *Phyllostegia hirsuta* | OPA-G* | Helemano and Opaeula | GSC/T1 | Wild |
| Insect | *Drosophila substenoptera* | OPA-A | Lower Opaeula | MFS/T1 | Wild |

MFS= Manage for Stability GSC= Genetic Storage Collection *= Population Dead T1 = Tier 1 T2=Tier 2

**Other Rare Taxa at Opaeula Lower**

| Organism Type | Species | Status |
|---|---|---|
| Plant | *Cyanea lanceolata* | Endangered |
| Plant | *Exocarpos gaudichaudii* | Endangered |
| Plant | *Joinvillea ascendens* subsp. *ascendens* | Endangered |
| Plant | *Stenogyne kaalae* subsp. *sherffii* | Endangered, outplanted in 2013 with Oahu Plant Extinction Prevention Program (OPEPP). |
| Mollusc | *Achatinella curta* | Extirpated; last observed by Dr. Hadfield in 1998. |
| Mollusc | *Achatinella sowerbyana* | Extirpated; last observed 1996 |
| Insect | *Drosophila craddockae* | Rare |

**Rare Resources at Opaeula Lower**

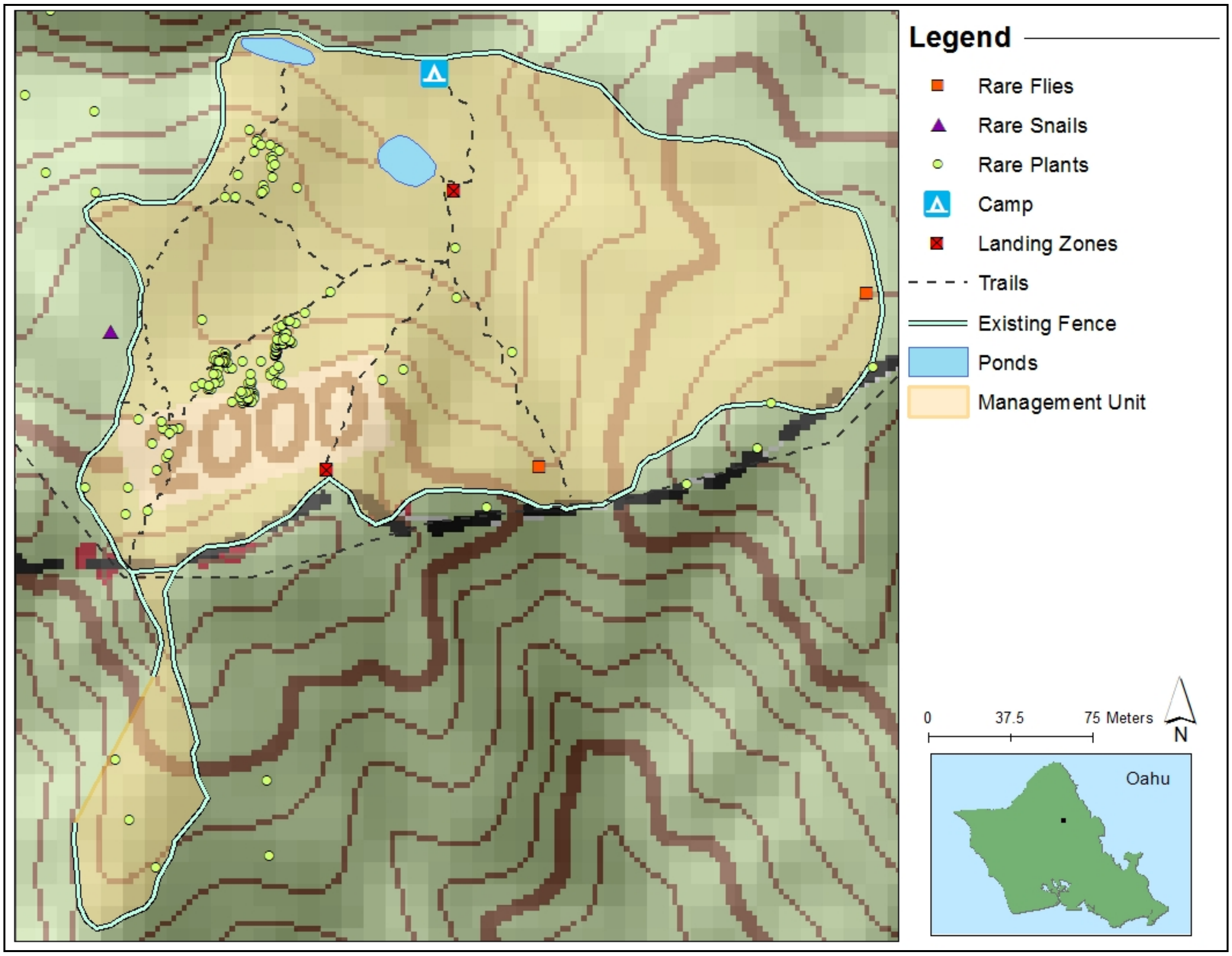

*Gardenia mannii*

*Stenogyne kaalae* subsp. *sherffii*

*Cyrtandra dentata*

*Drosophila substenoptera*

## Locations of Rare Resources at Opaeula Lower




## Threats to MIP/OIP MFS Taxa

| Threat | Taxa Affected | Management Strategy | Current Status |
|---|---|---|---|
| Rats | All | A24 trapping grid | Rodent damage has been observed in the past on *Cyrtandra dentata*. Snap traps were established in 2016 around the population. In April 2018, the trapping grid was converted to 50 A24s encompassing the whole MU. |
| Pigs | All | Fence | Area fenced and ungulate-free. |
| Weeds | All | Focus on IP rare taxa sites primarily, across MU secondarily. | Regular maintenance required several times per year. Weeds are a threat to both understory and canopy across the whole MU. |
| Fire | None | N/A | Fire is expected to be highly unlikely given the wet habitat at Opaeula Lower. In the unlikely event of a fire, OANRP will assist by providing information on rare resources and trails to incident command, and may also provide air support. |

**Threats to MIP/OIP MFS Taxa (Continued)**

| Threat | Taxa Affected | Management Strategy | Current Status |
|---|---|---|---|
| Black Twig Borer (BTB) | *Melicope lydgatei* | No effective control methods available. | No control feasible at this time, since the current BTB control methods are not effective. In addition, *M. lydgatei* is a T2 OIP species and is not being actively managed. |
| Slugs | *Cyrtandra dentata, Gardenia mannii, Phyllostegia hirsuta, Myrsine judii* | Yes. Treat IP rare plant sites with molluscide. | Area has been surveyed by an experienced malacologist to determine whether native snails are present. No native snails have been found. Currently, FerroxxAQ is applied quarterly only around the *C. dentata* population, which has had observed slug damage in the past. Slug damage has not been seen on other T1 taxa. |
| Ants | *Drosophila substenoptera* | Annual surveys | Only *Solenopsis papuana* is currently known from the area; may impact rare taxa populations Control may be warranted if more problematic species become established. |

**Management History**

- 1999- May 2001: Initial management began with the use of snares in the area. OANRP ran the snare groups, but removed them due to the area being accessed by hunters.
- 1998-2000: OANRP surveys MU and proposed fenceline for *A. sowerbyana* and *A. curta*, which was reported by Dr. Hadfield. No rare snails were found during those rare snail surveys.
- 2001: Funding for a portion of the MU fence from DLNR was funneled through the Koolau Mountain Watershed Partnership.
- 2002-2003: OANRP begins weed control in flat portions of MU near the pond. However, it was soon discontinued as OANRP staff observed severe pig damage in freshly weeded areas.
- 2011: Staff conduct initial line clearing for fence construction in June. The fence construction was completed in December.
- 2011: During the fence construction, large stands of *Psidium cattleianum* are removed in order to create a camp site for OANRP staff. The area soon turned into grass (*Urochloa maxima* and *Paspalum conjugatum*). This was a major change to the MU's infrastructure and landscape.
- 2012: OANRP resumes snaring to remove any ungulates from the MU. The unit was declared ungulate-free.
- 2012: A tree fall on fence was observed by staff in April during a routine fence check. Staff observed ungulate sign within the fence, so snare groups were promptly set. By June, OANRP caught seven pigs in snares and the unit was deemed pig-free.
- 2012: OANRP resumes ecosystem weed control in the flat areas of the MU.
- 2012: *Rhynchospora caduca*, an incipient weed species not commonly found in Opaeula Lower, was first discovered by staff along the Peahinaia trail that follows the MU fenceline.
- 2013: The Oahu Plant Extinction Prevention Program (OPEPP) reintroduced a population of *Stenogyne kaalae* subsp. *sherffii* in the MU.
- 2013: Due to Army training level changes and a decrease in funding, OANRP no longer receive funding to work with T2/T3 taxa and work on these species halts. MIP/OIP taxa in Lower

Opaeula only to include *Cyrtandra dentata* and *Gardenia mannii*. OANRP no longer manages for *Melicope lydgatei* and *Myrsine juddii*.

- 2013-2014: OANRP conducted a *Clidemia hirta* control trial to gain a better understanding of how quickly *C. hirta* grows in Opaeula Lower. Results from this trial helped to inform the most effective ways to control *C. hirta*.
- 2013: LZ Frog pond was discontinued due to safety concerns of the unstable muddy grounds, the lack of wind for helicopter lift, and the tall trees surrounding the LZ. OANRP began and currently uses LZ Puu Curta. Although LZ Frog pond was discontinued as an LZ, it still used as a drop zone for camping gear.
- 2015: Staff Surveyed for slugs and native snails in the MU, especially around *C. dentata* population, to gauge need for possible future slug control.
- 2015: OANRP installed fickle fence skirting along the existing fenceline to prevent piglets from entering unit along fence sections below pond/behind camp where pressure is highest.
- 2016: A platform for the future weather port was built by the staff for camping since the area in the MU is constantly muddy and wet.
- 2016: OANRP installs a small localized grid of Victor snap traps around the *C. dentata* population following observations of rat predation of the fruit.
- 2016: OANRP reintroduced *G. mannii* (OPA-A) by the wild *G. mannii* (OPA-B) population. This is the first *G. mannii* reintroduction in this MU.
- 2016: OANRP begins control for slugs around *C. dentata* using Sluggo.
- 2017: OANRP constructed a weather port where the old platform was located.
- 2017: Two new *R. caduca* ICAs were found by staff by the newly constructed weather port and along the Melicope finger fenceline. Because of the new discoveries, OANRP starts to mix a pre-emergent pesticide (sulfomet) to control the seed bank as well as the plants found.
- 2017: Staff noticed fickle skirting beginning to deteriorate/fail due to the extreme soil moisture, but unit remains pig-free. OANRP will investigate using longer lasting materials to replace the deteriorating fickle skirting.
- 2017: OANRP discovers *Setaria palmifolia* along the MU fenceline and around the “little” pond. Although *S. palmifolia* is found elsewhere in the Koolau Mountain Range, is was never previously observed in this MU. Thus, a new ICA was created. Staff check and control ICA quarterly.
- 2017: The use of Sluggo is discontinued since FerroxxAQ, a more effective and longer lasting molluscicide, was approved for forestry-use. OANRP currently uses FerroxxAQ for the *C. dentata* site.
- 2018: OANRP planted more *G. mannii* (OPA-A). To increase native habitat, staff also reintroduces common native shrub *Clermontia kakeana*. This was the restoration action to occur in the MU. OANRP plans to plant more common native species around the G. mannii and weather port in the next few years.
- 2018: OANRP converted the Victor snap trapping grid around the *C. dentata* to a GoodNature A24 grid of 50 traps across MU.

## Ungulate Control

Species: *Sus scrofa* (Pigs)

Threat Level: High

Management Objective:

- Maintain MU as ungulate-free.

Strategy and Control Methods:

- Fence constructed in 2011.
- Maintain the fenced area as ungulate-free by maintaining fence.
- Monitor for sign while checking the fence (inside/outside) and conducting other management actions. Outside activity is reported to gauge pig pressure.
- Conduct quarterly fence checks and monitor stream crossings after storms.
- Document pig sign during vegetation monitoring transects.
- As fickle skirting deteriorates, a suitable replacement may need to be found and installed in the future.

Discussion: The MU fence is 1.397 kilometers long and encompasses 16 acres. The major threats to the perimeter fence are tree falls and erosion. There are many large, old trees in the area. After the fence was completed, snares were set and monitored for a year. No ungulates were caught during this time and there was no activity within the fence. In 2012, tree fall damaged the fence and ungulate sign was observed. Snares were set again and monitored for a few months. Several pigs were successfully caught and removed from the MU. The fence was then deemed ungulate-free. Snares were also set outside the fence to reduce pig pressure. As of 2018, all snares have been removed from inside and outside of the MU. The fence is currently ungulate free. However, if there continues to be heavy pig activity outside of the fence, especially close to the weather port, snares may be set again outside of fence to reduce pressure. The vegetation along the fence will be maintained low (especially grasses and uluhe) to facilitate quarterly monitoring. This weed control is discussed in the Weed Control section. Special emphasis will be placed on checking the fence after extreme weather events since part of the fenceline runs through the “little” pond, which often times is submerged halfway under water. This may deteriorate the fence materials faster, erosion can occur, and/or cause debris to pile up, which can create high spots for pigs to climb over the fence. Monitoring for ungulate sign will occur during the course of other field activities.

# Weed Control

Weed Control actions are divided into 4 subcategories:

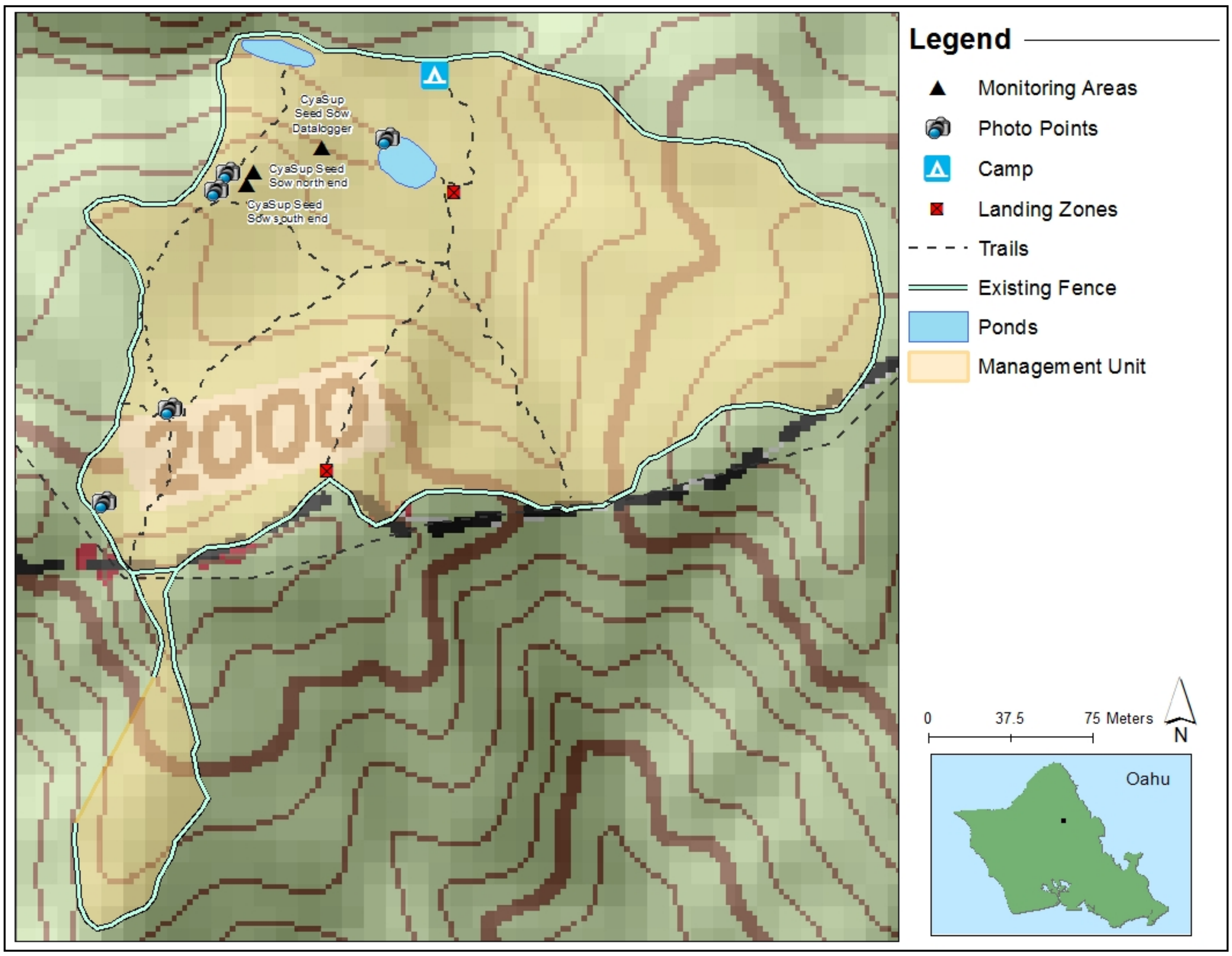
1) Vegetation Monitoring
2) Surveys
3) Incipient Taxa Control (Incipient Control Area - ICAs)
4) Ecosystem Management Weed Control (Weed Control Areas - WCAs)

These designations facilitate different aspects of MIP/OIP requirements.

## Vegetation Monitoring

Due to small size and high density of native vegetation in the MU, belt plot transect protocols implemented at other MUs are not appropriate here. Instead, OANRP has adapted the photo point method of monitoring the changes of the plant community existing in the MU since this was the easiest monitoring method tool to use at the time. Photo points capture change in vegetation qualitatively, however these are not set up to be analyzed. Instead, these photo points were established in order to document the vegetation changes following weeding efforts and around the *Gardenia mannii* population. If the Blue team takes on more aggressive weeding control efforts by removing large stands of *Psidium cattleianum* and outplanting more native common species, OANRP may use point intercept monitoring to document vegetation changes quantitatively. Future use of a drone to capture the vegetation changes in this MU may be used.

**Vegetation Monitoring Areas and Photo Points Map**



## Surveys

Potential Vectors. The Army conducts helicopter training in Kawailoa. The nearby Puu Curta LZ is not currently used by the Army, however OANRP staff use this LZ to access Opaeula Lower MU. Because of the difficulty of accessing the area via hiking, it is unlikely for recreational hikers to access the MU. However, the Peahinaia trail, which was a public trail, is nearby. The trail has since been overgrown and is not used. If recreational hikers are observed near the MU, a weed transect survey may be established to track the weed species seen in Opaeula Lower. OANRP staff, ungulates and birds are all possible vectors of new weed species.

Management Objective:

- Prevent the establishment of any new invasive alien plant or animal species through regular surveys along trails, LZs, campsites and other high traffic areas (as applicable).

Strategy and Control Methods:

- Quarterly surveys of LZ PMH 190 (Poamoho Connex) and LZ KLO 33 (Puu Curta).
- Quarterly survey of the weather port/camp (if used).
- Note unusual, significant or incipient alien taxa during the course of regular field work. Map and complete Target Species form to document sighting.
- Novel alien taxa found will be researched and evaluated for distribution and life history. If taxa found are to pose a major threat, control will begin and will be tracked via ICAs.
- Annual survey of Poamoho road.

Discussion: Surveys are designed to be the first line of defense in locating and identifying potential new weed species. Staff should always be vigilant on finding any new weed species while working in the MU. During a quarterly fence check, *Rhynchospora caduca* was first discovered along the fenceline. This was most likely introduced to the MU by the fence materials that flew from an LZ that had *R. caduca*. *R. caduca* is established along the Poamoho road and the Poamoho Connex LZ. Both Poamoho road and Poamoho Connex LZ are high traffic points that may introduce new weed species to Opaeula Lower MU.

### Incipient Taxa Control

All weed control geared towards eradication of a particular invasive weed is tracked via Incipient Control Areas, or ICAs. Each ICA is species-specific and geographically defined. One infestation may be divided into several ICAs or one ICA, depending on infestation size, topographical features, and land ownership. Some ICA species are incipient island-wide, and are a priority for ICA management whenever found. Others are locally incipient to the MU, but widespread elsewhere. In either case, the goal is eradication of the ICA. The goals, strategies, and techniques used vary between ICAs, depending on terrain, surrounding vegetation, target taxon, size of infestation, and a variety of other factors.

Two incipient species *R. caduca* and *Setaria palmifolia* have been identified by OANRP. *R. caduca* is new to the MU and was likely introduced by management efforts. There are currently three *R. caduca* ICAs and one *S. palmifolia* ICA that are being treated quarterly. OANRP will control *R. caduca* in order to remove all matures within the MU. Return visits will be scheduled in order to prevent immature individuals from reaching maturity. OANRP will continue to monitor and consider control on other possible incipient plant species when appropriate.

Management Objectives:

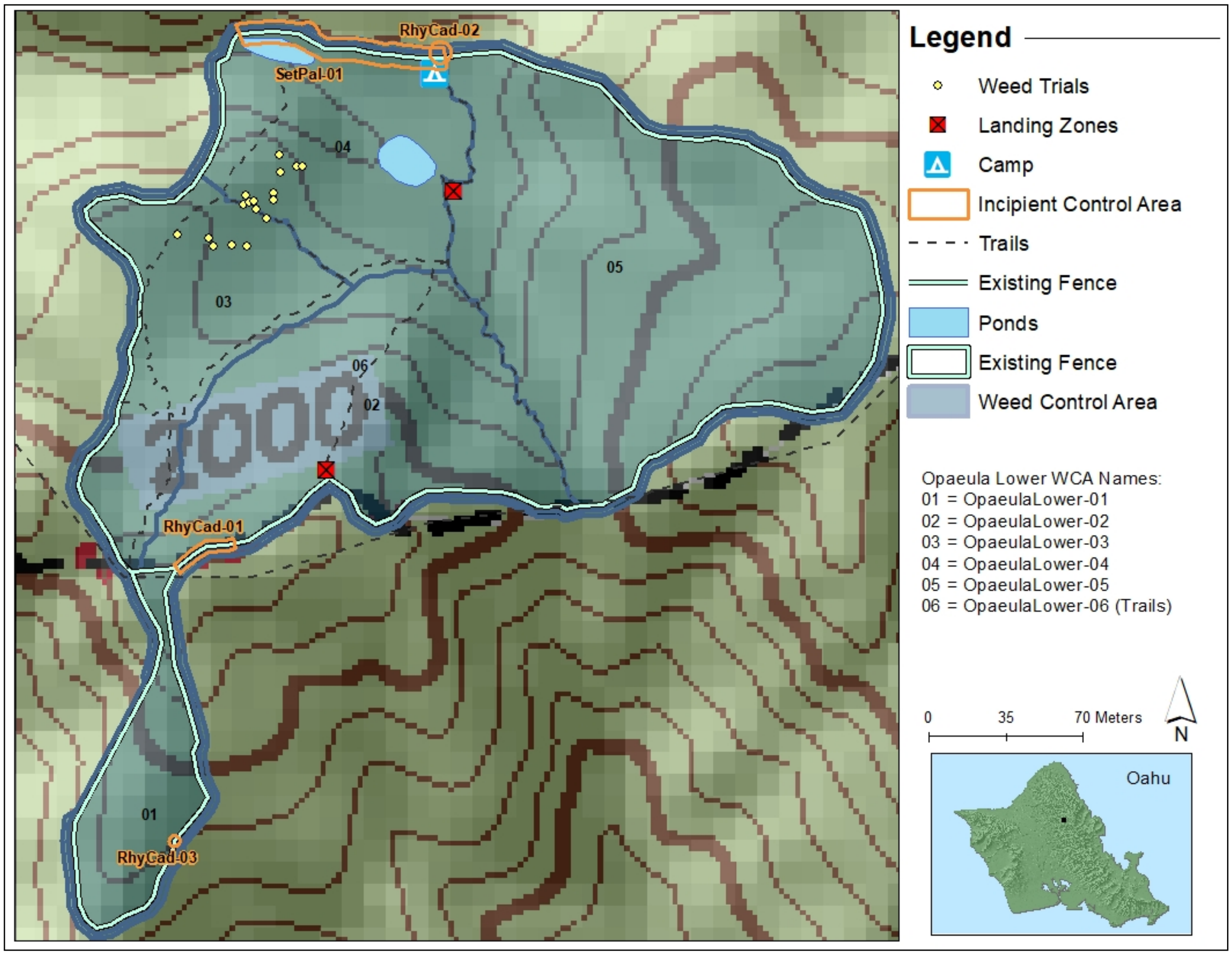
- Eradicate ICAs through regular and thorough monitoring and treatment. In the absence of any information about seed bank longevity for a particular species, eradication is defined as 10 years of consistent monitoring with no target plants found.

- Study seed bank longevity of ICA taxa, and revise eradication standards per taxon.
- Evaluate any invasive plant species newly discovered in MU, and determine whether ICA-level control is warranted. Factors to consider include distribution, invasiveness, and location, and infestation size, availability of control methods, resources, and funding.

Strategy and Control Methods:

- Species and ICAs are listed in the table below. History and strategy is discussed for each species.
- Monitor the progress of management efforts, and adjust visitation rates to allow staff to treat plants before they mature. Remember that one never finds 100% of all plants present.
- Use aggressive control techniques whenever possible.

**Survey locations, Incipient and Weed Control Areas Map**



## Summary of ICAs

| Taxon | ICA Code | Control Discussion |
|---|---|---|
| *Rhynchospora caduca* | LowerOpaeula-RhyCad-01 | All three ICAs are monitored and treated quarterly. *R. caduca* is a high priority for control as it is not found throughout the MU and thrives in wet environments. The Poamoho Connex LZ, used to access this MU, is infested with *R. caduca*. This ICA is found along the Peahinaia. Five mature plants were discovered in 2012 and controlled by foliar application using a Ranger Pro, water, and pre-emergent mixture. Seed heads are removed and bagged. Although the original spot where *R. caduca* was found has been effectively controlled, the *R. caduca* continues persist and is moving along the fenceline. There are some areas in the ICA where it is difficult to search/see *R. caduca* since the uluhe can be quite thick. Staff will continue to control ICA and will GPS any hotspots. |
| | LowerOpaeula-RhyCad-02 | This ICA is located by the weather port. *R. caduca* was found in 2017. Three mature and about 30 immature plants were observed outside of the fenceline and were buried under the *Setaria palmifolia* ICA. |
| | LowerOpaeula-RhyCad-03 | This ICA is located along the Melicope finger trail. Two mature and 5 immature *R. caduca* were found in 2017 during a fence check. |
| *Setaria palmifolia* | LowerOpaeula-SetPal-01 | There is one site of this taxon close to the weather port and was first discovered in 2017 just outside the fence. About 10 *S. palmifolia* plants were found that time. A few months later, the S. palmifolia spread along the fenceline. About 20 mature and 40 immature plants were found and treated. Currently, there are two distinct hotspots that have been monitored and controlled. This is a high priority for control, as *S. palmifolia* is a highly invasive grass that is not found throughout the MU. *S. palmifolia* is effectively controlled by frequent visits by foliar application using Ranger Pro, water, and a pre-emergent pesticide. Seed heads are removed and bagged. |

## Incipient Weed Photos

Pictures of mature *Rynchospora caduca*

## Ecosystem Management Weed Control

All weed control geared towards general habitat improvement is tracked in geographic units called Weed Control areas, or WCAs. The goals, strategies, and techniques used vary between WCAs, depending on terrain, quality of native habitat, and presence or absence of rare taxa.

MIP Goals:

- Within 2 m of rare taxa: 0% alien vegetation cover except where removal causes harm.
- Within 50 m of rare taxa: 25% or less alien vegetation cover
- Throughout the remainder of the MU: 50% or less alien vegetation cover

Management Objectives:

- Focus weeding around *Gardenia mannii* and *Cyrtandra dentata* populations to expand suitable native habitat.
- Maintain 50% or less alien vegetation cover in the understory across the MU.
- Reach 50% or less alien canopy cover across the MU in the next 5 years.
- In WCAs within 50m of rare taxa, work towards achieving 25% or less alien vegetation cover in understory and canopy.
- Modify weeding efforts if population monitoring indicates weed control efforts are not contributing to stable population growth.

Discussion: OANRP weed control at Opaeula Lower is focused on reducing alien vegetation encroachment on the populations of *C. dentata* and *G. mannii*, however T2/T3 OIP taxa also benefit when weeding throughout the MU. The major weed threats in the MU are *P. cattleianum* and *C. hirta*, which have the potential to form dense monotypic stands, and are a dominant presence in other areas of the Koolau Mountains. From 2013-2014, OANRP conducted *C. hirta* control trials to evaluate how fast *C. hirta* was able to re-invade weeded areas. The trial was able to show that *C. hirta* weeded areas were best to re-visit weed control within 6 to 12 months. If re-visitation to weed do not happen within 6 to 12 months, *C. hirta* will return to near prior weeding levels. Additionally, in order to give potential native recruitment a chance to grow, re-visits are not recommended any time before 6 months from weeding the area. This experiment also revealed that if weeding occurs in *C. hirta* dominated areas, non-native grass quickly invaded the area, so grass control should be coupled with *C. hirta* management (OANRP, 2015).

Another priority for weed control in Opaeula Lower will focus on conducting ground sweeps across all portions of the MU where the more intact native forest patches are, targeting *P. cattleianum* and other weeds (listed in the Summary Target Taxa table). The entire MU has been divided into Weed Control Areas (WCAs) to assist in tracking and scheduling control efforts. WCAs will be weeded on a rotational basis given the difficulty of access, terrain, and limited staff resources. The WCAs that are most accessible, have the gentlest terrain, the rarest resources, and the fewest weeds will be prioritized for control. If the Blue team decides to remove stands of *P. cattleianum*, the use of a chipper and aggressively outplanting common native plant species must also happen.

The table below summarizes invasive weeds found at Opaeula Lower, excluding ICA species. While the list is by no means exhaustive, it includes the species targeted/prioritized for control. The distribution of each taxon is estimated as: Widespread (moderate to high densities of individuals, common across MU), Scattered (low densities across all or much of the MU), or Restricted (low or high densities, all in one discrete location).

**Summary of Target Taxa:**

| Taxa | Distribution | Notes |
|---|---|---|
| *Angiopteris evecta* | Scattered | Incidental observations of *A. evecta* around the MU have been made. Plants seen should be GPSed and removed manually or with herbicide. The adjacent gulches are infested with this taxa, which feed spores into Opaeula Lower. Control is a high priority. Control any plants found during regular weed sweeps using Garlon4 or Polaris (for large mature plants). Also control plants seen outside the MU, if near the fence. Conduct aerial surveys as needed to guide ground treatments. |
| *Citharexylum caudatum* | Scattered | Trees are scattered across MU and the presence of numerous seedlings and saplings point to an increase of this taxa within Opaeula Lower. While not as prone to forming monotypic stands as *P. cattleianum*, this taxa should be controlled due to it having bird dispersed seeds and its aggressive competition with native shrubs and trees. |
| *Clidemia hirta* | Widespread | Widespread throughout the MU. *C. hirta* has the potential to grow into monotypic stands. OANRP targets this taxa around rare taxa. Follow-up on C. hirta removal must be no more than a year, otherwise *C. hirta* will grow back quickly. |
| *Lantana camara* | Widespread | One large patch was at campsite in OpaeulaLower-04 and has since been controlled. *L. camara* is scattered throughout the MU and should be targeted when weeding through the MU. |
| *Leptospermum scoparium* | Unknown | Not known in Opaeula Lower at this time, however, vigilance is important in keeping it out of the MU. *L. scoparium* is commonly found in the adjacent areas of this MU and the seeds are wind dispersed. There are known and managed ICAs along the Poamoho road. If found in the MU, it would be a priority for control and will be an ICA. |
| *Paspalum conjugatum* | Widespread | Concentrated around the campsite and ponds in OpaeulaLower-04, but also scattered throughout the MU. *P. conjugatum* is controlled around the campsite, trails, and around rare taxa. Ranger Pro for Aquatic use is applied around the weather port and camp DZ to control *P. conjugatum*. While, Fusilade sprayed around rare taxa to control *P. conjugatum*. |
| *Pterolepis glomerata* | Widespread | This melastome is ubiquitous across the Koolaus. It thrives in disturbed areas, particularly pig wallows. NRS do not currently target it for control but now that pigs have been excluded, hopefully native vegetation will colonize *P. glomerata* zones, as anecdotally observed in the Opaeula fence. |
| *Psidium cattleianum* | Widespread | Patches scattered across Opaeula Lower. Primary target of WCA sweeps for isolated stands in the more native and intact forest patches. In the Koolaus, *P. cattleianum* take on a multi-trunked clump form and have the proclivity for slash to re-sprout. The largest and thickest stands tend to be in gulches and draws. |
| *Sphaeropteris cooperi* | Scattered | Scattered individuals in the middle of the MU, especially in OpaeulaLower-03. Lower Opaeula is perfect habitat for *S. cooperii*, and many immature plants have already been removed from the MU. Few large, mature individuals have been found. Due to its documented invasiveness, it is a priority for control. The most effective control method is to cut-stump with no herbicide application. |
| *Urochloa maxima* | Scattered | One population treated at campsite in OpaeulaLower-04. While the habitat here is a little wet for this grass, its habitat-altering characteristics make it a control priority. Target when seen in MU. Possibility for eradication. |

Restoration activities are discussed in the notes section for each WCA. The table below contains specific notes on what native taxa and what type of stock may be appropriate for restoration projects at Opaeula Lower.

**Taxa Considerations for Restoration Actions**:

| Native Taxon | Outplant? | Seedsow/ Division/ Transplant? | Notes |
|---|---|---|---|
| *Acacia koa* | Yes | No | Tree. Fast-growing. Easily grown from seed. |
| *Alyxia stellata* | Yes | Seed sow | Fast-growing shrub. Easily grown from seed. |
| *Cheirodendron trigynum* | Yes | No | Tree. Moderately fast-growing. |
| *Cibotium* spp. | No | Transplant | Fern. Translocate *Cibotium* spp. along and outside the fenceline into weeded areas. |
| *Clermontia kakeana* | Yes | No | Easily grown from seed. |
| *Dianella sandwicensis* | No | Division | Small shrub. Grows easily from divisions. |
| *Freycinetia arborea* | Yes | Seed sow | Can grow from seeds; slow to reach outplant size. |
| *Ilex anomala* | Yes | No | Small tree. Slow growing. Can grow from seed. |
| *Metrosideros polymorpha* | Yes | No | Slow growing tree. Can grow from seed and cuttings. |
| *Microlepia strigosa* | No | Division | Fern. Translocate *M. strigosa* from along the fenceline. |
| *Polyscias oahuensis* | Yes | No | Tree. Easily grown from seed. |
| *Pipturus albidus* | No | Seed sow | Fast-growing. Easily grown from seed. |
| *Psychotria* spp. | Yes | No | Tree. Can grow from seed. |
| *Scaevola* spp. | Yes | No | Fast-growing. Easily grown from seed. |

**WCAs: OpaeulaLower-01 (Melicope Finger Fence)**

Veg Type: Wet Montane

OIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: All woody species, particularly *Psidium cattleianum*, *Clidemia hirta*, and *Citharexylum caudatum*.

Notes: This is the southernmost WCA and encloses a *Melicope lydgatei* rare plant population. The majority of this WCA is dominated by *Dicranopteris linearis*, with a *Metrosideros polymorpha* and *Acacia koa* overstory. Most of the weeds (*C. hirta* and *C. caudatum*) are concentrated at the southern end of the WCA near the stream bottom and low lying areas. This area is also under consideration for additional *Gardenia mannii* reintroduction with the hope of replicating wild sites and other successful reintroductions in West Range in *D. linearis* dominated habitat. Weed sweeps will concentrate on *C. hirta* removal around rare taxa locations and native forest patches every 3-5 years. If the site becomes a *G. mannii* reintroduction site, weeding efforts in the bottom of the WCA will be scheduled.

**WCA: OpaeulaLower-02 (Puu Curta Slopes/Ridge)**

Veg Type: Wet Montane

MIP/OIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover.

Targets: All woody species, particularly *P. cattleianum* and *C. hirta*.

Notes: Rare plants in this WCA include *Cyrtandra dentata*, *Melicope lydgatei* and *Exocarpos gaudichaudii*.

This WCA encompasses northern slopes of Puu Curta and the vegetation is predominantly native, with a heavy *D. linearis* understory. Weed sweeps will focus on *P. cattleianum* and *C. hirta*, which are concentrated in the lower part of the WCA. This WCA also contains the main landing zone for the MU, as well as a *Rhynchospora caduca* ICA along the southwest fenceline. The main focus in this WCA are to minimize alien cover around the *C. dentata* plants. Other high priority actions are to maintain trails and fencelines as needed in order to facilitate other work in this area. Weed sweeps in native areas that are *D. lineraris* and native dominated and steep will utilize spotters with binoculars to direct targeted weed control to minimize damage to *D. linearis*. These sweeps are scheduled once every 3-5 years. Weed sweeps around the *C. dentata* plants are scheduled annually. Additionally, weeding canopy species should be gradual as the light gaps allow grass and *C. hirta* to invade area quicker.

**WCA: OpaeulaLower-03 (South-West exclosure)**

Veg Type: Wet Montane

OIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover elsewhere.

Targets: *Sphaeropteris cooperi* and *Angiopteris evecta.* All woody species, particularly *P. cattleianum, C. caudatum,* and *C. hirta.*

Notes: The flatter areas of this WCA contain large stands of nearly monotypic *P. cattleianum* and *C. hirta*, which are targeted for removal around the native-dominated forest patches and managed OIP taxa. Mature and immature *S. cooperi* and immature *A. evecta* have also been observed in the WCA and will be controlled weed sweeps once every 3-5 years. This WCA has an abundance of native species in some areas, including *M. polymorpha*, *Antidesma platyphyllum*, and *C. platyphyllum* in the canopy, and *Wikstroemia oahuensis*, *Psychotria hathewayi*, and *Cibotium* spp. in the understory. Rare plants in this WCA include *C. dentata* (wild) and a *S. kaalae* var. *sherffii* (reintroduction). Since OANRP does not manage *S. kaalae* var. *sherffii*, OANRP will coordinate with the Oahu Plant Extinction Prevention Program on weeding efforts around the *S. kaalae* var. *sherffii*. Photopoints to document changes in vegetation after weeding have been set throughout the WCA. Other high priority actions are to maintain trails and fencelines as needed in order to facilitate other work in this area.

**WCA: OpaeulaLower-04 (North-West Corner and Ponds)**

Veg Type: Wet Montane

OIP Goal: Less than 25% alien cover around rare plants. Less than 50% alien cover.

Targets: All woody species, particularly *P. cattleianum*, *Psidium guajava*, *C. caudatum*, and *C. hirta. Paspalum conjugatum*, *Urochloa maxima*, and *Lantana camara* will be targeted at the camp site and around the ponds.

Notes: This WCA is easy to access and weed sweeps can be conducted over the entire area. The "little" pond is located in this WCA, which maintains an open area of a native aquatic fern and weeds. This is the only area that will not be swept and will remain weedy. Weed sweeps to cover the whole WCA is to focus on select weed species, such as *Angiopteris evecta*, *Citharexylum caudatum*, and *Sphaeropteris cooperi* once every 3-5 years. Weed sweeps around the *Gardenia manii* reintroduction site are scheduled annually and the main focus is to control *P. cattleianum* and *C. hirta*. Other weeds including *P. conjugatum*, *U. maxima*, and *L. camara* will be targeted at the camp site and around the ponds. The western half of the WCA contains high amounts of native vegetation, including *W. oahuensis*, *Alyxia stellata, Freycinetia arborea*, and *Antidesma platyphyllum*. Photo points to document changes in vegetation after weeding are established near the main pond. Other high priority actions are to maintain trails and fencelines as needed in order to facilitate other work in this area. This WCA is the first area for restoration work. Minimal restoration efforts in this WCA began in 2017 (OANRP YER Restoration 2018). *Clermontia kakeana* plants have been outplanted around the *G. mannii* reintroduction site. There are plans to further expand restoration efforts to supplement native understory and canopy around the *G. mannii* and reduce alien dominated areas in other areas of the WCA. OANRP plans to continue restoration efforts for the next few years by slowly removing *P. cattleianum* and planting native common plants including *Acacia koa*, *Clermontia kakeana*, *Ilex anomala*, and *Cheirodendron trigynum*, especially in the native forest patches to increase native abundancy and decrease *C. hirta* and *P. cattleianum*.

**WCA: OpaeulaLower-05 (Puu Melicope Slopes/Fenceline/Blue Puu Curta trail)**

Veg Type: Wet Montane

OIP Goal: Less than 50% alien cover elsewhere.

Targets: All woody species, particularly *P. cattleianum, P. guajava, C. caudatum,* and *C. hirta.*

Notes: This WCA contains a high percentage of native vegetation, including *D. linearis*, *M. polymorpha*, *A. koa,* and *F. arborea*. There is a *M. lydgatei* rare plant population on the southern fenceline. Sweeps will be conducted to remove canopy weed species, every 3-5 years, across the WCA. Spotters with binoculars will be utilized to direct targeted weed control to minimize damage to *D. linearis*. There are two large non-native palms in this WCA that need to be identified and controlled. Understory weed control will be concentrated around the rare taxa and native forest patches. Other high priority actions are to maintain trails and fencelines as needed in order to facilitate other work in this area.

**WCA: OpaeulaLower-06 (Fence and Trails maintenance)**

Veg Type: Wet Montane

OIP Goal: N/A

Targets: *P. cattleianum*, *P. guajava, C. caudatum, C. hirta,* and alien grasses.

Notes: This WCA was created to maintain the main trails and the fencelines. The main trails are important to keep maintained since they are used as WCA boundaries.

## Small Vertebrate Control

Species: *Rattus rattus* (Black rat), *Rattus exulans* (Polynesian rat), *Mus musculus* (House mouse)

Threat level: High for *Rattus* spp. for *Cyrtandra dentata*. Unknown for *Gardenia mannii* and *Drosophila* spp.

Seasonality/Relevant Species Biology: Spikes in rodent population are often observed in other MUs following the fruiting season (about twice a year) of *Psidium catteleianum*, then followed by a return to normal activity levels. It is assumed rodent activity follows similar patterns.

Management Objectives:

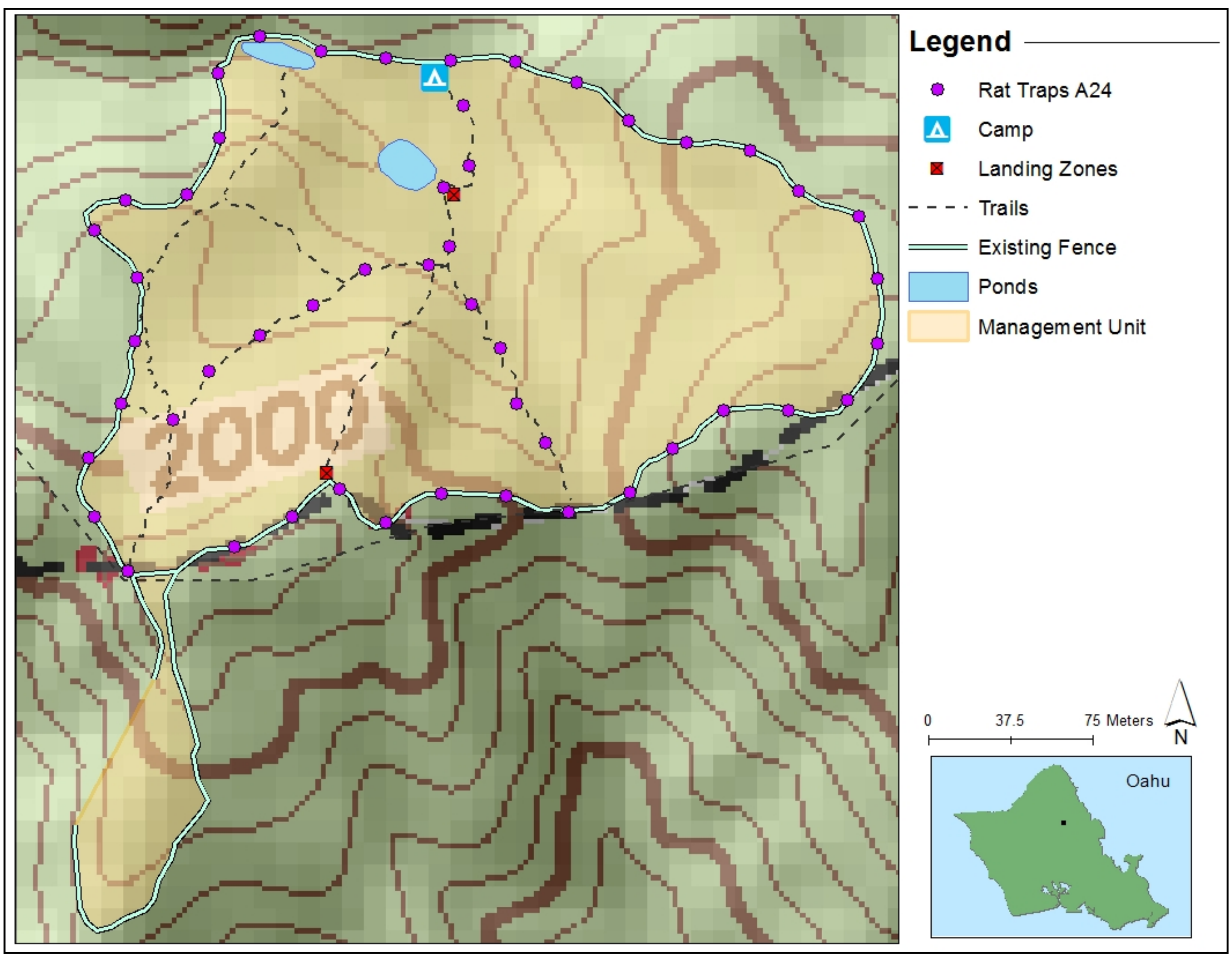
- Mitigate threat of rodent activity on managed plants.

Strategy and Control Methods:

- Active GoodNature A24 (50) grid across the MU. Traps are deployed every 20 m along trails and the perimeter fenceline.
- Monitor MIP/OIP rare plant (*C. dentata* and *Gardenia mannii*) populations, as well as other native species.

Discussion: Formerly rodent control was only conducted around the *C. dentata* reintroduction site using Victor snap traps. All Victor snap traps were replaced with GoodNature A24s to protect *C. dentata* year-round. Since this MU is relatively small in area, OANRP created a GoodNature A24 trapping grid encompassing the whole MU excluding the *Melicope* finger, since there are no IP species located there. OANRP staff check A24s every 4 months.

**Small Vertebrate Management Map**



## Ant Control

Species: *Solenopsis papuana* (Detected in August 2018)

Threat Level: High for endangered *Drosophila*.

Seasonality/Relevant Species Biology: Varies by species.

Management Objectives:

- Prevent spread of ant species into areas where not already established. Conduct annual surveys during the summer to determine what ant taxa are present in the MU.
- Implement control if incipient, high-risk species are found or if needed for *Drosophila* conservation.
- Detect incursions of new ant species prior to establishment.

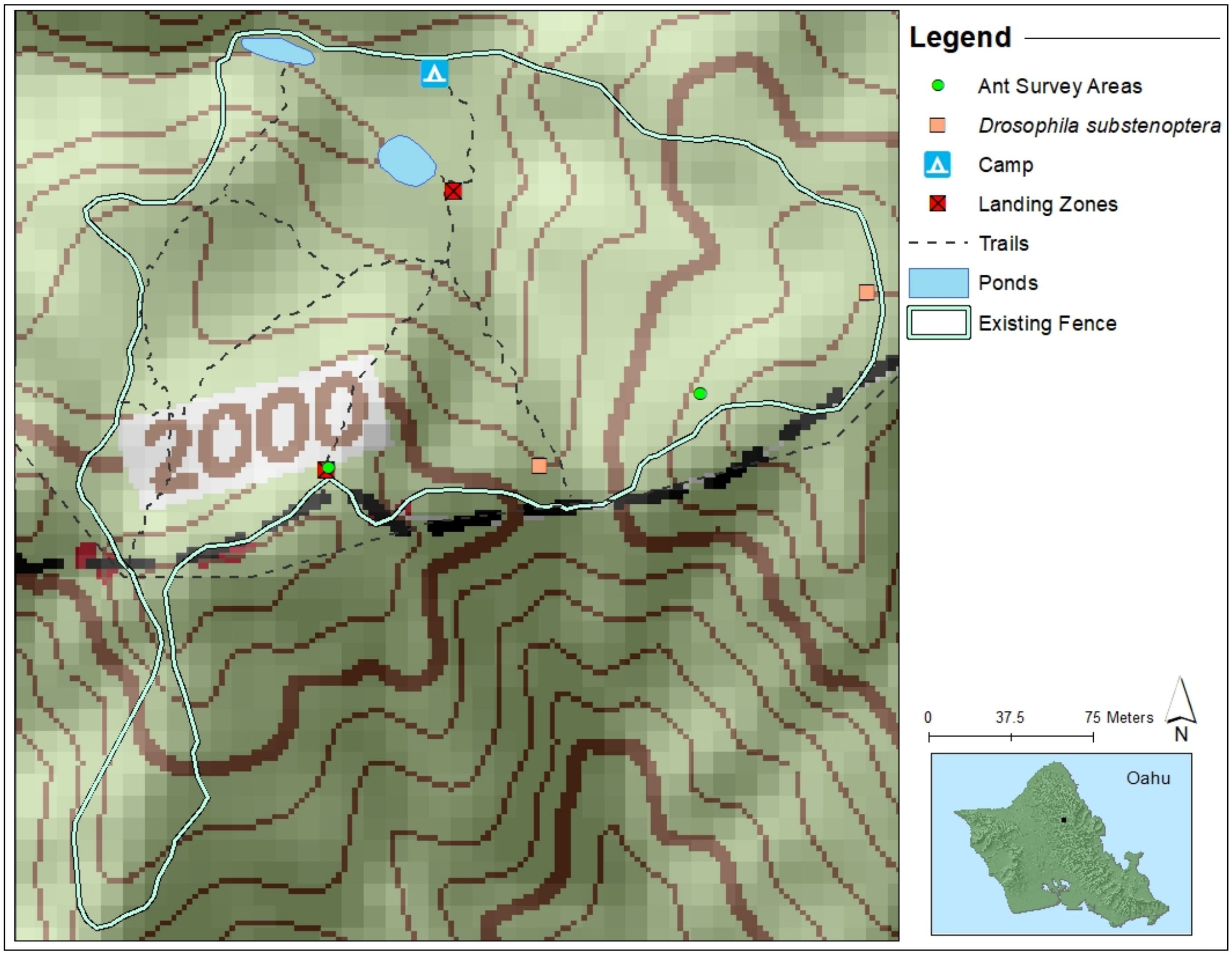
Strategy and Control Methods:

- Sample ants at human entry points using the standard survey protocol (Plentovich and Krushelnycky 2009) and *Drosophila* sites a minimum of once a year (see table below). Use samples to track changes in existing ant densities and to alert OANRP to any new introductions.
- If incipient species are found and deemed to be a high threat and/or easily eradicated locally (<0.5 acre infestation), begin control.
- Sample ants at campsite, LZ and Drosophila sites.

**Ant Survey Site Table**

| Site description | Reason for survey |
|---|---|
| Puu Curta LZ | High risk of accidental ant introduction. |
| *Drosophila substenoptera* area | *Drosophila* are sensitive to high ant abundance. |

**Ant Management Map**




Discussion: Surveying for ants at this MU was conducted twice in 2015 and 2016 around the camp site and no ants were detected. However, during *Drosophila* monitoring by the program's entomologist, *S. papuana* has been observed at the *D. substenoptera* sites along the fenceline. *S. papuana* is a known threat to *Drosophila* populations. If present, this species would be locally controlled using Amdro (registered for forest use). *S. papuana* is an aggressive ant specie that is known to reduce *Drosophila* survival by 58% (Krushelnycky *et al.* 2017). OANRP plans to conduct annual ant surveys at the LZ Puu Curta and the *D. subsenoptera* site along the fenceline.

## Slug Control

<u>Species</u>: *Deroceras leave*, *Meghimatium biliniatum* and *Limax maximus*

<u>Threat level</u>: High for *Cyrtandra dentata*.

<u>Seasonality/Relevant Species Biology</u>: Slugs are seasonally abundant during the wet season (September-May). However, due to the already wet environment in Lower Opaeula, slug population numbers can be sustained throughout the dry season.

<u>Management Objectives:</u>

- Control slugs locally to ensure germination and survivorship of *C. dentata*.
- Conduct annual census monitoring of T1 OIP rare plant taxa to look for seedling recruitment and slug herbivory.

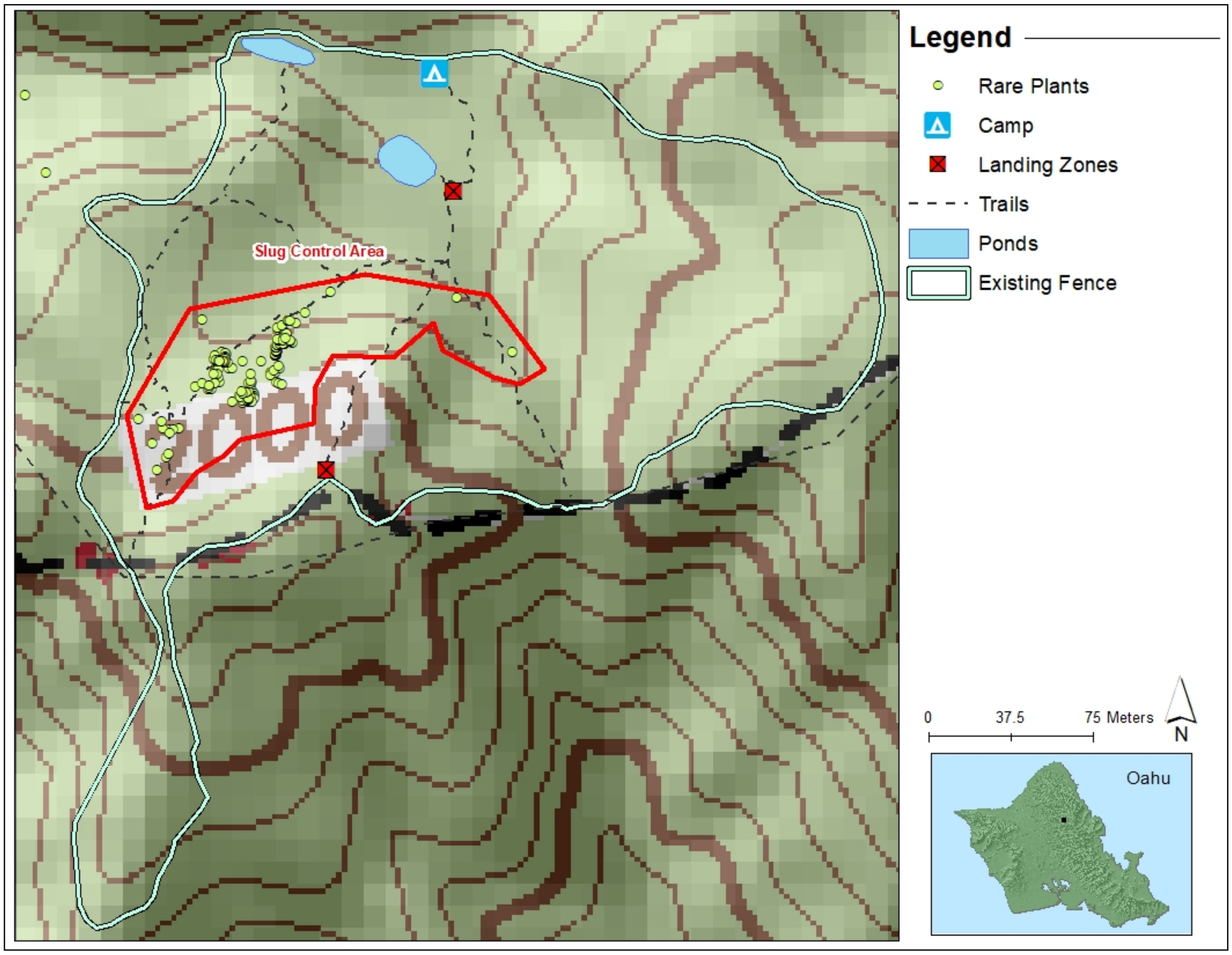
<u>Strategy and Control Methods:</u>

- Slug Control Areas (SLCAs) around rare taxa locations have been surveyed (2015) and cleared of native snails.
- FerroxxAQ is applied to these SLCAs once a quarter. FerroxxAQ is not applied within 20 m of known populations of native snails, however that are no native snails located in the MU.
- If new sites for rare plant reintroductions are chosen outside of the existing SLCAs, areas will be searched thoroughly by an experienced malacologists for slug densities and native snails during the day and at least one night prior to application of FerroxxAQ.

**Slug Control Area Locations Table**

| SLCA Code | Plant population reference codes | Date slug control begun |
|---|---|---|
| OPA-A | *C. dentata* (OPA-F) | 2016 |

## Slug Management Map




Discussion: Based on sampling at the *Cyanea superba* subsp. *superba* seed sow trial sites, slugs are present, but not abundant, at this site (Appendix 4-4 OANRP 2017). However, due to the low *C. dentata* recruitment, OANRP controls any slugs around the *C. dentata* population using molluscicide FerroxxAQ. Our current management actions (sampling slugs once per year and treating rare plants with molluscicide every quarter) are sufficient to mitigate this threat.

# Action Table

The table below is a comprehensive list of threat control actions planned for the MU for the next five years. Actions are grouped by type; for example, Ungulate Control or Ant Control. Weed control actions are grouped into the following categories: General Survey, ICA, or WCA code. Cells with **X** denote the quarters in which an action is scheduled. IP years run from October of one year through September of the next. Therefore, Quarter 4 (October-December) is listed first for each report year, followed by Quarter 1 (January-March), Quarter 2 (April-June), and Q3 (July-September). Species names are written as six-digit abbreviations, such as 'CenSet' instead of *Cenchrus setaceus*, for brevity.

| **Action ID** | **Action Type** | **Taxon Code** | **Action Site Code** | **Actions** | **MIP Year 15 Oct 2018-Sept2019** | | | | **MIP Year 16 Oct 2019-Sept2020** | | | | **MIP Year 17 Oct 2020-Sept2021** | | | | **MIP Year 18 Oct 2021-Sept2022** | | | | **MIP Year 19 Oct 2022-Sept2023** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| 7843 | Ant Monitoring | None | OPA-F | Sample ants using peanut butter and syrup at LZ and at Drosophila site, 10 baits at each site, leave for 1 hour (can leave longer but a minimum of 1 hour). Note weather. Avoid sampling on rainy cold days. If baits are left in the sunshine, place them in the shade under vegetation. | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 7444 | Ecosystem Restoration: Collections | None | | Obs/Collect common native plants for restoration use throughout Lower Opaeula MU. Collect from Lower Opaeula MU and/or appropriate nearby locations. General action for collections not specified for that year. Action includes monitoring phenology. | X | | | | X | | | | X | | | | X | | | | X | | | |
| 7715 | Ecosystem Restoration: Collections | CheTri | | Common native collection of Cheirodendron trigynum (Olapa): Collect/monitor fruit for use in restoration projects in Lower Opaeula and Seed Zone: OA-11. Action includes monitoring phenology of common native species. | | | X | | | | | | | | | | | | | | | | | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 7686 | Ecosystem Restoration: MU re-veg projects | None | OpaeulaLower-04 | Common native restoration actions in Opaeula Lower-04: Scoping, Planting (outplant, sows, divisions/transplants), Monitoring (plant monitoring, watering). | X | | | | | X | | | | X | | | | X | | | | | | |
| 3422 | Fence | None | KLO-A | All fence monitoring and maintenance actions. Maintenance is defined as any minor repair work or that is LESS THAN 100m. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 7748 | Rodent Control-RP | CyrDen | OPA-B | CyrDen.OPA-F | | X | | X | X | X | | X | X | X | | X | X | X | | X | X | X | | X |
| 7073 | Slug Control | CyrDen | OPA-A-1 | Please deploy 5 lbs of Sluggo or 2.5 lbs of FerroxxAQ quarterly at the CyrDen plants. Sluggo surveys, sluggo application-related activities. Work with Steph to conduct base monitoring. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6232 | Weed: Incipient Control | RhyCad | LowerOpaeula-RhyCad-01 | Monitor/control Rhycad at fenceline site quarterly/every 6 months. Dig out plants and remove from field, along with any potentially viable fruit. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 7475 | Weed: Incipient Control | RhyCad | LowerOpaeula-RhyCad-02 | Monitor/control Rhycad at platform site quarterly/every 6 months. Dig out plants and remove from field, along with any potentially viable fruit. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 7476 | Weed: Incipient Control | RhyCad | LowerOpaeula-RhyCad-03 | Monitor/control Rhycad at Melicope finger fence site quarterly/every 6 months. Dig out plants and remove from field, along with any potentially viable fruit. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 7541 | Weed: Incipient Control | SetPal | LowerOpaeula-SetPal-01 | Monitor/control SetPal at little pond site quarterly/every 6 months. Dig out plants and remove from field, along with | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

**Action Table (Continued)**

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| | | | | any potentially viable fruit. | | | | | | | | | | | | | | | | | | | | |
| 4432 | Weed: LZ Survey | None | LZ-KLOA-033 | Survey Puu Curta LZ whenever used, not to exceed once per quarter. If not used, do not need to survey. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 6231 | Photopoint Monitor | None | | Take photopoints installed across MU 1x year. | X | | | | X | | | | X | | | | X | | | | X | | | |
| 6245 | Weed Control | None | OpaeulaLower-01 | Sweep entire subunit for canopy weeds and sparse understory weeds, working slowly towards removing all Clihir, once every 2-3 years. Prioritize rare taxa locations and native forest patches. | | | | | | | | X | | | | | | | X | | | | | |
| 6249 | Weed Control | None | OpaeulaLower-02 | Conduct control in weedy gulch to west of Blue Curta Saddle trail. Target understory control, and gradual removal of canopy. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 7555 | Weed Control | None | OpaeulaLower-02 | Control weeds around CyrDen, annually. | | | | X | | | | X | | | | X | | | | X | | | | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6246 | Weed Control | None | OpaeulaLower-02 | Sweep entire WCA for canopy weeds and sparse understory weeds, once every 3-5 years. Use spotters with binoculars to guide control and minimize damage to uluhe. | | | | | | | X | | | | | | | | | | | | | |
| 7554 | Weed Control | None | OpaeulaLower-03 | Control weeds around CyrDen, annually. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 6243 | Weed Control | None | OpaeulaLower-03 | Control stands of Psicat and other dense weeds. Consider clearcutting, chipping, volunteer groups. | | | X | | | | | | | | | | | | | | | | | |
| 5919 | Weed Control | None | OpaeulaLower-03 | Sweep WCA once a year, targeting AngEve, SphCoo, CitCau in particular, and focusing on controlling Clihir and sparse canopy weeds in native forest patches and around rare taxa. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 6233 | Weed Control | None | OpaeulaLower-03 | Control grasses (mostly PasCon) in forested areas, every 6 months or as needed. | | | X | | X | | X | | X | | X | | X | | X | | X | | X | |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6234 | Weed Control | None | OpaeulaLower-03 | Control weeds around SteKaaShe reintro annually. Target all weedy taxa; always control SphCoo, AngEve, CitCau if seen. | X | | | | X | | | | X | | | | X | | | | X | | | |
| 7553 | Weed Control | None | OpaeulaLower-04 | Control weeds around GarMan.OPA-A reintro, 2x per year. | X | | X | | X | | X | | X | | X | | X | X | | | X | | X | |
| 6244 | Weed Control | None | OpaeulaLower-04 | Control stands of Psicat and other dense weeds. Consider clearcutting, chipping, volunteer groups. | | | X | | | | | | | | | | | | | | | | | |
| 6240 | Weed Control | None | OpaeulaLower-04 | Control grasses in forested areas, every 6 months or as needed. Ignore areas directly around Frog Pond and Little Pond | | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 6241 | Weed Control | None | OpaeulaLower-04 | Control UroMax and other weeds around Frog Pond camp quarterly. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (Continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018- Sept2019 | | | | MIP Year 16 Oct 2019- Sept2020 | | | | MIP Year 17 Oct 2020- Sept2021 | | | | MIP Year 18 Oct 2021- Sept2022 | | | | MIP Year 19 Oct 2022- Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 6242 | Weed Control | None | OpaeulaLower-04 | Sweep WCA once a year, targeting AngEve, SphCoo, CitCau in particular, and focusing on controlling Clihir and sparse canopy weeds in native forest patches and around rare taxa. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 6247 | Weed Control | None | OpaeulaLower-05 | Sweep entire WCA for canopy weeds and sparse understory weeds, once every3- 5 years. Use spotters with binoculars to guide control and minimize damage to uluhe. | | | | | | | | | | | X | | | | | | | | | |
| 6248 | Weed Control | None | OpaeulaLower-05 | Conduct control in weedy gulch to east of Blue Curta Saddle trail. Target understory control, and gradual removal of canopy. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 7813 | Weed Control - Trails/Rds | None | OpaeulaLower-06 | Clear/maintain WCA marker trails, access trails, and fencelines as needed. Intent = maintenance, NOT | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

**Action Table (Continued)**

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| | | | | vegetation restoration. | | | | | | | | | | | | | | | | | | | | |
| 5873 | Weed: Camp/Other Survey | None | OS-KLOA-02 | Survey Frogpond Campsite (by fence) whenever used, not to exceed once per quarter. If not used, do not need to survey. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

# Ecosystem Restoration Management Plan

## MIP Year 15-19, October 2018 – September 2023

# MU: Kaluaa and Waieli

### Overall MIP Management Goals:

- Form a stable, native-dominated matrix of plant communities which support stable populations of IP taxa.
- Control ungulate, weed, predatory snail, rodent, and slug threats in the next five years to allow for stabilization of IP taxa.

## Background Information

Location: Southern Waianae Mountains

Land Owner: State of Hawaii

Land Manager: Army Natural Resource Program – Oahu (OANRP)

Acreage: 200 acres

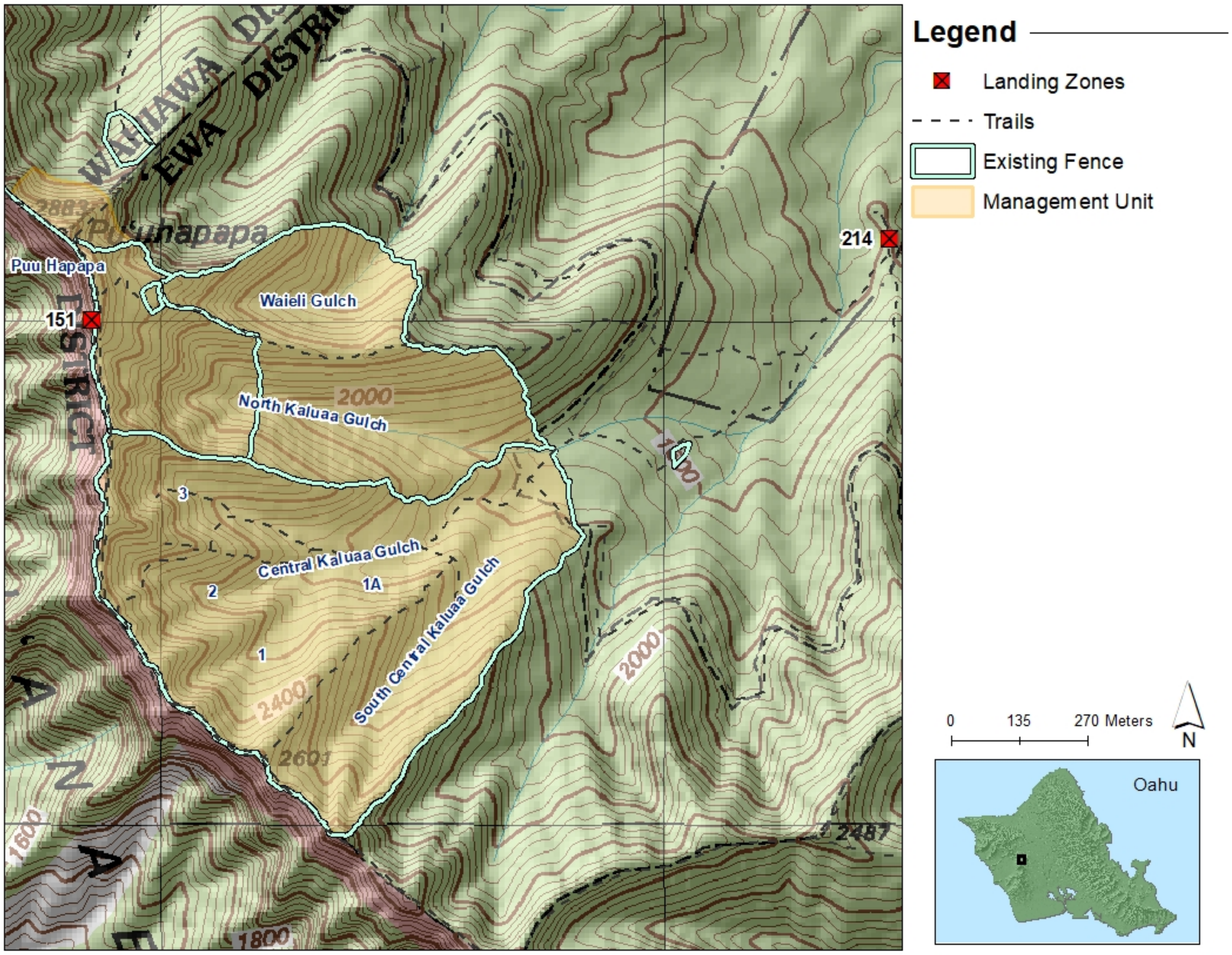
Elevation Range: 1,800-2,883ft

Description: The Kaluaa and Waieli Management Unit (MU) is located on the northern end of Honouliuli Forest Preserve, and is accessed via Schofield Barracks South range. Access is by 4WD road through the SR-1 gate and IED lanes. Two improved landing zones located on state land enable access to Puu Hapapa via helicopter, one at the Kaluaa trailhead, and one on the ridge near Puu Hapapa. Terrain is varied, ranging from gradual slopes to vertical cliffs. The vegetation type across the Kaluaa and Waieli MU is mixed mesic forest, though the dominant native trees vary by aspect and elevation.

The Kaluaa and Waieli MU fence is comprised of three subunits. Subunit I (Central Kaluaa) on the south is the largest section encompassing four sub-gulches and extending from the bottom of this gulch system up to the Waianae summit ridge. From south to north, the sub-gulches within Central Kaluaa are referred to as South Central Gulch, Gulch 1, Gulch 2, and Gulch 3. In the lower elevations of Central Kaluaa, before the Gulch 1-2-3 split, is a site referred to as Gulch 1A, a core outplanting site of The Nature Conservancy (TNC) later adopted and expanded by OANRP. To the north of Central Kaluaa, the Subunit II fence encompasses the upper elevations of North Kaluaa Gulch up to Puu Hapapa. Below Puu Hapapa, on a flatter area referred to as Hapapa bench, is the Hapapa snail enclosure. Subunit III encompasses the lower elevations of North Kaluaa Gulch as well as Waieli Gulch to the north. North Kaluaa Gulch and Waieli Gulch are divided by the Hapapa Access Ridge.

Below and to the east of Kaluaa and Waieli MU runs a contour trail. This trail extends throughout Honouliuli Forest Reserve. It is intersected by the main Kaluaa gulch trail, which runs from the trailhead LZ up into North Kaluaa and Central Kaluaa, and the Hapapa access trail, which splits off from the Kaluaa gulch trail and follows Hapapa Access Ridge to the Hapapa snail enclosure and the Hapapa LZ.

**Gulch names in Kaluaa and Waieli MU**



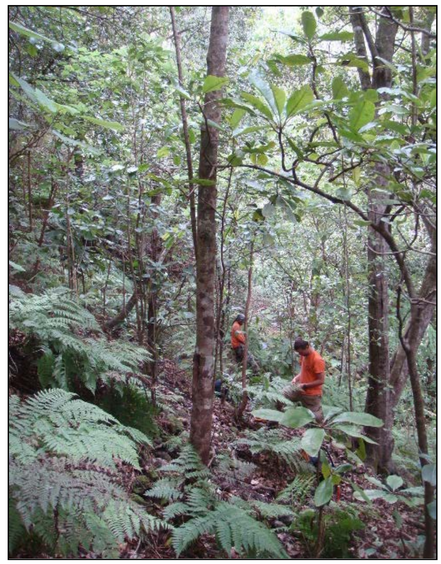

**Native Vegetation Types**

| Waianae Vegetation Types | |
|---|---|
| Mesic mixed forest | <u>Canopy includes</u>: *Acacia koa*, *Metrosideros polymorpha*, *Nestegis sandwicensis*, *Diospyros* spp., *Planchonella sandwicensis*, *Charpentiera* spp., *Pisonia* spp., *Psychotria* spp., *Antidesma platyphyllum*, *Bobea* spp. and *Santalum freycinetianum*.<br><u>Understory includes</u>: *Alyxia stellata*, *Bidens torta*, *Coprosma* spp., and *Microlepia strigosa* |
| NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted. | |

**Terrain and Vegetation Types at Kaluaa and Waieli MU**

Kaluaa and Waieli MU from east; the prominent, rounded peak on right is Puu Hapapa.


Kaluaa from Puu Hapapa looking south



Mesic forest within MU

Typical crest vegetation

Typical mesic gulch vegetation

## MIP/OIP Rare Resources at Kaluaa and Waieli MU

| Organism Type | Species | Pop. Ref. Code | Population Unit | Management Designation | Wild/ Reintroduction |
|---|---|---|---|---|---|
| Plant | *Alectryon macrococcus* var. *macrococcus* | KAL-A*,B*,C*<br>ELI-A*,B*<br>Reintro KAL-E* | Central Kaluaa to Central Waieli | GSC | Both |
| Plant | *Cyanea grimesiana* subsp. *obatae* | KAL-B<br>Reintro KAL-C,D, E | Central Kaluaa | MFS | Both |
| Plant | *Delissea waianaeensis* | ELI-A<br>KAL-B<br>Reintro KAL-C,D | Kaluaa | MFS | Both |
| Plant | *Euphorbia herbstii* | Reintro KAL-A | Kaluaa | MFS | Reintroduction |
| Plant | *Flueggea neowawraea* | KAL-A* | Kaluaa | | Wild |
| Plant | *Phyllostegia hirsuta* | KAL-A<br>ELI-A,B*,C*<br>SBS-A*,B* | Hapapa to Kaluaa | MFS | Wild |
| Plant | *Phyllostegia mollis* | KAL-D*<br>Reintro KAL-B*,C | Kaluaa | MFS | Both |
| Plant | *Plantago princeps* var. *princeps* | Reintro ELI-A | Waieli | GSC | Reintroduction |
| Plant | *Schiedea kaalae* | KAL-A*<br>Reintro KAL-B,C | Kaluaa and Waieli | MFS | Both |
| Plant | *Stenogyne kanehoana* | KAL-A*<br>Reintro KAL-B,C*,D | Central Kaluaa | MFS | Both |
| Insect | *Drosophila montgomeryi* | n/a | Kaluaa and Waieli | MFS | Wild |
| Snail | *Achatinella mustelina* | ELI-A, B<br>KAL-A, B†,C†, D†,E,F†, G | ESU-D1 | MFS | Wild |

MFS= Manage for Stability *= Population Dead
GSC= Genetic Storage Collection †=Population translocated into enclosure

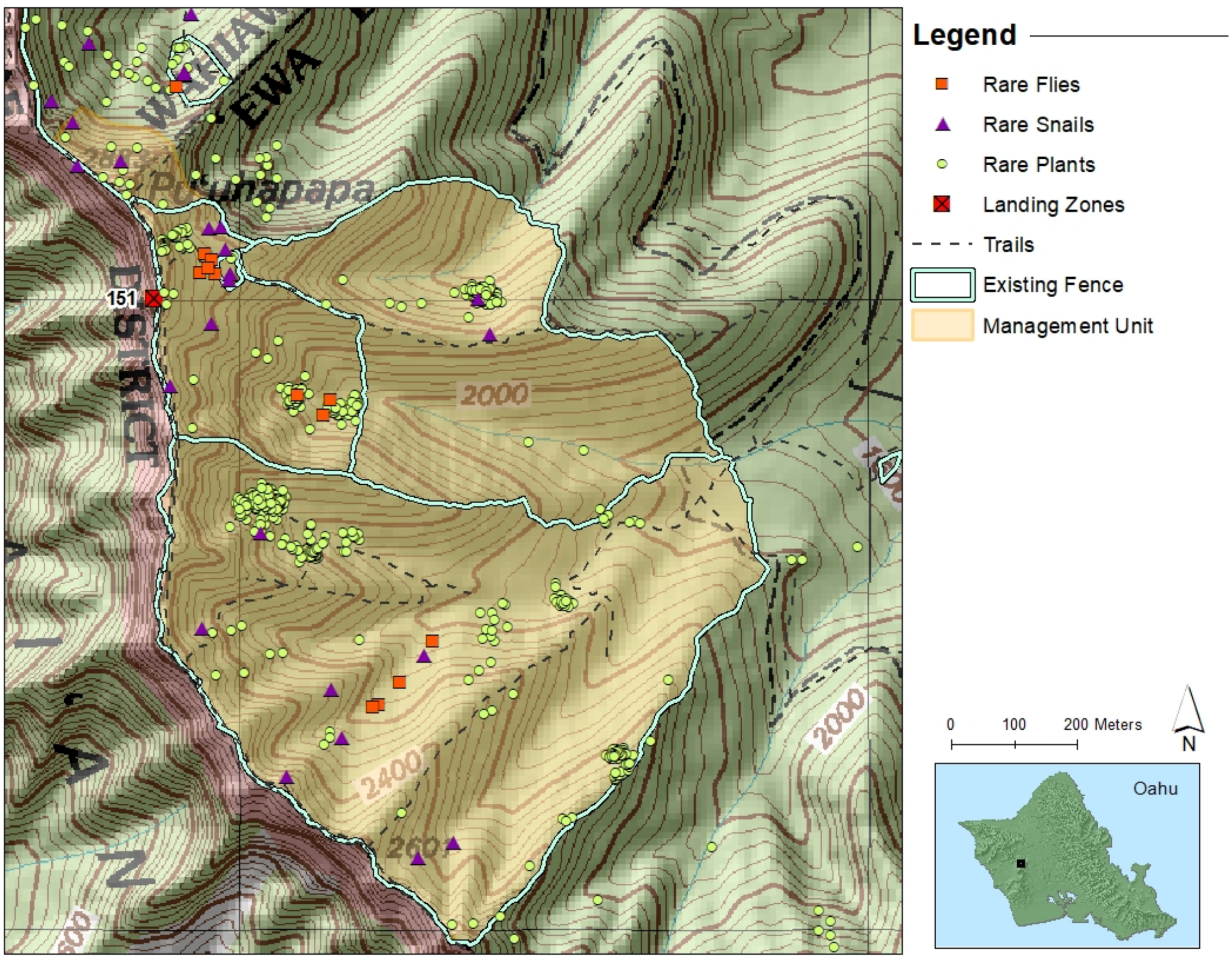
## Other Rare Taxa at Kaluaa and Waieli MU

| **Organism Type** | **Species** | **Status** |
|---|---|---|
| Plant | *Asplenium dielfalcatum* | Endangered |
| Plant | *Cenchrus agrimonioides* var. *agrimonioides* | Endangered |
| Plant | *Chrysodracon forbesii* | Endangered |
| Plant | *Clermontia persicifolia* | Endangered |
| Plant | *Cyanea calycina* | Endangered |
| Plant | *Cyanea membranacea* | No status |
| Plant | *Cyanea pinnatifida* | Endangered |
| Plant | *Cyanea superba subsp. superba* | Extinct |
| Plant | *Embelia pacifica* | No status |
| Plant | *Exocarpos gaudichaudii* | No status |
| Plant | *Gardenia brighamii* | Endangered |
| Plant | *Labordia kaalae* | Endangered |
| Plant | *Melicope christophersenii* | Endangered |
| Plant | *Melicope cornuta* var. *decurrens* | Endangered |
| Plant | *Notocestrum longifolium* | No status |
| Plant | *Panicum beecheyi* | No status |

**Other Rare Taxa at Kaluaa and Waieli MU (continued)**

| Organism Type | Species | Status |
|---|---|---|
| Plant | *Pteralyxia macrocarpa* | Endangered |
| Plant | *Schiedea hookeri* | Endangered |
| Plant | *Schiedea pentandra* | No status |
| Plant | *Solanum sandwicense* | Endangered |
| Plant | *Tetramolopium lepidotum* subsp. *lepidotum* | Endangered |
| Plant | *Urera kaalae* | Endangered |
| Bird | *Chasiempis ibidis* | Endangered |
| Insect | *Drosophila divaricata* | No status |
| Insect | *Drosophila hemipeza* | Endangered |
| Snail | *Amastra intermedia* | No status |
| Snail | *Amastra spirazona* | No status |
| Snail | *Laminella sanguinea* | No status |

**Locations of Rare Resources at Kaluaa and Waieli MU**



**Rare Resources at Kaluaa and Waieli MU**

*Euphorbia herbstii*

*Stenogyne kanehoana*

*Cyanea grimesiana* subsp. *obatae*

*Achatinella mustelina*

*Drosophila montgomeryi*

*Schiedea kaalae*

**Threats to MIP/OIP MFS Taxa**

| Threat | Rare Taxa Affected | Management Strategy | Current Status, 2018 |
|---|---|---|---|
| Pigs | All | Across MU (fence) | No animals within fence. |
| Weeds | All | Focus primarily on rare taxa sites, across MU secondarily | Regular maintenance required several times per year. |
| Rodents | *Achatinella mustelina, Cyanea grimesiana* subsp. *obatae, Delissea waianaeensis* | Predator-proof snail enclosure, localized A24 grids | No animals within snail enclosure. Trap grids maintained tri-annually. |
| Jackson's chameleon | *Achatinella mustelina* | Predator-proof snail enclosure, manual capture and removal | No animals within snail enclosure. Manual control conducted quarterly outside. |
| Rosy Wolf Snail | *Achatinella mustelina* | Predator-proof snail enclosure | No predatory snails within the enclosure. Enclosure inspected/maintained every 6 weeks and swept annually. |
| Slugs | *Cyanea grimesiana* subsp. *obatae, Delissea waianaeensis* | Affected rare taxa sites only | Ferroxx AQ slug toxicant applied every 6 weeks. |
| Ant | *Drosophila montgomeryi* | No control as toxicants may harm *Drosophila* | Research on possible control method to be completed by 2020. Sites monitored annually. |
| Vespula | *Drosophila montgomeryi* | *D. montgomeryi* sites only | No vespula present. Sites monitored monthly. |
| Downy Mildew | *Phyllostegia hirsuta* | No control | Monitor rare plants. No tools to control in the field; research on-going. |

## Management History

- 1860s-80s: The Kaluaa and Waieli area is severely degraded by overgrazing by unmanaged herds of cattle. James Campbell purchases Honouliuli and drives more than 30,000 head of cattle off the slopes and lets the land "rest."
- 1925: Honouliuli Forest Reserve is established for watershed protection purposes.
- 1930s-50s: Division of Forestry and Civilian Conservation Corps builds roads, trails and fences; continues removal of feral goats and cattle; and plants 1.5 million trees in the Honouliuli Forest Reserve, mainly below 800' elevation.
- 1940s: The area below the contour trail in Kaluaa is actively farmed and used for ranching by Leilehua Ranch.
- 1940s-50s: The area below the contour trail is first used for US Army training.
- 1970s: *Clidemia hirta* is first introduced to the Waianae Mountains in the South Kaluaa contour trail area.
- 1972: One individual of *Drosophila montgomeryi* is recorded from Kaluaa Gulch.
- 1990-2009: Honouliuli Preserve is managed by TNC after they obtain a conservation easement from the Campbell estate.
- 1996: TNC installs the 0.2 acre Ti Leaf Flats fence; *Delissea waianaeensis* and *Cyanea pinnatifida* are the first endangered plant reintroductions.

- 2000-2007: TNC management consists of installing an extensive catchment system, project stewardship plots, and field nursery; trail construction; reintroduction of several thousand common and endangered natives (including *S. kaalae* and *S. kanehoana*); rat control for snail and elepaio protection; and a volunteer hunting program.
- 2001: The 115 acre Subunit I (Central Kaluaa) fence is completed by TNC staff, volunteers and contractor John Hinton.
- 2002: OANRP begins using the Central Kaluaa fence area for endangered reintroductions as part of the MIP plan. *Delissea waianaeensis*, *P. mollis*, and *U. kaalae* are planted.
- 2003: *Cyanea grimesiana* subsp. *obatae* reintroductions are planted in Central Kaluaa Gulch 1.
- 2003: Extensive archeological surveys in the area below the boundary of the TNC preserve document numerous cultural and historical sites.
- 2004: The US Army acquires the South Range Acquisition Area from James Campbell Estate for a second qualifying training range in the South Range area (now known as SRQTR2). This area consists mostly of old pineapple fields, but also some portions of the forested area as a buffer safety zone.
- 2006: The 25 acre Subunit II (Hapapa/North Kaluaa) fence is completed by TNC, volunteers, and OANRP staff (NRS).
- 2007: *Plantago princeps* var. *princeps* are reintroduced at Hapapa. This population is subsequently augmented in 2009 and 2013.
- 2007: *Angiopteris evecta* is first discovered in South Central Kaluaa gulch.
- 2007: An incipient control area (ICA) is created for *Casuarina equisetifolia* along the southern fence as a follow-up to eradication work done previously by TNC.
- 2007: OANRP begins control of *Morella faya* in an area previously controlled by the Oahu Invasive Species Committee (OISC). An ICA is created in the flats between the Hapapa access trail, the Kaluaa gulch trail and the contour trail.
- 2008: One mature *Clusia rosea* is found and controlled along the contour trail.
- 2008: Several mature individuals of *Solanum capsicoides* are found along the stream bed below the management unit. This ICA is later extended further up into North Kaluaa Gulch as more plants are discovered.
- 2009: One mature *Arthrostemma ciliatum* is found along the trail by the TNC Ti Leaf Flats fence.
- 2009-2010: The Army Compatible Use Buffer Program purchases Honouliuli Preserve with assistance from State and private partners, and negotiation by Trust for Public Land, primarily for endangered species management. The title transfers to the State of Hawaii for management as a forest reserve with uses such as recreational hiking and hunting. This is done partially as a result of shifting management focuses within TNC, and their decision to discontinue work in Honouliuli Forest Reserve.
- 2010: *Drosophila montgomeryi* is documented by Karl Magnacca at one site in Kaluaa gulch and at a second site near the summit of Puu Hapapa (2640 ft. elevation).
- 2010: NRS completes construction of the 56 acre Subunit III (Waieli/ North Kaluaa) fence and all pigs are removed.
- 2010: MU vegetation monitoring is conducted for the first time via belt plot transects.

- 2011: A contracted New Zealand company, Xcluder, completes the 0.25 acre snail enclosure at Puu Hapapa. Translocation of snails into the enclosure begins.
- 2011: In December, 6 Jackson's Chameleons (*Triceros jacksonii* subsp. *xantholophus*) are found and removed from the newly built snail enclosure. Manual search and removal, including tree-climbing, is implemented. A total of 32 chameleons are removed, the last one found in May 2015.
- 2011: OANRP begins active habitat management of *D. montgomeryi* sites via specific weed control efforts. Host plants *Urera kaalae* and *Urera glabra* are first planted by OANRP at Hapapa bench the following year (2012) in conjunction with other common native outplantings. *Urera* restoration areas are expanded in 2015 to include *D. montgomeryi* populations in North Kaluaa and Gulch 1.
- 2012: *Achatinella mustelina* are released into the Puu Hapapa snail enclosure from the UH lab. Since its completion, over 1800 *A. mustelina* have been released into the Hapapa enclosure; it is home to 70% of the *A. mustelina* protected in such enclosures, as well as other species of concern relocated by the Snail Extinction Prevention Program (SEPP).
- 2012: A single mature *M. faya* is found along the crest north of Puu Hapapa.
- 2013: A small patch of *Dovyalis hebecarpa* is found in Waieli gulch.
- 2013: One mature *Ehrharta stipoides* is found near the Hapapa shelter.
- 2013: Incision point application (IPA) sweeps are first conducted by the OANRP Ecosystem Restoration crew focusing on mature *Toona ciliata* and *Grevillea robusta* trees throughout the management unit.
- 2014: More *E. stipoides* is found along the Hapapa access trail.
- 2015: Puu Hapapa LZ is reconstructed.
- 2015: MU vegetation monitoring is conducted for a second time.
- 2015: Monthly slug control using Sluggo is implemented at the Kaluaa Gulch 1A site to protect wild *C. grimesiana* subsp. *obatae* and a large reintroduction of *D. waianaeensis.*
- 2015: Outreach finds an immature *A. evecta* in a volunteer weeding area in lower Central Kaluaa gulch.
- 2016: The Army Corps of Engineers improves Kaluaa access road. A new LZ is constructed on state land near the Kaluaa trailhead to facilitate helicopter operations and ease of access to the management unit.
- 2016: Localized rat control is implemented at the Kaluaa Gulch 1A and North Kaluaa *C. grimesiana* subsp. *obatae* sites. In 2017, these are converted to A24 grids.
- 2017: Ferroxx AQ Slug and Snail Bait is approved for use on state land; it is implemented within the MU and slug control is changed to a 6-week interval.
- 2017: The OANRP ungulate team skirts a problem section of the fence in Waieli gulch, where outside pressure is high and pig sign outside the fence is often observed.
- 2017: Paul Krushelnycky confirms the adverse effects of the thief ant (*Solenopsis papuana*) on native *Drosophila*. One study sites is Hapapa bench.
- 2017: The first *E. herbstii* are planted in North Kaluaa. This population is augmented in 2018.

- 2018: Pig sign is detected in the upper North Kaluaa fence by the *C. grimesiana* subsp. *obatae* outplanting. This is the first pig in this section of the fence. It is successfully snared.
- 2018: *Chromolaena odorata* is found along the Hapapa access trail. Buffer sweeps and trail surveys are implemented to determine further actions.
- 2018: The *E. stipoides* ICA (Kaluaa-EhrSti-01) at Hapapa bench is eradicated.

## Ungulate Control

Species: *Sus scrofa* (pigs)

Threat Level: High

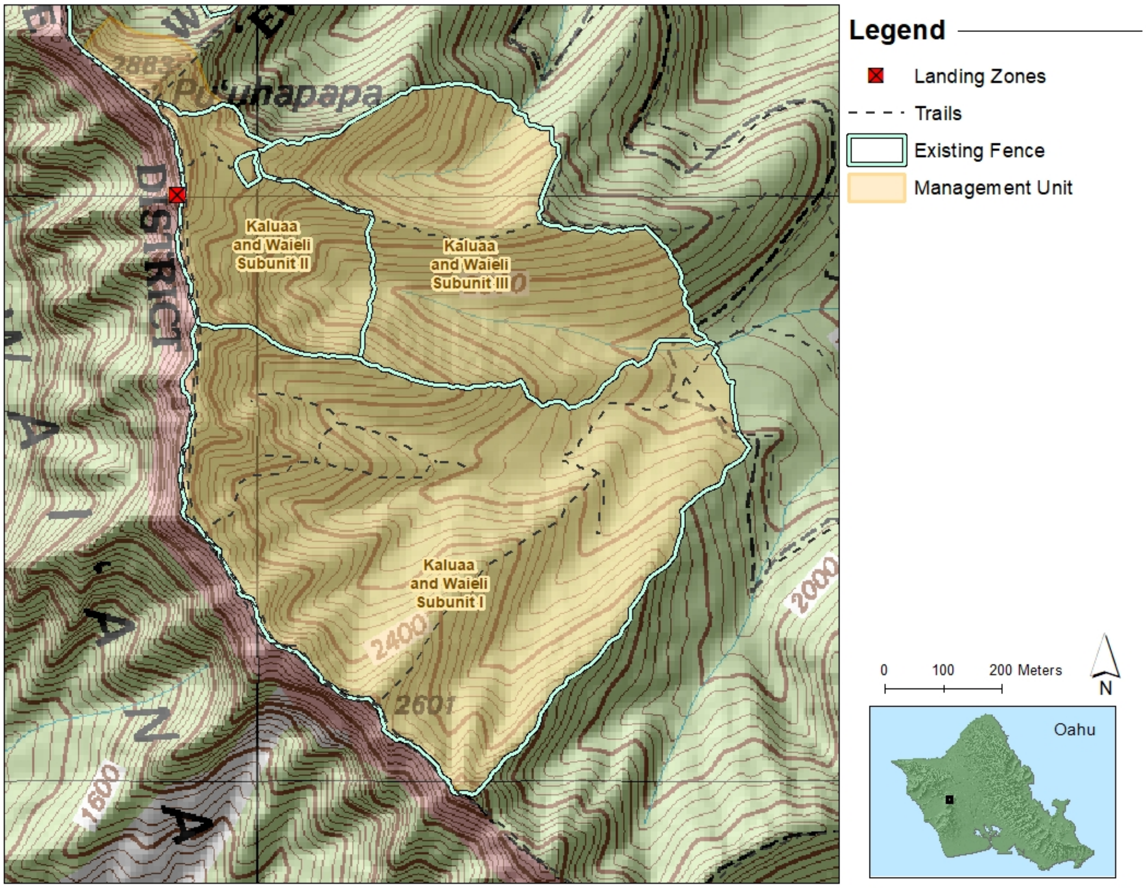
Management Objectives:

- To maintain all areas within fenced units as pig free.

Strategy and Control Methods:

- Conduct perimeter and centerline fence checks quarterly. Maintain fences and monitor for pig ingress.
- Annually monitor interior fence section separating units II and III.
- Monitor for pig sign while conducting other management actions in the fence.
- If any pig activity is detected in the MU, implement snaring program or conduct control hunts with permission from the State of Hawaii.
- Conduct fence checks after storm events with emphasis at gulch crossings.

**Ungulate Management at Kaluaa and Waieli MU**




Discussion: Quarterly checks, including maintenance, on fence integrity are conducted along the perimeter and centerline (separating Subunit I from Subunits II and III). The fence separating Subunits II and III is checked annually. Though not necessary to prevent ingress, this fence can make surveying and snaring easier if a pig does enter from the outside, as keeps the animal contained to a smaller area. Fences are also checked after extreme weather events, and staff monitors for pig sign during the course of other field activities.

The fence is especially vulnerable at its two stream crossings. Though water rarely flows here, there is typically water present, resulting in higher pig presence and increase pressure from the outside. In addition, extreme weather events can cause water to rush down the gulches, collecting debris and pressuring the fence from the inside. To mitigate these threats, baffles are installed inside Subunits I and III where the Kaluaa gulch trail crosses into North and Central Kaluaa Gulches, and both stream crossings are skirted.

# Weed Control

Weed Control actions are divided into 4 subcategories:

1) Vegetation Monitoring
2) Surveys
3) Incipient Taxa Control (Incipient Control Area - ICAs)
4) Ecosystem Management Weed Control and Restoration Actions (Weed Control Areas - WCAs)

These designations facilitate different aspects of MIP requirements.

## Vegetation Monitoring

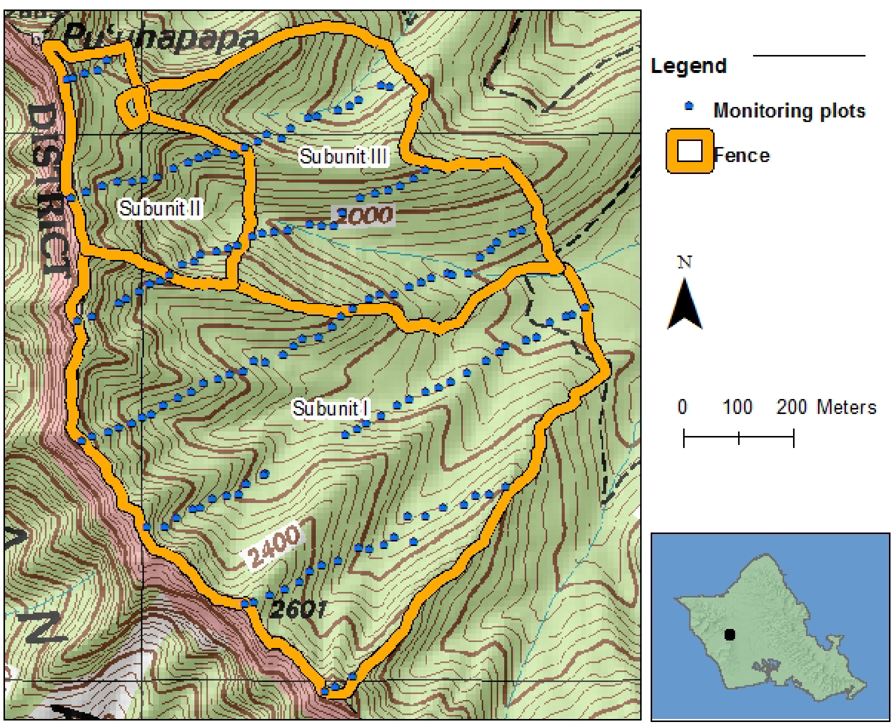
Background:

Vegetation monitoring occurs on a five-year interval at Kaluaa and Waieli MU in association with MIP/OIP requirements for long term monitoring of vegetation composition and change over time (OANRP 2008). The primary objective of MU monitoring is to assess if the percent cover of non-native plant species is less than 50% across the MU, or is decreasing towards that threshold requirement. The secondary objective is to assess if native cover is greater than 50% across the MU, or is increasing towards that threshold recommendation.

Methods:

Monitoring was conducted in 2010 (OANRP 2011) and 2015 (OANRP 2016) in 148 plots generally located every 30 m along transects spaced approximately 200 m apart. Vegetation was recorded by percent cover for all non-native and native species present. Summary percent cover by vegetation type (shrub, fern, grass/sedge) in the understory, overall summary percent cover of non-native and native vegetation in the understory and canopy, and bare ground (non-vegetated < 25 cm AGL), were also documented.

**Kaluaa and Waieli MU vegetation monitoring plot locations**



<u>Summary results</u>:

In both monitoring years, management objectives were met only for percent cover of non-native canopy. Native cover was low, and non-native canopy was high.

**Median cover (%) of vegetation in plots at Kaluaa and Waieli MU from 2010 to 2015.**

| | 2010 | 2015 |
|---|---|---|
| Native understory | 15.0 | 7.5 |
| Non-native understory | 35.0 | 35.0 |
| Native canopy | 25.0 | 25.0 |
| Non-native canopy | 75.0 | 85.0 |

There were a number of noteworthy significant differences in the 2015 data as compared with 2010, including:

- Increase in non-native canopy cover
- Decrease in non-native understory richness
- Increase in non-native canopy richness
- Decrease in frequency for non-native understory species:
    - *Toona ciliata*
- Increase in frequency for non-native canopy species:
    - *Passiflora suberosa*
    - *T. ciliata*
- An increase in percent cover for non-native species:
    - *Blechnum appendiculatum* (understory)
    - *P. suberosa* (canopy)
    - *Psidium cattleianum* (canopy)
    - *T. ciliata* (canopy)
- An increase in percent cover for native species:
    - *Acacia koa* (canopy)
    - *Metrosideros polymorpha* (canopy)
- A decrease in percent cover for non-native understory species:
    - *Schinus terebinthifolius* (understory)
    - *T. ciliata* (understory)
- Increase in non-native canopy cover in plots without IPA control
- Increase in *T. ciliata* (canopy) in plots without IPA control

The beneficial changes that occurred were generally small, while the worsening changes were larger, particularly in the canopy, irrespective of weeding efforts. Given the high level of non-native canopy cover in the MU, management goals of < 50% cover may be unrealistic across the MU. Refinement of management goals to apply specifically to prioritized areas (those with greater potential for restoration) within the MU may result in goals that are more likely to be successfully accomplished.

*Toona ciliata* frequency and cover decline in the understory paired with an increase in the canopy may be explained in part by vertical growth of individuals that were in the understory in 2010, but reached the canopy by 2015. Plots where *T. ciliata* was absent in the understory in 2015 but present in 2010 were anecdotally observed to have *T. ciliata* individuals in the lowermost portions of the canopy in 2015.

The significant increase in non-native cover (including *T. ciliata*), in plots outside, but not inside IPA controlled areas suggest IPA efforts may be preventing increases in non-native canopy cover within the areas treated. However, IPA treatment occurred in the lower elevations of the MU, where non-native cover was already uniformly high, as opposed to the higher elevation areas where non-native cover was lower. IPA control targeted only the largest mature individuals of two species in attempts to minimize primary seed sources, such that other non-native species and smaller individuals of the targeted taxa remained in the lower reaches of the canopy, potentially masking impacts of canopy reduction via IPA. As IPA efforts expand into higher elevations, perhaps resulting canopy reduction will be more apparent.

Recommendations:

Based on the results of vegetation monitoring, a number of recommendations were made with the goal of making progress towards meeting management objectives:

- more aggressive weed control paired with restoration efforts in prioritized areas
- target uncommon weeds when seen (particularly target taxa)
- expand IPA efforts into new areas, including higher elevations with more native cover, and continue IPA efforts within areas already treated, as *T. ciliata* and *Grevillea robusta* grow to the targeted size/stage, as necessary
- monitoring of understory change in direct association with IPA treatments (via a separate monitoring regime) should be done to better understand it's impact on native and non-native understory cover

## Surveys

Potential Vectors: Army Training, OANRP activity, hikers/hunters, pig, rodents, alien birds, wind

Management Objective:

- Prevent the establishment of any new invasive alien plant or animal species through regular surveys along roads, landing zones, camp sites, fence lines, trails, and other high traffic areas.

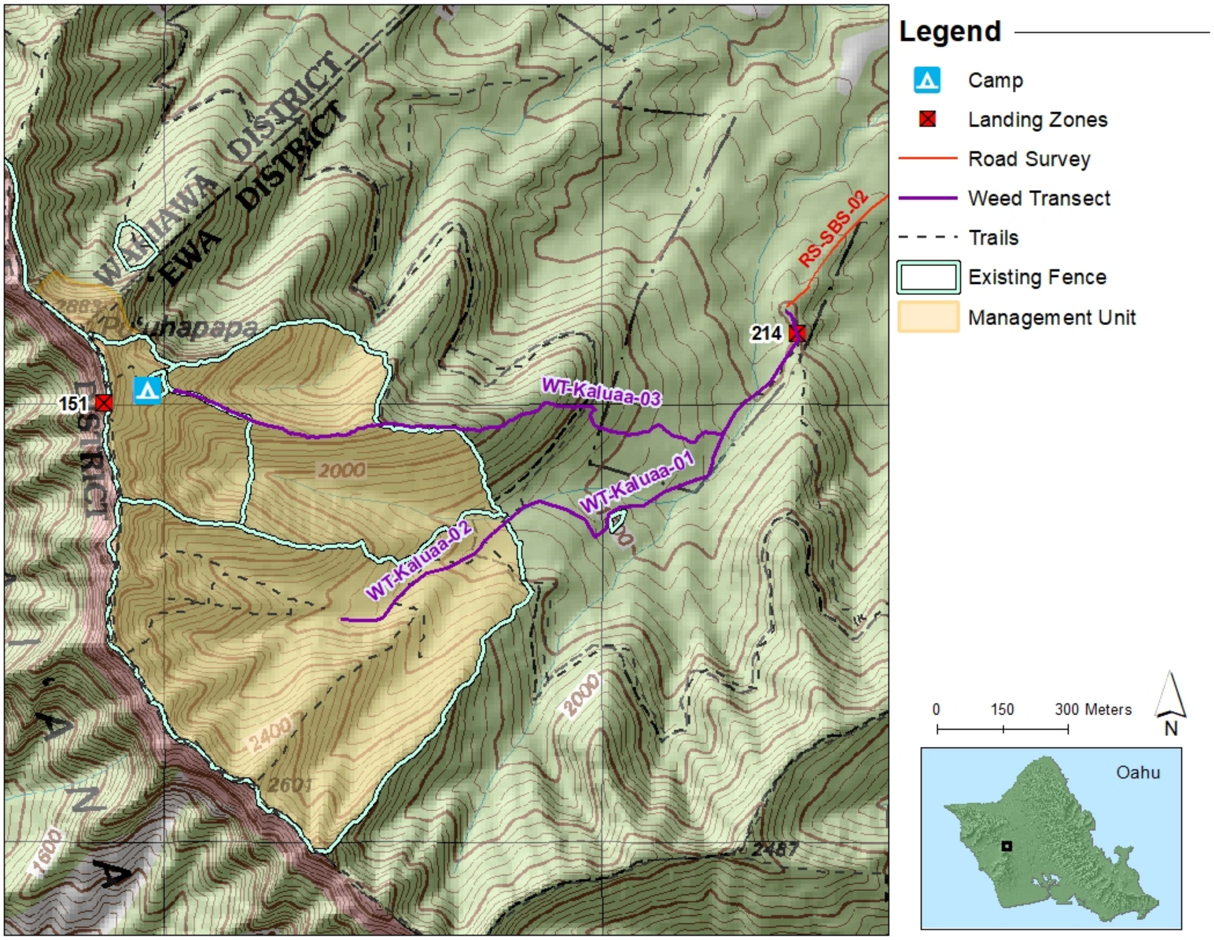
Strategy and Control Methods:

- Quarterly surveys of LZs when used, to include: Waieli-TNC Hapapa LZ (151) and Kaluaa Trailhead LZ (214)
- Quarterly survey of Hapapa shelter/campsite when used.
- Annually survey 3 weed transects along main Kaluaa gulch trail and Hapapa access trail for incipient weeds (see map).
- Annually survey Kaluaa access road as part of the Schofield Barracks South range (SBS) road surveys.
- Note unusual, significant or incipient alien taxa during the course of regular field work, and particularly when doing fence checks. Map and complete Target Species form to document sighting.

Discussion:

Surveys are designed to be the first line of defense in locating and identifying potential new weed species. At Kaluaa and Waieli, LZs, camp sites, trails, and the access road are inventoried regularly to facilitate early detection and rapid response. The only LZs approved for use within this MU are Waieli-TNC Hapapa LZ (151) and Kaluaa Trailhead LZ (214). In addition to LZ surveys, staff also conduct surveys at the Puu Hapapa shelter (the primary campsite in the MU), and along 3 heavily trafficked trails. The Kaluaa access road is also surveyed annually as part of the SBS road surveys.

**Survey Locations at Kaluaa and Waieli**




## Incipient Taxa Control

All weed control geared towards eradication of a particular invasive weed is tracked via Incipient Control Areas, or ICAs. Each ICA is species-specific and geographically defined. Some ICA species are incipient island-wide, and are a priority for ICA management whenever found. Others are locally incipient to the MU, but widespread elsewhere. In either case, the goal is eradication of the ICA. The goals, strategies, and techniques used vary between ICAs depending on terrain, surrounding vegetation, target taxon, size of infestation, and a variety of other factors.

Management Objective:

- Eradicate ICAs through regular and thorough monitoring and treatment. In the absence of any information about seed bank longevity for a particular species, eradication is defined as 10 years of consistent monitoring with no target plants found.
- Study seed bank longevity of ICA taxa, and revise eradication standards per taxon.
- Evaluate any invasive plant species newly discovered in MU, and determine whether ICA-level control is warranted. Factors to consider include distribution, invasiveness, location, infestation size, availability of control methods, resources, and funding.

<u>Strategy and Control Methods:</u>

- Monitor the progress of management efforts, and adjust visitation rates to allow staff to treat plants before they mature. Remember that one never finds 100% of all plants present.
- Use aggressive control techniques where possible. These include applying pre-emergent herbicides, clearcutting, aerial spraying, and frequent visits.

Species and ICAs are listed in the table below. History and strategy is discussed for each species.

**Summary of ICAs**

| **Taxon** | **ICA Code** | **Control Discussion** |
|---|---|---|
| *Angiopteris evecta* | Kaluaa-AngEve-01 | This ICA follows the bottom of South Central Kaluaa Gulch. It is monitored every 6 months. *Angiopteris evecta* are mostly found on rocks within 5 meters from the bottom of the gulch. Smaller, immature plants, such as those typically found in this area, have been successfully controlled manually. However, *A. evecta* here have been observed to re-sprout vegetatively from cut parts of the root ball in sufficient moisture; thus controlled plants should be hung off the ground, thoroughly pulverized to facilitate desiccation, or treated with herbicide. Foliar spray of 20% triclopyr, 80% biodiesel is also known to be effective.<br>This ICA has been expanded considerably since it was established in 2007 with additional plants being found up and down-gulch. Since 2007, no additional matures were found, but immatures are consistently found. There is no known data on the longevity of spores, or time to maturity. Further buffer surveys may be necessary to ensure we are not missing other mature plants up-gulch (a possible source for the plants we control in the bottom), and to more accurately determine the extent of the infestation. |
| *Angiopteris evecta* | Kaluaa-AngEve-03 | One immature plant was found by Outreach in lower Central Kaluaa Gulch. It seems to be an outlier as it was right along the trail in a frequently weeded area. Monitoring will continue every 6 months. If no additional plants are found, this ICA will be considered eradicated in 2020. |
| *Arthrostemma ciliatum* | Kaluaa-ArtCil-01 | A member of the Melastomataceae family, *A ciliatum* is highly invasive, seeds prolifically and has a presumably long-lasting seedbank. It is known mostly from the Koolau mountains. Given these characteristics, this area should be closely monitored for recruitment in order to prevent infestation. However, only one plant is known in this location: a small mature along the trail below the TNC Ti Leaf Flats fence. Though primarily bird-dispersed, this individual was likely introduced by hikers, hunters or NRS. If no other plants are found, this ICA will be considered eradicated in 2019. Individual plants may be hand-pulled, seeds bagged and removed, or vegetative plants can be controlled with a foliar spray of 2% glyphosate. |
| *Casuarina equisetifolia* | Kaluaa-CasEqu-01 | This ICA is along the southern side of the fence. It was established as a follow up to eradication work done here previously by TNC. It is currently monitored annually. Plants are controlled via cut stump with of 20% triclopyr, 80% biodiesel. |

**Summary of ICAs (continued)**

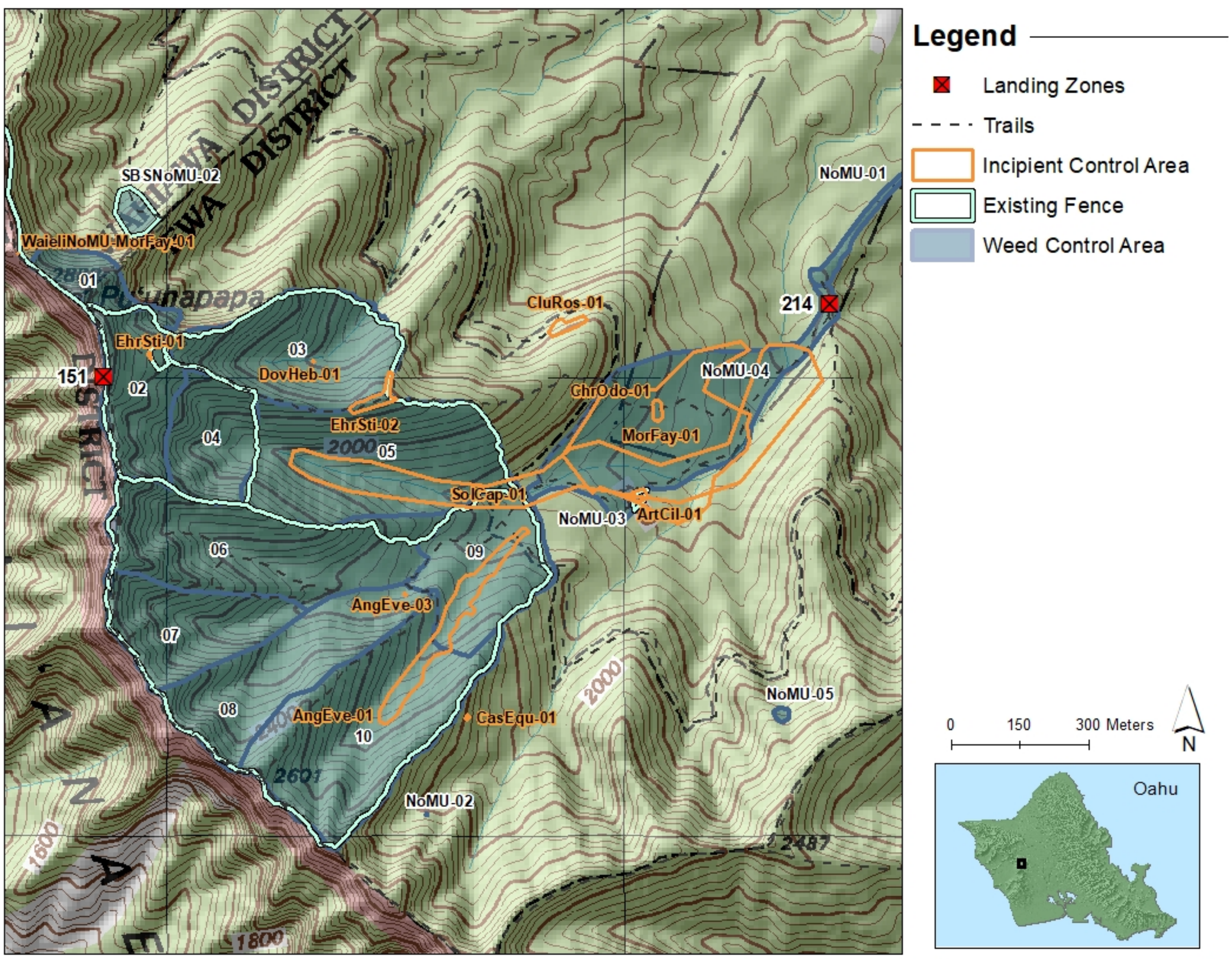
| Taxon | ICA Code | Control Discussion |
|---|---|---|
| *Chromolaena odorata* | KaluaaNoMU-ChrOdo-01 | This highly invasive shrub is a major target. It was discovered in May 2018 along the Hapapa access trail. Staff conducted 200m buffer surveys around the site, and a thorough trail survey from the parking area to Hapapa snail enclosure. Only one mature *C. odorata* was found, and all other plants were concentrated around it to about 40 meters at the most. Given their proximity to a frequently travelled trail, these plants were likely introduced by NRS. Seeds are primarily wind-dispersed, but can also spread via contaminated boots and gear. Seeds of *C. odorata* last at least 3 years in soil, and further seed bank longevity testing is underway.<br>This ICA is a high priority. It is currently monitored quarterly. Plants are hand-pulled, seeds bagged and removed, or controlled via cut stump with 20% triclopyr, 80% biodiesel. Larger patches, or plants that have already dropped seeds should be controlled aggressively with a thorough spray of 2% glyphosate and a pre-emergent to prevent recruitment. |
| *Clusia rosea* | Kaluaa-CluRos-01 | This ICA is located along the contour trail, north-east of the management unit. It is currently monitored annually. A hardy tree with often hard-to-reach prop roots, *C. rosea* may require several follow-up treatments, or use of a chainsaw for effective control. Control has previously been done via cut stump or a deep girdle with 20% triclopyr, 80% biodiesel. The most effective control known to date for large trees is a drilling method with 100% triclopyr. |
| *Dovyalis hebecarpa* | Kaluaa-DovHeb-01 | This ICA is in the bottom of Waieli Gulch below a *D. waianaeensis* outplanting. It is currently monitored annually. Although large populations are known to exist lower in the gulch, only plants within the fence (and management unit) are controlled. Control via cut stump with 20% triclopyr, 80% biodiesel. |
| *Ehrharta stipoides* | Kaluaa-EhrSti-02 | Although common in other MUs, this is only the second *E. stipoides* site found within Kaluaa and Waieli MU. This ICA is found along the trail to the Hapapa snail enclosure; the first was at the enclosure. As it is common in other areas where snail management occurs (namely Palikea MU), and the seeds are readily spread when stuck to boots, clothing, or gear, it was likely spread by NRS or others involved in snail conservation work. An invasive grass that can dominate understory even in the shade, *E. stipoides* is a high priority target. This ICA is currently monitored every 6 months. Control aggressively with a thorough spray of 2% glyphosate and pre-emergent to prevent recruitment. Mature seeds should be bagged and removed. |
| *Morella faya* | Kaluaa-MorFay-01 | This ICA encompasses the flats between the Hapapa access trail, the Kaluaa gulch trail and the contour trail. This area was previously controlled by OISC. *Morella faya* is a significant habitat modifier. Although common in other areas along the Waianae mountains, its extent near the Kaluaa and Waieli MU is limited and therefore eradication is feasible. This ICA is currently swept annually. Control via basal-bark method or cut stump with 20% triclopyr, 80% biodiesel. |
| | WaieliNoMU-MorFay-01 | A single mature *M. faya* was found and controlled along the crest north of Puu Hapapa. This ICA is currently monitored annually. If no additional plants are found, this ICA will be considered eradicated in 2022. |

**Summary of ICAs (continued)**

| Taxon | ICA Code | Control Discussion |
|---|---|---|
| *Solanum capsicoides* | Kaluaa-SolCap-01 | This ICA follows the stream starting near the Kaluaa trailhead and extending into North Kaluaa Gulch. The winged seeds of *S. capsicoides* imply wind-dispersal, but the locations of previously found plants suggest they may have spread along the gulch via water movement. *Solanum capsicoides* has a high fruit yield, and fruit have been observed to mature even after the plant is pulled; thus any fruit (immature or mature) should be bagged and removed to prevent recruitment. In addition, revisiting sites of mature plants should be prioritized to check for and control recruits. This ICA is currently surveyed annually. Its large area can possibly be decreased depending on future survey results and the extent of new plants found. |

<u>ICAs Eradicated at Kaluaa and Waieli MU:</u> *Ehrharta stipoides* (Kaluaa-EhrSti-01)

**Incipient and Weed Control Areas**




## Ecosystem Management Weed Control

All weed control geared towards general habitat improvement is tracked in geographic units called Weed Control areas, or WCAs. The goals, strategies, and techniques used vary between WCAs, depending on terrain, quality of native habitat, and presence or absence of rare taxa.

MIP Goals:

- Within 2m of rare taxa: 0% alien vegetation cover
- Within 50m of rare taxa: 25% or less alien vegetation cover
- Throughout the remainder of the MU: 50% or less alien vegetation cover

Management Objectives:

- Maintain 50% or less alien vegetation cover in the understory across the MU.
- Reduce alien canopy cover by 5% across the MU in the next 5 years.
- In WCAs within 50m of rare taxa, work towards achieving 25% or less alien vegetation cover in understory and canopy.
- Increase/expand weeding efforts if MU vegetation monitoring (conducted every 5 years) indicates that goals are not being met.

Discussion:

The following is a discussion of unique considerations for managing the Kaluaa and Waieli MU. The habitat overall in this MU is patchy. The habitat along and just below ridge crest is largely native. In addition, there are belts of *Acacia koa* (koa) canopy which run along prominent ridgelines that are in relatively good condition, with many native components. The gulches and slopes within the MU are a mix of native and alien forest. Patches of intact diverse mesic forest remain within the unit. MIP and OIP taxa are found across these zones and thus most of the Kaluaa and Waieli MU is important for stabilization.

The majority of management action are focused directly around rare taxa. However, the expansion of the Ecosystem Restoration crew (EcoRest) and the implementation of new weed-control techniques, have made possible more MU-scale management. One of these techniques is incision point application (IPA) sweeps. First implemented in 2013, use of IPA sweeps has resulted in 268 acres surveyed and controlled with minimal time of 465 staff hours. Target species include *T. ciliata* and *G. robusta*. IPA sweeps have been implemented in every WCA within the Kaluaa and Waieli fence, and there are plans to expand these efforts further.

**Native *Drosophila***

One unique consideration in Kaluaa and Waieli MU is picture-wing *Drosophila* habitat. Picture wing flies require particular host plants to complete their lifecycles. The endangered *Drosophila montgomeryi* is found within the Kaluaa and Waieli MU and is an OIP stabilization species. *Drosophila montgomeryi* breed in rotting plant material of *Urera glabra* and *Urera kaalae*. While *U. glabra* occurs widely across the Waianae range, it often occurs as scattered clumps of one or a few individuals, unsuited for survival of *D. montgomeryi* and probably not viable for long-term survival of this dioecious, wind-pollinated tree. *Urera kaalae* is critically endangered and only a handful of wild plants remain. Therefore, the remnant patches of these plants should be maintained and expanded.

Since 2002, NRS have planted a total of 137 *U. kaalae* and 211 *U. glabra*, with a survivorship rate averaging around 84%. Active management of *D. montgomeryi* habitat began in 2011 with specified weed actions, as well as augmentations and outplantings of these host trees. One of these reintroductions was in response to a large tree-fall in North Kaluaa that opened a canopy gap in the middle of existing *D. montgomeryi* habitat. *Urera* species should be considered in any future restoration outplantings where they might serve to maintain or restore possible *D. montgomeryi* habitat. *Drosophila montgomeryi* habitat is currently managed in WCA-02 (Hapapa bench), WCA-04 (North Kaluaa), WCA-07 (Gulch 2; weed actions focused around PEPP (Plant Extinction Prevention Program) *U. kaalae* reintroductions), and WCA-08 (Gulch 1).

***Stenogyne kanehoana***

*Stenogyne kanehoana* prefers the koa forest zone along ridges that contain large amounts of *Dicranopteris linearis* (uluhe) in the understory. This habitat requires delicate management to ensure the uluhe is not disrupted. Anecdotal evidence suggests *D. linearis* is sensitive to trampling, and gaps made while weeding or monitoring are often re-vegetated with much less desirable weeds, such as *C. hirta*. OANRP does not have the capacity to actively restore uluhe and thus should conduct weed control and outplanting very carefully and with minimal impact to the fern cover. Conversations with horticulturists around the state suggest that uluhe is very difficult to propagate. Reintroductions of *S. kanehoana* are currently managed in WCA-02 (along the ridge crest above Hapapa bench) and WCA-10 (along the southern fence line).

**Hapapa bench habitat**

Another unique consideration for the Kaluaa and Waieli MU is the Hapapa bench habitat (WCA-02). This zone has a unique set of conditions that support numerous rare native tree and ground snail species, as well as the endangered *D. montgomeryi*. Rare native ground snails in the genera *Amastra* require unique food. They browse fungi growing in leaf litter of plants in the family Urticaceae such as *Pipturus albidis* (mamaki) and *Urera* spp. Native *Achatinella* can also live happily on *Urera*, and, as mentioned earlier, these taxa are essential for the life cycle of *D. montgomeryi*.

While not MIP or OIP taxa, considerations should be made to not affect ground dwelling snails as their habitat can be negatively impacted by digging activities associated with outplanting and fence construction. Particular caution should be taken to survey sites prior to conducting any digging and tree felling activities. These actions should be planned in collaboration with the Snail Extinction Prevention Program (SEPP).

The table below summarizes invasive weeds found at Kaluaa and Waieli MU, excluding ICA species. While the list is by no means exhaustive, it includes the species targeted/prioritized for control. The distribution of each taxon is estimated as: Widespread (moderate to high densities of individuals, common across MU), Scattered (low densities across all or much of the MU), or Restricted (low or high densities, all in one discrete location).

**Summary of Target Taxa**

| Taxa | Distribution | Notes |
|---|---|---|
| *Ardesia elliptica* | Restricted | Not known inside MU. Concentrated in South Kaluaa. Target whenever seen inside MU.<br>Control technique: Cut stump with 20% triclopyr, 80% biodiesel. |
| *Blechnum appendiculatum* | Widespread | An invasive fern that can create a thick ground cover and hinder recruitment, control with priority directly around rare taxa.<br>Control technique: Foliar spray with 2% glyphosate is most effective, clip-and-drip with 20% triclopyr, 80% biodiesel is moderately successful. |
| *Buddleja asiatica* | Widespread | A fast-growing shrub, *B. asiatica* produces a lot of seed.<br>Control technique: Basal-bark or cut stump with 20% triclopyr, 80% biodiesel. |
| *Clidemia hirta* | Widespread | Widespread and often forming dense patches throughout the MU. Known to quickly invade and spread into canopy gaps.<br>Control technique: Basal-bark or cut stump with 20% triclopyr, 80% biodiesel. Immatures can be hand-pulled. |
| *Cyclosorus parasiticus* | Widespread | Though easily overlooked, this invasive fern can grow in dense patches and replace natives such as *Microlepia strigose* (palapalai).<br>Control technique: 20% triclopyr, 80% biodiesel applied to tips of rhizomes. |
| *Dicliptera chinensis* | Restricted | Not known inside MU. Control along access trail to prevent spread into MU.<br>Control technique: Foliar spray with 2% glyphosate. |

**Summary of Target Taxa (continued)**

| Taxa | Distribution | Notes |
|---|---|---|
| *Erigeron karvinskianus* | Widespread | Establishes a thick ground cover, spreading by seed and runners. Control in WCAs. Target in cliff and bench areas in habitat for MFS plant taxa (e.g. *Plantago princeps* var. *princeps*). Effective control achieved with 2% glyphosate spray. Trial lower concentrations to avoid negative impacts on native recruits. |
| *Falcataria moluccana* | Scattered | Fast growing, habitat-modifying tree. Not known inside MU, but well established below. Treat as part of WCA work. Kill all mature trees within fence.<br>Control technique: Cut stump or girdle with 20% triclopyr, 80% biodiesel. Can also IPA with 100% aminopyralid. |
| *Grevillea robusta* | Widespread | Commonly known as silk oak, *G. robusta* is a large tree, widespread across the MU. Control in WCA sweeps (including IPA). Priority to kill matures. Lower priority than *Toona ciliata*.<br>Control technique: Cut stump or girdle with 20% triclopyr, 80% biodiesel; IPA with 100% aminopyralid. |
| *Heliocarpus popayensis* | Widespread | Commonly called moho, this tree is concentrated in the northern part of the unit, North Kaluaa and Hapapa bench. Target matures as a priority and in canopy weed sweeps across WCAs.<br>Control technique: IPA with 100% imazapyr. |
| *Lantana camara* | Widespread | Widespread throughout the MU, this shrub can form dense thickets and climb into the canopy. Its thorns are a hazard to NRS when along trails or survey areas. Larger plants have been observed to re-root in sufficient moisture at Hapapa when cut and left on the ground.<br>Control technique: Cut stump with 20% triclopyr, 80% biodiesel. Stack large stumps off the ground or apply herbicide. |
| *Mallotus philippensis* | Scattered | Seedling/saplings are observed in low densities across the MU. Abundant in Lualualei, so re-invasion is likely. Control whenever found.<br>Control technique: Cut stump or girdle with 20% triclopyr, 80% biodiesel. |
| *Melinis minutiflora* | Widespread | Commonly known as molasses grass, *M. minutiflora* can form a thick ground cover impeding recruitment and choking out native plants.<br>Control technique: Foliar spray with 1% glyphosate. Manual control has also been used effectively, and grass-specific herbicides (e.g. Fusilade) should be used in sensitive areas. |
| *Oplismenus hirtellus* | Widespread | Commonly known as basket grass, control is focused mostly along trails.<br>Control technique: Foliar spray with 1% glyphosate. |
| *Paspalum conjugatum* | Widespread | Commonly known as Hilo grass, control is focused mostly along trails.<br>Control technique: Foliar spray with 1% glyphosate. |
| *Passiflora suberosa* | Widespread | A vigorous vine, *P. suberosa* can form dense curtains smothering native plants, and causing a tripping hazard for NRS.<br>Control technique: Cut stump with 20% triclopyr, 80% biodiesel. Can be time-consuming to find where all stalks enter the ground. |
| *Psidium cattleianum* | Widespread | Widespread and often forming dense patches throughout the MU. Rare tree snails have been observed on this taxa. Take care when controlling in known snail sites.<br>Control technique: Cut stump or girdle with 20% triclopyr, 80% biodiesel. |
| *Rubus rosifolius* | Widespread | Widespread and often forming dense patches throughout the MU. Known to quickly invade and spread into canopy gaps.<br>Control technique: Hand-pull. Also basal-bark or clip-and-drip with 20% triclopyr, 80% biodiesel, particularly in areas sensitive to soil disturbance. |

**Summary of Target Taxa (continued)**

| Taxa | Distribution | Notes |
|---|---|---|
| *Schefflera actinophylla* | Widespread | Bird dispersed and well established below MU. Target matures as a priority and in canopy weed sweeps across WCAs.<br>Control technique: IPA with 100% aminopyralid, 100% imazapyr, or 100% glyphosate (glyphosate is the cheapest option). |
| *Schinus terebinthifolius* | Widespread | Commonly known as Christmas berry, *S. terebinthifolius* is widespread and often forms dense patches throughout the MU. Especially abundant on southern-facing slopes.<br>Control technique: Basal-bark with 20% triclopyr, 80% biodiesel. Even large trees are controlled more effectively without cutting. |
| *Setaria palmifolia* | Scattered | Commonly known as palm grass, *S. palmifolia* is a shade tolerant grass that can form dense patches with dense root masses. Within the MU, it is most commonly found in the gulch bottoms (especially North Kaluaa), and in one location at Hapapa bench. It is found in higher densities below the MU. High priority to control around rare taxa and along trails to minimize spread.<br>Control technique: Foliar spray with 2% glyphosate. |
| *Spathodea campanulata* | Widespread | Commonly known as African tulip, *S. campanulata* is a vigorous, easily dispersed tree. It is well established below the MU and found throughout. Target matures as a priority and in canopy weed sweeps across WCAs.<br>Control technique: Cut stump immature trees with 20% triclopyr, 80% biodiesel. IPA larger trees with 100% imazapyr. Follow-up monitoring may be necessary to avoid vigorous re-sprouting from root suckers. May not be effective for trees over 160cm diameter (though these are rare within the MU). Further trials are needed. |
| *Toona ciliata* | Widespread | Commonly known as Australian red cedar, *T. ciliata* is a fast growing, habitat-modifying tree that can produce a lot of seed and grow in high densities. It is a high priority for control. Target in canopy weed sweeps (including IPA) across higher elevation WCAs. Focus on large matures in lower elevations.<br>Control technique: Cut stump or girdle with 20% triclopyr, 80% biodiesel. Can also basal-bark immatures under 7.5 cm diameter with 20% triclopyr, 80% biodiesel. IPA with 100% imazapyr. |
| *Triumfetta semitriloba* | Scattered | Commonly known as Sacramento bur, seeds are easily dispersed hitchhiking on hikers, gear, or pigs. Not known in high densities in the MU, it should be controlled whenever seen, and with priority along trails.<br>Control technique: Clip-and-drip or basal-bark with 20% triclopyr, 80% biodiesel. Immatures can be hand-pulled. |
| *Urochloa maxima* | Widespread | Seen in its highest densities along the ridges and fence lines, control of *U. maxima* (Guinea grass) is needed in these areas to facilitate monitoring and maintenance of affected fences, and to prevent spread throughout the MU. Sprays here are logistically difficult because water needs to be hiked or flown in. Use of water catchments should be investigated, and existing catchments rehabilitated as needed. While rarely seen around rare resources, the habitat-altering characteristics of *U. maxima* and its ability to quickly invade light gaps also make it a target for sprays within the gulches.<br>Control technique: Foliar spray with 2% glyphosate. 1% may be used in more sensitive areas. |

Restoration activities are discussed in the notes section for each WCA. The table below contains specific notes on what native taxa and what type of stock may be appropriate for projects at Kaluaa and Waieli MU.

**Taxa Considerations for Restoration Actions**:

| Native Taxon | Outplant? | Seedsow/ Division/ Transplant? | Notes |
|---|---|---|---|
| *Acacia koa* | | No | Tree. Grow from seed. |
| *Antidesma platyphyllum* | | No | Tree. Grow from cutting. |
| *Bidens torta* | | SeedSow | Herb. Easily grown via seed sows. |
| *Carex wahuensis* | | Seedsow | Sedge. Grow from seed. Seed sows slow to germinate but effective. |
| *Dianella sandwicensis* | | No | Shrub. Grow from seed. |
| *Freycinetia arborea* | | No | Woody vine. Grow from seed. |
| *Kadua cordata* subsp. *cordata* (*H. schlechtendahliana*) | | Transplant | Shrub. Grow from seed or transplant. |
| *Labordia kaalae* | | No | Tree, Grow from seed. |
| *Microlepia strigosa* | | Division | Fern. Survives transplanting in mesic environments. |
| *Myrsine lessertiana* | | | Tree. Grow from seed. |
| *Perrottetia sandwicensis* | | No | Tree. Grow from cutting. |
| *Pipturus albidus* | | Seedsow | Small tree. Fast growing. Known to grow from seed sows. |
| *Pisonia umbellifera* | | Seedsow/Transplant | Tree. Fast growing. Easy to propagate. Know to grow from seed sows. |
| *Planchonella sandwicensis* (*Pouteria sandwicensis*) | | Seedsow | Tree. Grow from seed |
| *Psychotria hathewayi* | | No | Tree. Grow from seed. |
| *Urera glabra* | | No | Tree. Grow from cutting. |
| *Urera kaalae* | | No | Tree, Grow from seed or cutting. |

**WCA Kaluaa and Waieli-01: SBS side of Hapapa**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Canopy weeds include *S. terebinthifolius, Psidium cattleianum, H. popayensis,* mature *T. ciliata* and *G. robusta*. Understory weeds include *R. rosifolius, C. hirta, E. karvinskianus,* and *M. minutiflora*.

Notes: *Achatinella mustelina* are historically abundant in the area, but most have been translocated into Hapapa snail enclosure. Ground/arboreal dwelling snails were also moved (*Laminella sanguinea* and *Cookeconcha* sp.). Much of this WCA is steep and difficult to move around. Access is also limited as it is partially in the Safety Danger Zone (SDZ) of South Range. Though there are still native taxa in the area (i.e. *Lobelia yuccoides* and *Cyanea calycina*), weed efforts here are thus minimized.

**WCA Kaluaa and Waieli-02: Hapapa bench**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Canopy weeds include large *S. terebinthifolius, P. cattleianum,* mature *T. ciliata, S. campanulata,* and *G. robusta*. Understory weeds include *S. palmifolia*, *R. rosifolius*, *C. hirta*, *P. suberosa*, *L. camara, C. parasiticus, B. appendiculatum, E. karvinskianus, M. minutiflora, U. maxima, P. conjugatum*.

Notes: This large WCA is home to several rare plant wild sites and reintroductions sites, as well as the largest populations of *A. mustelina* in the Waianae Mountains. The Hapapa snail enclosure is included in this WCA. Ground dwelling snails and *Drosophila* are also present. For these reasons, it is the major focus of restoration activities within Kaluaa and Waieli MU. Rare plant taxa (wild and reintroduced) include: *D. waianaeensis*, *P. princeps* var. *princeps*, *S. kaalae*, *S. kanehoana*, *U. kaalae, C. membranacea*, *Platydesma cornuta* var. *decurrens*, *L. yuccoides*, *Labordia kaalae*, and *Embelia pacifica*.

Trails within the enclosure are needed to establish designated walking paths as more vegetation is planted and with increased natural recruitment. Weeding within the enclosure is needed on a continual basis to ensure adequate food supply for *A. mustelina*. This will likely include gradual removal of mamaki after shade is established and replaced with better host species for *A. mustelina*.

Due to the presence of such a variety of rare and endangered taxa, care must be taken in replacing weeds with natives, and when conducting any ground disturbance. Conduct gradual removal of canopy weeds, focusing on *S. terebinthifolius*, mature *T. ciliata* and *G. robusta*, to foster native recruitment. Remove understory weeds, focusing on shrubs, herbs, and *C. parasiticus*. Snails in the area are using *Psidium* spp., and control of these taxa should be strategic. The entire WCA should be swept for target canopy species, such as *S. campanulata* and *T. ciliata*. At rare plant sites, both understory and canopy control should be conducted.

*Setaria palmifolia* has been found on the trail from the Hapapa enclosure up to the Hapapa LZ. There is zero tolerance for this target taxa in this WCA.

**WCA Kaluaa and Waieli-03: South Waieli**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 50% non-native cover

Targets: Canopy weeds include mature *T. ciliata, G. robusta, S. actinophylla, S. campanulata,* and *H. popayensis*. Understory weeds include *C. hirta*, *B. asiatica*, *C. parasiticus* and *R. rosifolius*.

Notes: Weed control is focused around reintroduced *D. waianaeensis*. This area is a priority for control. Understory weeds are targeted in addition to limited canopy control. This WCA encompasses the south branch of Waieli, which is dominated by large *T. ciliata* with nice remnant patches of *Pisonia* and *Diospyros*. The back wall of the gulch, just the Hapapa bench WCA, is very steep and dominated by *S. terebinthifolius*. Control of mature *T. ciliata* is a priority, as this is likely an important dispersal source for this taxa throughout the MU. IPA sweeps were done in this gulch in 2013 and 2014.

**WCA Kaluaa and Waieli-04: North Kaluaa above old fence**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Canopy weeds include mature *T. ciliata*, *G. robusta,* and *S. terebinthifolius.* A variety of understory weeds include *P. suberosa*, *R. rosifolius*, *L. camara, C. hirta, P. cattleianum, B. asiatica, B. appendiculatum, U. maximum,* and *S. palmifolia.*

Notes: This WCA encompasses reintroductions of *D. waianaeensis* and *C. grimesiana* subsp. *obatae, E. herbstii, S. kaalae, U. kaalae and U. glabra.* Wild trees of *A. macrococcus* var. *macrococcus* are historically found within this WCA. In addition, there are a few large wild *U. glabra* trees which are appropriate habitat for *D. montgomeryi*. Weed control should be focused on both canopy and understory species around these rare taxa.

The western portion (higher elevations) of this WCA is very steep and dominated by *S. terebinthifolius* canopy; however, successful IPA sweeps were conducted here in 2016 and 2017. This is a priority are for continued IPA sweeps targeting *T. ciliata*.

*Setaria palmifolia* and *U. maximum* are known within this WCA and should be controlled with priority along trails and around rare taxa.

**WCA Kaluaa and Waieli-05: North Kaluaa below old fence**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 50% non-native cover

Targets: Mature *T. ciliata* prioritized for control as well as *G. robusta, S. actinophylla, S. campanulata, H. popayensis, U. maximum* and *S. palmifolia* to prevent/minimize spread throughout the MU.

Notes: There are no managed rare taxa within this WCA. Control is focused on preventing spread of target weeds and reducing recruitment pressure on adjacent WCAs. Canopy sweeps are conducted with priority on mature, fruiting *T. ciliata*, as well as *G. robusta, S. actinophylla, S. campanulata,* and *H. popayensis.* IPA sweeps have been conducted here since 2014 and are scheduled to continue.

*U. maximum* and *S. palmifolia* are abundant within this WCA and should be controlled with priority along trails and fences to prevent spread throughout the MU.

**WCA Kaluaa and Waieli-06: Gulch 3**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Canopy weeds include mature *T. ciliata, G. robusta,* and *S. terebinthifolius.* A variety of understory weeds include *P. suberosa, R. rosifolius, L. camara, C. hirta, B. asiatica, T. semitriloba, P. cattleianum, C. parasiticus, U. maximum,* and *M. minutiflora.*

Notes: Weeding in this WCA is focused around reintroductions of *P. mollis, C. grimesiana* subsp. *obatae,* and *S. kaalae*. The back of Gulch 3, where most of these rare taxa are concentrated, is dominated by native *Pisonia* patches. Habitat on the native slopes contains rock talus substrate which can be challenging for weed control. Care should be taken to avoid harm to ground snails, which are known from this area. Canopy is thick and predominately native within the *Pisonia* patches, minimizing the need for aggressive weed control. Weeding efforts are focused on maintaining understory around rare taxa.

An augmentation of *C. grimesiana* subsp. *obatae* further down gulch has patchier native canopy. While there is a decent native seed bank here, increased control is needed targeting both canopy and understory to encourage native recruitment and expand native habitat. Non-native vines such as *P. suberosa* are especially a problem. This is a possible site for restoration work.

Further upslope, there is also a wild population of *D. waianaeensis*. The slope here is especially steep, and the canopy open. NRS should consider erosion and rock fall hazards while conducting weed control. Control is focused on understory weeds such as *M. minutiflora*. Canopy species should be targeted selectively to avoid sudden light changes or canopy gaps that would boost invasion of understory weeds. This is a possible site for restoration focusing on understory species to prevent erosion.

*Urochloa maximum* is also present in this WCA along the fence bordering WCA-05. It should be maintained to facilitate monitoring and maintenance of the fence line, and to prevent spread throughout the MU. Sprays here are logistically difficult because water needs to be hiked or flown in. Use of water catchments should be investigated, and existing catchments rehabilitated as needed.

IPA sweeps have been conducted in WCA-06 since 2014 and are scheduled to continue.

**WCA Kaluaa and Waieli-07: Gulch 2**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 50% native cover.

Targets: Canopy weeds include mature *T. ciliata*, *G. robusta*, and *S. terebinthifolius*, and understory weeds include *L. camara*, *P. conjugatum*, and *R. rosifolius.*

Notes: There are no managed taxa in this WCA. There is a substantial patch of *U. glabra* trees, which have been augmented by a PEPP outplanting of *U. kaalae*. Although no *D. montgomeryi* are known from this area, it is viable habitat and other rare *Drosophila* are present. Weeding is conducted annually to support this potential habitat. IPA sweeps were conducted in WCA-07 in 2016, and will resume in 2019 focusing first around native forest patches, and secondarily around degraded habitat.

**WCA Kaluaa and Waieli-08: Gulch 1**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Canopy weeds include mature *T. ciliata*, *G. robusta*, *P. cattleianum,* and *S. terebinthifolius*. Understory weeds include *P. suberosa*, *C. hirta,* and *R. rosifolius.*

Notes: This WCA was a core TNC outplanting site which was adopted and expanded by OANRP. A large concentration of rare taxa are found in the lower gulch at the 1A site. These are a combination of reintroductions by TNC, OANRP and PEPP. They include a large outplanting of *D. waianaeensis*, *S. kaalae*, *S. sandwicensis*, *Cyanea pinnatifida* and *U. kaalae*. Also present nearby is the only wild location of *C. grimesiana* subsp. *obatae* in Kaluaa and Waieli MU. There is an intact canopy of native trees, which include *Acacia koa* (koa), *Pisonia umbellifera, Psychotria mariniana*, *Metrosideros polymorpha, Planchonella sandwicensis,* and *Antidesma platyphyllum.*

Weed control is a high priority in the 1A site. It is a large area, requiring substantial maintenance. Understory weeds, particularly *C. hirta,* grow aggressively in areas where *P. cattleianum* canopy was removed. Encouraging koa recruitment into these sites or common native plantings of koa would likely reduce understory weed prevalence. However, canopy species must be carefully managed to ensure they do not shade out *D. waianaeensis* outplants, which prefer more open canopy.

Weed control in this WCA also takes place around *Urera* outplantings in the back of the gulch as part of *Drosophila* habitat stabilization.

The final area of focus for weed control in WCA-08 extends below the 1A site to the stair trail. Weed control in this area is managed by Outreach. The area includes a population of *Cyanea superba* subsp. *superba* planted by TNC, and there are former project stewardship sites located here. In addition, there is a unique grove of *Pittosporum glabrum*, *Gynochthodes trimera* and *P. mariniana*. The terrain is generally conducive to volunteer project weed control, though areas of appropriate terrain should be carefully chosen as the slope gets progressively steeper away from the gulch bottom.

Canopy sweeps throughout the WCA were formerly conducted by the Orange team, but will be taken over by EcoRest in the form of IPA sweeps. IPA sweeps were conducted in 2015, and will continue in 2020 focusing primarily in native forest patches, but also in degraded areas.

**WCA Kaluaa and Waieli-09: Lower Gulch Gate**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 50% native cover

Targets: Canopy weeds include *T. ciliata*, *G. robusta*, *P. cattleianum*, and *S. terebinthifolius*. Understory weeds include *P. suberosa*, *C. hirta*, *R. rosifolius*, *B. appendiculatum* and *O. hirtellus*.

Notes: This WCA encompasses the lowest elevations of Central Kaluaa gulch. There are no managed taxa within the WCA, but there is a population of *Cyanea superba* subsp. *superba* planted by TNC. This WCA is a focal site for outreach activities. Current weed control, conducted by volunteers, is focused primarily around native forest patches as an extension of WCA-08, and secondly in adjacent weedy zones. Non-native understory, including ferns, is targeted with gradual control of canopy weeds. Common native reintroductions will be used where necessary to support restoration activities.

Along the ridge crest leading up the southern fence line, a fairly intact canopy and seed bank of koa remains. This taxon will be used in restoration efforts to replace alien vegetation. A strategy of peeling back alien vegetation beginning at the koa dominated ridge crest first, and moving down slope as koa saplings come up could also be employed in restoring this WCA, and the adjacent WCA-10.

The outreach program formerly targeted *T. ciliata* in the upper portions of the WCA to minimize spread into higher WCAs. IPA sweeps were conducted by EcoRest in 2015 and 2017, and more are scheduled in the future. IPA targets include mature *T. ciliata*, *G. robusta*, *S. campanulata*, *H. popayensis*, and *S. actinophylla*.

**WCA Kaluaa and Waieli-10: South Central/Catchment Ridge**

Veg Type: Mesic Mixed Ridge

MIP Goal: Less than 25% non-native cover

Targets: Mature *T. ciliata*, *P. cattleianum*, *G. robusta*, *S. terebinthifolius*, *C. hirta*, *L. camara*, *R. rosifolius*, and *P. suberosa*

Notes: Weed control in this WCA is concentrated around rare taxa: a reintroduction of *S. kanehoana*, and wild population of *Phyllostegia hirsuta.* Both are located along the southern-most ridge in Kaluaa and Waieli MU. As explained earlier, *S. kanehoana* are planted in sensitive uluhe habitat, and care should be taken to avoid trampling which would encourage incursion of weedy species. In addition, *S. kanehoana* have a sprawling habit and delicate canes that weave throughout the uluhe making it difficult to move among them without breaking them. Weed efforts here are better spent buffering the reintroduction zone to expand native habitat and decrease chances of non-native recruitment into the uluhe. Weed control around the *P. hirsuta* focuses on understory taxa with selective canopy control. There is also potential for volunteer weed control efforts lower on this ridge.

The gulch habitat in this WCA is largely degraded. Weed control here is currently limited to IPA sweeps scheduled for 2020, with priority to native forest patches. There is potential for a Drosophila restoration site in this gulch, but other WCAs (02, 04, 07, and 08) are more promising.

**WCA KaluaaNoMU-01: Kaluaa Access Road**

Veg Type: Mesic Mixed Forest

MIP Goal: None

Targets: *U. maximum*

Notes: This WCA follows the Kaluaa access road from the water tank to the trailhead. Road improvements in 2016 have minimized the need for extensive maintenance. *Urochloa maximum* is power sprayed, and downed-trees cleared as needed.

**WCA KaluaaNoMU-02: CryMan**

Veg Type: Mesic Mixed Forest

MIP Goal: None

Targets: *B. asiatica*, *R. rosifolius*, *T. ciliata*

Notes: No current MIP or OIP goals for this site. Visits were historically conducted to collect from *A. macrococcus* var. *macrococcus* in the area, which has since died, and weed control was conducted in conjunction with PEPP management for *Cryptocarya manii*.

**WCA KaluaaNoMU-03: Ti Leaf Flats**

Veg Type: Mesic Mixed Forest

MIP Goal: None

Targets: *T. ciliata, S. terebinthifolius, S. actinophylla, C. hirta, R. rosifolius, L. camara, C. parasiticus, D. chinensis, O. hirtellus*, and *P. conjugatum*

Notes: This WCA includes the TNC Ti Leaf Flats fence located along the access trail before the contour trail junction. The goal of weed control within this WCA is to ensure continued survival of *Abutilon sandwicense* reintroductions (planted by TNC). The habitat is alien dominated and most of the native plants within the enclosure were planted. This is a low priority action as there are no current MIP goals for this *A. sandwicense* population.

**WCA KaluaaNoMU-04: Kaluaa Access Trail**

Veg Type: Mesic Mixed Forest

MIP Goal: None

Targets: *T. Semitriloba*, *D. chinensis*, *O. hirtellus*, *U. maximum,* and *S. palmifolia*

Notes: The trail corridor is managed annually or as needed to facilitate access by NRS, and minimize the movement of weeds into the MU. *Triumfetta semitriloba, D. chinensis, U. maximum,* and *S. palmifolia* are of particular concern as they are easily spread and not yet well-established in the fence. In addition, the Kaluaa trailhead LZ is included in this WCA; it is a priority to maintain vegetation on and around it as needed.

**WCA KaluaaNoMU-05: GarMan**

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Mature *T. ciliata*, *P. cattleianum*, *G. robusta*, and *C. hirta*

Notes: Weed control is conducted around the endangered *G. mannii* at this site, in conjunction with rare plant monitoring trips. As this *G. mannii* is designated for Genetic Storage Collection, rather than management, limited effort is spent here. Understory weeds and some canopy weeds are targeted directly around the plant to encourage its continued health.

**WCA SBSNoMU-02: (Ie ie Patch)**

Veg Type: Mesic Mixed Forest

MIP Goal: None

Targets: *P. cattleianum*, *S. terebinthifolius*, and *C. parasiticus*

Notes: A small fence once protected a patch of *Frecinetium arborescens*, outplanted *U. glabra*, and a small patch of native forest. *Achatinella mustelina*, *A. micans*, and *L. sanguinea* are known historically from this location, but are no longer extant. This site is not in an MU, and is not a priority for management. Some weed control may be conducted here in conjunction with other rare taxa monitoring activities. Access to the site is limited, as it lies behind a live fire training range and the area is frequently closed to OANRP.

## Rodent Control

Species: *Rattus rattus* (black rat, roof rat), *Rattus exulans* (Polynesian rat)

Threat level: High for *A. mustelina*, *C. grimesiana* subsp. *obatae*, and *D. waianaeensis*

Seasonality: Year-round

Management Objectives:

- Maintain low levels of rat activity around localized control grids.
- Zero-tolerance for rats within the Puu Hapapa snail enclosure.

Strategy and Control Methods:

- Keep sensitive snail populations safe from rat predation via predator proof fence (*Achatinella mustelina* enclosure completed in 2011).
- Maintain predator fence to ensure no breaches occur.
- Monitor ground shell plots for predation of *A. mustelina* by rats.
- Quarterly census monitoring of *A. mustelina* population within the Hapapa snail enclosure to determine population trend and determine if any new threats are present.
- Annual census monitoring of rare plants during fruiting season (*D. waianaeensis*, *C. grimesiana* subsp. *obatae*,) with particular focus on detecting rat damage (gnawed fruit or stalks).
- Maintain 3 localized A24 grids around Hapapa bench, Kaluaa Gulch 1A *D. waianaeensis*, and North Kaluaa *Cyanea grimesiana* subsp. *obatae* sites.
- Keep trails clear and GPS traps to facilitate grid maintenance.

Discussion: Rats are a high threat to both rare plants and invertebrates. They negatively impact rare endangered plants, such as *D. waianaeensis* (pictured below) consuming fruit and seeds and consequentially decreasing seedling recruitment. Rats will also gnaw plants to obtain moisture, especially in drier months, effectively girdling or even chewing through the affected stalk. In addition, rats are known to eat rare snails, as evidenced by predated shells of *A. mustelina* (also pictured below).

Most *A. mustelina* within the management unit are protected from rats by the Hapapa snail enclosure. The enclosure is inspected every 6 weeks and after major rain events. It is inspected for premature rust or weathering of material and erosion that might compromise integrity of the wall. The hood is checked to ensure rats and Jackson's chameleons cannot enter, and surrounding trees are kept well-trimmed to ensure rats cannot jump over the wall. In addition, an Intellesense automatic notification system is maintained in the event of a breach.

Other rodent control in Kaluaa and Waieli MU is currently focused in small-scale grids around affected taxa. There are three grids of automatic self-resetting A24 traps: KAL-A, KAL-D and KAL-E. The KAL-A grid is comprised of 12 traps at Hapapa bench around the snail enclosure; these are intended to protect rare snails in the area that were not translocated into the enclosure, and to reduce outside pressure on the enclosure and possibility of rodent incursion. The KAL-D grid is 6 traps arranged around outplanted *C. grimesiana* subsp. *obatae* in upper North Kaluaa. The KAL-E grid in Kaluaa gulch 1 is the largest, with 30 traps. It was established to protect a large outplanting of *D. waianaeensis* and wild *C. grimesiana* subsp. *obatae*. Other rare taxa protected by this grid are outplanted *S. kaalae*, S*olanum sandwicense*, *U. kaalae*, and *C. pinnatifida*.

Limited research has been done on rat densities or frequencies within Kaluaa and Waieli MU specifically. However, population spikes are known to occur in other areas during the summer coinciding with increased availability of resources, such as *Psidium cattleianum* fruit. With the implementation and improvement of A24 traps, year-round protection for affected taxa is now more efficient and effective. Automatic lure pumps (ALPs) allow constant protection with decreased staff time and maintain efficacy despite seasonal population spikes. A24s require minimal maintenance. The baits are currently changed on a 4-month interval, and trails are maintained as needed. Effectiveness of rodent control is measured by observed impacts (or lack thereof) on target taxa.

**Rat Photos**

Rat predation of *D. waianaeensis* caught on a game camera


Predated *D. waianaeensis* fruit


Gnaw marks on *Coffea arabica*


Evidence of rat predation on *A. mustelina* shells

## Jackson's Chameleon Control

Species: *Triceros jacksonii* subsp. *xantholophus* (Jackson's Chameleon)

Threat level: High for *A. mustelina* and other native snails present in the MU

Seasonality: Year-Round

Management Objective:

- Keep sensitive snail populations safe from Jackson's Chameleon via predator proof fence (*A. mustelina* enclosure).
- Reduce numbers in proximity to outside snails to reduce predation risk.

Strategy and Control Methods:

- Maintain enclosure to ensure no breaches occur.
- While surveying for native snails or conducting any other field work in the MU, note and remove any chameleons.
- Quarterly census monitoring of *A. mustelina* population within the Hapapa snail enclosure to determine population trend and determine if any new threats are present.
- Record locations of captured chameleons to track changes in their distribution and proximity to native snails. Follow numbers of captured animals over time to estimate density.

Discussion:

*Triceros jacksonii* subsp. *xantholophus* are known to consume native snails, including *A. mustelina*, and inhabit many of the same areas. Chameleons were first detected in Kaluaa and Waieli MU in December 2011 after the completion of the Hapapa snail enclosure. Subsequent surveys, including tree-climbing, resulted in 32 total chameleons removed from the enclosure, the last one found in May 2015. In addition, over 600 individuals have since been found and removed from the surrounding area.

The closest naturalized chameleon population is currently located directly outside the Hapapa snail enclosure. Control is limited to hand removal. Spot-lighting at night is the most effecting survey method. It is unknown whether manual control is effective in decreasing overall populations of chameleons, but due to their high fecundity, it is remains a priority to remove them whenever seen in the field.

Night searches for chameleons occur at least quarterly at the Hapapa bench in conjunction with census monitoring of *A. mustelina*. No scheduled control takes place at other *A. mustelina* sites throughout the MU, however chameleons are removed whenever and wherever found during the course of other field work.

**Chameleon photos**


Chameleon with dissected stomach contents (including *A. mustelina* and other native snails)

Juvenile chameleon found in North Kaluaa

Male chameleon found in North Kaluaa

Female chameleon (note lack of horns) at Hapapa

## Predatory Snail Control

Species: *Euglandina rosea* (rosy wolf snail)

Threat level: High for *A. mustelina* and other native snails present in the MU

Seasonality: Peak numbers recorded March through June

Management Objective:

- Maintain enclosure as *E. rosea*-free and reduce numbers outside to promote *A. mustelina* survival.
- Maintain enclosure to ensure no breaches occur.

Strategy and Control Methods:

- Quarterly census monitoring of *A. mustelina* population within the Hapapa snail enclosure to determine population trend and determine if any new threats are present.
- Quarterly sweeps for predatory snails within Hapapa snail enclosure. The entire enclosure should be swept annually. Include searching for *E. rosea* in trees where feasible. If snails or egg caches are found during a quarterly sweep, frequency should be increased to once a week until area has been clear of snails for at least 40 days.
- Close inspection of *Euglandina* barriers.
- Close inspection of any tools, gear, outplantings or transplanted material to prevent introduction of *E. rosea* into the snail enclosure.

Discussion:

*Euglandina rosea* is one of the biggest threats to native snails and the most difficult to control. Predator proof fences, such as the Hapapa snail enclosure, are currently the only viable method of satisfactory control. No baits have been developed for the control of predatory snails that would not also adversely affect native snails. Little is known regarding their distribution and prey preference. Control is limited to hand removal. Visual searches are time-consuming and difficult, but effective when used in conjunction with a well-maintained snail enclosure. Thus staff time should be prioritized to maintain an *E. rosea*-free enclosure through thorough quarterly sweeps of the enclosure, and close inspection and maintenance of the enclosure barriers.

***Euglandina rosea* Photos**

*E. Rosea*

*E. Rosea* predating *A. mustelina*

## Slug Control

Species: *Deroceras laeve, Limax maximus, Meghimatium biliniatum*

Threat level: High for *C. grimesiana* subsp. *obatae* and *D. waianaeensis*

Seasonality: Wet season

Management Objectives:

- Eradicate slugs locally to ensure germination and survivorship of *C. grimesiana* subsp. *obatae* and *D. waianaeensis*
- Avoid potential impacts to rare snails.

Strategy and Control Methods:

- Control slugs at sensitive plant populations via Ferroxx AQ application every 6 weeks. A buffer of at least 5 meters from vulnerable plants is recommended. 10 meters is optimal.
- If rare snails are found in an established Slug Control Area (SLCA), treatment will be halted. Rare snails will be relocated to the Hapapa snail enclosure. The site will then be resurveyed (day and night) to ensure no rare snails are present before treatment is resumed. Annual day and night surveys will be conducted at the SLCA for two years after the last rare snail sighting and annual day surveys will continue indefinitely.
- Annual census monitoring of rare plant seedling recruitment following fruiting events (*U. kaalae*, *D. waianaeensis*, *C. grimesiana* subsp. *obatae*, *Plantago princeps* var. *princeps*, *Phyllostegia mollis*, *P. hirsuta* and *Schiedea kaalae*) with particular focus on detecting evidence of slug feeding (slime trails, leaf margins and lower leaves consumed, upper surface of thicker-leaved species scraped off.)

- If new outplantings of plants vulnerable to slug attack take place, or if existing sites are enlarged, the Rare Snail Specialist must complete a day and nighttime survey to ensure there are no rare snails are in the area. If no native snails are found, apply Ferroxx AQ every 6 weeks.

Discussion:

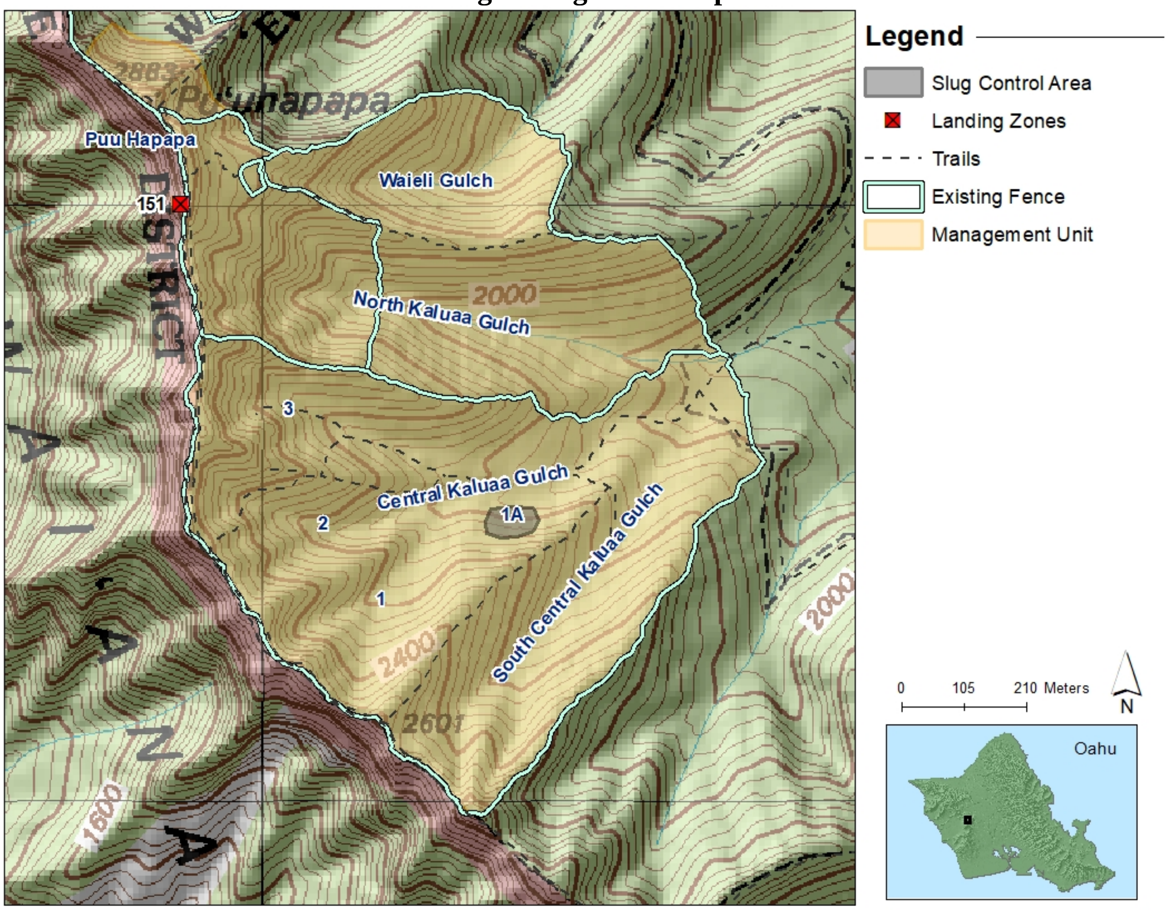
Slugs have an adverse effect on native plants as a result of their feeding behavior. They have been observed to consume leaves and strip plant stalks, reducing their survivorship. Certain species are especially vulnerable to slugs in the seedling stage, and slug presence can reduce recruitment significantly. Localized slug control is currently implemented at one site in Central Kaluaa Gulch 1A (SLCA KAL-A-1) to protect wild *C. grimesiana* subsp. *obatae* and outplanted *D. waianaeensis*.

Special consideration must be taken when performing slug control in the Kaluaa and Waieli MU due to the high presence of native snails. Staff should be aware of the possibility of native snails within the SLCA, and attentive when working in this area. Thorough snail surveys are especially important as well when considering any future SLCAs.

**Slug Control Area Locations Table**

| SLCA Code | Plant population reference codes | Date slug control began |
|---|---|---|
| KAL-A.1 | DelWai.KAL-C, CyaGriOba.KAL-B | 2015-05-25 |

**Slug Management Map**



**Slug photos**


*D. laeve* and typical damage from feeding behavior

Possible slug damage on *C. grimesiana*

*L. maximus* and eggs


*M. biliniatum*

## Ant Control

Species: *Pheidole fervens*, *Pheidole megacephala*, *Plagiolepis alluaudi*, *Solenopsis papuana*, *Technomyrmex albipes*

Threat level: High for *S. papuana* on rare *Drosophila*, unknown for other species

Seasonality/Relevant Species Biology: Varies by species, but nest expansion is typically observed in late summer to early fall

Management Objective:

- Prevent spread of ant species into areas where not already established. Conduct annual surveys during the summer to determine what ant taxa are present in the MU.
- Implement control if incipient, high-risk species are found or as needed for *Drosophila* conservation.

- Detect incursions of new ant species prior to establishment.

Strategy and Control Method:

- Continue to sample ants at human entry points using the standard survey protocol (Appendix 6-1 2010 Year End Report) and *D. montgomeryi* sites a minimum of once a year. Use samples to track changes in existing ant densities and to alert NRS to any new introductions.
- Investigate various toxicants and delivery systems for the purpose of ant control while preventing adverse impacts to *D. montgomeryi*.

Discussion: Ants have been documented to pose threats to a variety of resources, including native arthropods, plants (via farming of Hemipterian pests), and birds. It is therefore important to know their distribution and density in areas with conservation value. This is accomplished using a survey methodology outlined in Appendix 6-1 2010 Year End Report.

In 2017, Paul Krushelnycky (2017 Status Report for the Makua and Oahu Implementation Plans, Appendix ES-10) conducted research at Puu Hapapa and found conclusive evidence that *S. papuana* negatively affects native *Drosophila* survival. The study showed survival was reduced by 58% in the presence of *S. papuana,* whereas, survival was increased 2.4 fold when localized ant control was implemented. *Drosophila* are susceptible to these negative impacts in the larval and pupal stages of development.

Krushelnycky has received grant money and research is underway to assess the effects of AMDRO ant killer on native *Drosophila* and other non-target insects. Results from this study are expected in 2020, and will be used to determine the most effective ant control while preventing adverse impacts to *D. montgomeryi*. If proven safe for use around *D. montgomeryi*, AMDRO can be applied monthly to control ants around host plants and where larvae and pupae are found.

Ant surveys are currently scheduled annually at the 2 LZs: Waieli-TNC Hapapa LZ (151) and Kaluaa Trailhead LZ (214). Other surveys around *D. montgomeryi* populations may be implemented as deemed necessary by the Entomology Program Specialist and the Alien Invertebrate Control and Research Specialist.

## Vespula Control

Species: *Vespula pennsylvanica*

Threat level: High for *Drosophila*

Seasonality: Year-Round

Management Objective:

- Locate nests by following workers. Destroy nests mechanically (by bagging nests and leaving in the sun, for example) if possible, as pesticides may impact *D. montgomeryi.*
- Cooperate with Big Island researchers in getting fipronil bait registered.

Strategy and Control Methods:

- As needed, deploy traps baited with heptyl butyrate and repeat consecutive years at roughly the same time of year. Leave traps in place for two weeks then collect and record catch.
- Determine whether *D. montgomeryi* populations respond favorably to lower numbers of wasps.
- If populations increase substantially over time causing a decrease in *D. montgomeryi*, locate and destroy nests.

Discussion:

*Vespula pennsylvanica* is a known insect predator; flies have been recorded in their diets on Hawaii Island and Maui. They are likely a significant predator of *D. montgomeryi* and should be monitored within potential habitats. Wasps can also be a hazard to staff. No poison baits are currently approved for use in suppressing wasp numbers, however, USGS researchers at Hawaii Volcanoes National Park hope to get a finpronil bait registered. NRS will cooperate in this effort.

NRS currently monitor *V. pennsylvanica* numbers monthly at the Hapapa site using 10 traps baited with heptyl butyrate. No *V. pennsylvanica* have currently been detected at *D. montgomeryi* sites within Kaluaa and Waieli MU. Nests were destroyed along and below the contour trail by State of Hawaii Dept. of Agriculture staff in 2001.

## Fire Control

Threat Level: Low

Seasonality/Potential Ignition Sources: Ignition sources could be from military training although direction of fire from South range is to the north, away from the Kaluaa and Waieli MU. There is currently limited public access to this unit and therefore the threat of arson is low; however, campfires are a possible threat and fire pits have been observed (e.g. Hapapa LZ, Contour trail, Kaluaa trailhead).

Management Objectives:

- To prevent fire from burning any portion of the MU at any time.

Strategy and Control Methods:

- NRS to remain vigilant of campfires and other possible ignition sources seen when working within the MU.
- Monitor fires in surrounding areas to prevent spread into MU.
- Emergency landing zones were previously cleared and maintained by TNC on Mauna Una and the Hapapa Access Ridge but have since become overgrown. These could be cleared again as needed should fires break out in the MU.

Discussion:

Fire threat in Kaluaa and Waieli MU is low due to lack of nearby ignition sources, low fuel loads within the MU, and its wetter habitat. There is no recent history of fires burning near the MU; the closest fires have occurred over 1 km away on Schofield Barracks South Range. These are generally well contained and fire response is quick. This MU is easy to monitor from both OANRP baseyards and is within close proximity to the Army Wildland Fire baseyard. Since Honouliuli is state land, the Kaluaa and Waieli MU is within DOFAW’s primary response area, and they could also respond in the event of a fire inside the MU.

# Action Table

The table below is a comprehensive list of threat control actions planned for the MU for the next five years. Actions are grouped by type; for example, Ungulate Control or Ant Control. Weed control actions are grouped into the following categories: General Survey, ICA code, or WCA code. Cells with **X** denote the quarters in which an action is scheduled. IP years run from October of one year through September of the next. Therefore, Quarter 4 (October-December) is listed first for each report year, followed by Quarter 1 (January-March), Quarter 2 (April-June), and Q3 (July-September). Species names are written as six-digit abbreviations, such as 'CenSet' instead of *Cenchrus setaceus*, for brevity.

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 7837 | Ant Control | DroMon | None | Survey ants at LZ and at Puu Hapapa annually for the protection of Drosophila | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |
| 7845 | Common Collections | MyrLes | None | Common native collection of Myrsine lessertiana (Kolea): Collect/monitor fruit for use in restoration projects in Kaluaa and Waieli and Seed Zone: OA-8. Several founders on Hapapa bench and slope above. Action includes monitoring phenology of common native species. | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | |
| 1242 | Fence Monitor/ Maintenance | None | KAL-A | All fence monitoring and maintenance actions. Maintenance is defined as any minor repair work or that is LESS THAN 100m. Combined sections A and B so it is now just the entire perimeter. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| 3390 | Fence Monitor/ Maintenance | None | KAL-C | All fence monitoring and maintenance actions. Maintenance is defined as any minor repair work or that is LESS THAN 100m. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| 5620 | Fence Monitor/ Maintenance | None | KAL-D | All fence monitoring and maintenance actions. Maintenance is defined as any minor repair work or that is LESS THAN 100m. | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |
| 3136 | Predator Control: Rodent | AchMus | KAL-A | A24 Grid at Hapapa. Re-bait every 4 months. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| 7223 | Predator Control: Rodent | CyaGriOba | KAL-D | North Kaluaa CyagriOba Site A24 Grid. Re-bait every 4 months. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| 7726 | Predator Control: Rodent | DelWai | KAL-E | Kaluaa and Waieli 1A Site A24 Grid. Re-bait every 4 months. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| 5729 | Slug Control | DelWai | KAL-A-1 | Control slugs at Site 1 (DelWai.KAL-C & SchKaa.KAL-B). Rate is 10 Lbs. of FerroxxAQ for entire site once every 6 weeks. If using Sluggo then apply 20 lbs. of product every month | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018- Sept2019 | | | | MIP Year 16 Oct 2019- Sept2020 | | | | MIP Year 17 Oct 2020- Sept2021 | | | | MIP Year 18 Oct 2021- Sept2022 | | | | MIP Year 19 Oct 2022- Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 1190 | Weed Control | None | Kaluaaand Waieli-01 | Control weeds across upper section of SBS/Army Hapapa every 6 months/year. Focus around Achmus sites, potential Drosophila sites, Phyhir, native forest patches. Work to connect these areas. Target Schter, Toocil, Helpop, Erikar, weedy grasses. ACCESS LIMITED, CONDUCT AS FEASIBLE | | | | X | | | | X | | | | X | | | | X | | | | X |
| 2779 | Weed Control | None | Kaluaaand Waieli-02 | Conduct understory weed control around Plapri reintro annually. Area is steep and sensitive, exercise caution. | X | | | | X | | | | X | | | | X | | | | X | | | |
| 2781 | Weed Control | None | Kaluaaand Waieli-02 | Control Erikar across crest, steep slopes at west edge of WCA. Focus around native forest patches, potential reintroduction sites. Area is steep and fragile, exercise caution and avoid trampling sensitive areas. Use alternative technologies to treat if possible. | | | X | | | | X | | | | X | | | | X | | | | X | |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 2872 | Weed Control | None | Kaluaaand Waieli-02 | Control weeds across the bench portion of the WCA, including outside snail enclosure, every 6 months. Target understory and gradual removal of canopy weeds. Ensure NO control of snail trees. Focus effort around common reintros, native forest patches, snail zones; seek to connect these sites. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 3530 | Weed Control | None | Kaluaaand Waieli-02 | Control weedy grasses across WCA every 6 months/as needed. Target Melmin, UroMax, PasCon. Primary grass sites are crestline, fenceline, trail, bench flats. | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 4151 | Weed Control | SetPal | Kaluaaand Waieli-02 | Monitor/control SetPal on trail from bench to LZ every 6 months/annually. Handpull and remove plant from field. | X | | | | X | | | | X | | | | X | | | | X | | | |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| 6377 | Weed Control | AchMus | Kaluaaand Waieli-02 | Sweep entire enclosure at least once every 6 months. Focus on vines, woody weed keiki, and grasses. Zero tolerance inside enclosure for Bleapp, Passub, Nepmul, Bidalb. Short-lived herbaceous weeds are not a priority. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| 6710 | Weed Control | AchMus | Kaluaaand Waieli-02 | Clear/maintain fence (Ungulate fence, not snail enclosure). Remove downed trees, spray grass, treat thick understory, as needed to keep fence in good repair | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | |
| 5659 | Weed Control | None | Kaluaaand Waieli-03 | Control weeds around reintro zone every 6 months. Focus around Delwai, targeting understory. | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | |
| 6282 | Weed Control | None | Kaluaaand Waieli-03 | Clear/maintain fence. Remove downed trees, spray grass, treat thick understory, as needed to keep fence in good repair | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | |
| 2945 | Weed Control | None | Kaluaaand Waieli-04 | Control weeds around Cyagrioba reintro zone every 6 months. Target understory weeds and gradual control of canopy weeds. | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
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| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| 4948 | Weed Control | None | Kaluaaand Waieli-04 | Control weeds at Drosophila restoration sites and around Uregla patches, every 6 months. | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | |
| 4949 | Weed Control | None | Kaluaaand Waieli-04 | Control weedy grasses across WCA as needed, at least annually. Target UroMax and SetPal. Focus along trails to prevent further spread. | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | |
| 4962 | Weed Control | None | Kaluaaand Waieli-05 | Clear/maintain fence. Remove downed trees, spray grass, treat thick understory, as needed. | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | |
| 6397 | Weed Control | None | Kaluaaand Waieli-05 | Control weedy grasses across WCA as needed, at least annually. Focus on fence, trails to prevent further spread. Target UroMax and SetPal. | **X** | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** |
| 2943 | Weed Control | None | Kaluaaand Waieli-06 | Control weeds through reintro/potential reintro zone every 3-6 months (Cyagrioba, Phymol, Schkaa). Target understory weeds and gradual control of canopy weeds: Schter, Toocil, Budasi, Psicat, Lancam, Bleapp, Chrpar, Passub, etc. Expand boundaries of weeded zone. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 4950 | Weed Control | None | Kaluaaand Waieli-06 | Control weedy grasses across WCA as needed. Target UroMax, PasCon, SetPal. Focus on fence dogleg (UroMax) and gulch bottom (SetPal). | X | | X | | | | X | | | | X | | | | X | | | | X | |
| 5778 | Weed Control | None | Kaluaaand Waieli-06 | Clear/maintain fence. Remove downed trees, spray grass, treat thick understory, as needed. | | X | | | | X | | | | X | | | | X | | | | X | | |
| 4955 | Weed Control | None | Kaluaaand Waieli-07 | Control weeds across Alemacmac zone, annually. Target understory around rare taxa and gradual canopy control. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 5784 | Weed Control | None | Kaluaaand Waieli-07 | Clear/maintain fence. Remove downed trees, spray grass, treat thick understory, as needed. | | X | | | | X | | | | X | | | | X | | | | X | | |
| 6398 | Weed Control | None | Kaluaaand Waieli-07 | Control weeds in Uregla patches, annually, to support Drosophila habitat. Gradual control of understory and canopy. | X | | | X | | | | X | | | | X | | | | X | | | | X |
| 2874 | Weed Control | None | Kaluaaand Waieli-08 | Control weeds around reintro/rare taxa zone every 3-6 months. Target understory weeds (Clihir) and gradual control of canopy weeds (Schter, Psicat, Psigua). | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 5779 | Weed Control | None | Kaluaaand Waieli-08 | Control weeds at Drosophila restoration sites and around Uregla patches in back of gulch, every 6 months. | X | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |
| 6400 | Weed Control | None | Kaluaaand Waieli-08 | Clear/maintain fence. Remove downed trees, spray grass, treat thick understory, as needed. | | X | | | | X | | | | X | | | | X | | | | X | | |
| 3929 | Weed Control | UroMax | Kaluaaand Waieli-09 | Monitor/control UroMax along north Kaluaa fenceline quarterly, or as needed. | | X | | | | X | | | | X | | | | X | | | | X | | |
| 2785 | Weed Control | None | Kaluaaand Waieli-10 | Control weeds around Ste kan reintros (2) every 6 months. Target understory weeds (Clihir, Passub, Lancam, Psicat) and gradual control of canopy weeds (Psicat). Work to connect two reintro sites. Exercise caution around delicate SteKan. | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |
| 4953 | Weed Control | None | Kaluaaand Waieli-10 | Control weeds around Phyhir every 6 months/year. Target understory weeds (Bleapp, Rubros, Budasi, Melmin) and gradual control of canopy weeds. | | X | | X | | | | X | | | | X | | | | X | | | | X |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 4954 | Weed Control | None | Kaluaaand Waieli-10 | Clear/maintain fenceline. Remove fallen trees, spray grass, treat thick understory, keep trail clear of weeds, as needed. Target Passub, Lancam, Psicat along fence corridor. | | X | | | | X | | | | X | | | | X | | | | X | | |
| 5169 | Weed Control | None | KaluaaNo MU-01 | Control grass/herbaceous weeds, clear downed trees along the access road, from the water tank turn off to the trailhead, every 6 months/as needed. Use the power sprayer, chainsaw, weedwhack. Goal: maintain road, public safety, reduce weed spread. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 2876 | Weed Control | None | KaluaaNo MU-02 | Control canopy and understory weeds as necessary to allow for collections from Alemac at this site. Visit site with partners from OPEP. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 5550 | Weed Control | None | KaluaaNo MU-03 | Conduct weed control within ti-leaf fence as needed to promote survivorship of outplanted Abusan/Delwai to facilitate genetic collections (GSCs). Treat understory aggressively to minimize | X | | | X | | | | X | | | | X | | | | X | | | | X |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** |
| | | | | number of retreatments needed. | | | | | | | | | | | | | | | | | | | | |
| 6281 | Weed Control | None | KaluaaNo MU-04 | Control weeds along access trail, particularly understory taxa. Focus on DicChi and SetPal, to minimize their spread into MU. | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | |
| 5984 | Weed Control | None | KaluaaNo MU-05 | Conduct weed control around Garman, focusing on understory weeds and limited canopy control. This is a GS population. | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | |
| 5985 | Weed: Camp Survey | None | OS-Kaluaa-01 | Survey Hapapa shelter/campsite (5m buffer around shelter and adjacent areas used for camping) whenever used, not to exceed once per quarter. If not used, do not need to survey. | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| 2834 | Weed: Incipient Control | AngEve | Kaluaa-AngEve-01 | Monitor/control AngEve in South Central annually. Foliar spray of G4 works well; to reduce non-target drift, cut off large fronds of mature plants and treat when new croziers appear. | | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 5987 | Weed: Incipient Control | ArtCil | Kaluaa-ArtCil-01 | Monitor/control ArtCil along access trail. Only 1 plant found; search for seedlings. Monitor annually (and incidentally during other management work). | | X | | | | X | | | | X | | | | X | | | | X | | |
| 4157 | Weed: Incipient Control | CasEqu | Kaluaa-CasEqu-01 | Monitor/control CasEqu at spot just outside south fenceline annually. | | | | X | | | | X | | | | X | | | | X | | | | X |
| 4138 | Weed: Incipient Control | CluRos | Kaluaa-CluRos-01 | Monitor/control CluRos along contour trail. Bring chainsaw for large mature tree. Survey area around tree for keiki, 100m buffer. During course of other field work, keep lookout for other CluRos. Research reliable control method. | X | | | X | | | | X | | | | X | | | | X | | | | X |
| 6283 | Weed: Incipient Control | DovHeb | Kaluaa-DovHeb-01 | Monitor/control DovHeb in Waieli gulch. Monitor every 6 months/annually. | X | | | X | | | X | | | | X | | | | X | | | | X | |
| 6554 | Weed: Incipient Control | EhrSti | Kaluaa-EhrSti-02 | Monitor/control Ehrsti at Pig Trap site along Hapapa access trail quarterly. Pick and remove from field any potentially mature fruit. This species is cryptic and can be difficult to id. Spray with preemergents. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 4155 | Weed: Incipient Control | MorFay | Kaluaa-MorFay-01 | Monitor/control MorFay below contour trail. Continue to survey entire Morfay ICA for mature plants. Sweep entire ICA once a year. | | | X | | | | X | | | | X | | | | X | | | | X | |
| 7762 | Weed: Incipient Control | ChrOdo | KaluaaNoMU-ChrOdo-01 | Sweep whole ICA, 2-4x year. Pick and remove from field any potentially viable fruit. Check known hotspots and treat with pre-emergent every 3-6 months. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X | | X | | X |
| 3846 | Weed: Incipient Control | SolCap | Kaluaa-SolCap-01 | Monitor/control SolCap in gulch bottom, above and below contour trail, every 6 months. Use GPS to track coverage of weeded areas (ICA large). | X | | | | X | | | | X | | | | X | | | | X | | | |
| 6280 | Weed: Incipient Control | MorFay | WaieliNoMU-MorFay-01 | Monitor/control MorFay north of Hapapa on ridge, every 6 months/year. Only 1 mature plant found. | | | | X | | | | X | | | | X | | | | X | | | | |
| 3553 | Weed: LZ Survey | None | LZ-HON-151 | Survey Waieli/Hapapa improved LZ whenever used, not to exceed once per quarter. If not used, do not need to survey. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| 7174 | Weed: LZ Survey | None | LZ-Kaluaa-214 | Survey SBS-Kaluaa LZ (214) whenever used, not to exceed once per quarter. If not used, do not need to survey. | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 5870 | Weed: LZ Survey | None | LZ-SBS-164 | Survey Army LZ Cat whenever used, not to exceed once per quarter. Must survey annually at minimum, since Army LZ. | | X | | | | X | | | | X | | | | X | | | | X | | |
| 1232 | Weed: Road Survey | None | RS-SBS-01 | Survey all drivable roads inside SR-1 gate, around FP Halo, past Army Town, in front of underground storage areas(northern training area). GPS track and input in GIS. If see any soil/fill stockpiles, survey carefully around them and note location. | | X | | | | X | | | | X | | | | X | | | | X | | |
| 6260 | Weed: Road Survey | None | RS-SBS-02 | Survey every drivable road in southern training area (take left after SR-1 gate). TAKE MAP! Includes road to pistol range, roads through 'villages'/IED lanes, 'Medical' LZ/DZ, side roads through old fields, and 4x4 road to Kaluaa trailhead. GPS track and input in GIS. If see any soil/fill stockpiles, | | X | | | | X | | | | X | | | | X | | | | X | | |

## Action Table (continued)

| Action ID | Action Type | Taxon Code | Action Site Code | Actions | MIP Year 15 Oct 2018-Sept2019 | | | | MIP Year 16 Oct 2019-Sept2020 | | | | MIP Year 17 Oct 2020-Sept2021 | | | | MIP Year 18 Oct 2021-Sept2022 | | | | MIP Year 19 Oct 2022-Sept2023 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| | | | | survey carefully around them and note location. | | | | | | | | | | | | | | | | | | | | |
| 5871 | Weed: Transect Survey | None | WT-Kaluaa-01 | Survey access trail from parking area, along contour trail, to MU gate for weeds, annually. | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | |
| 5777 | Weed: Transect Survey | None | WT-Kaluaa-02 | Survey main Kaluaa gulch trail, from gate up gulch to 2/3 split for weeds, annually | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | |
| 5872 | Weed: Transect Survey | None | WT-Kaluaa-03 | Survey Hapapa access trail, beginning from Carnation trail, crossing contour trail, up fence to Hapapa Snail Enclosure. | | **X** | | | | **X** | | | | **X** | | | | **X** | | | | **X** | | |
| 7761 | Weed: Weed Survey | ChrOdo | KaluaaNoMU-ChrOdo-01 | Conduct surveys around known ICA, for 200m, to determine if true outlier. Use results of survey to revise ICA shape as needed. | **X** | | | | | | | | | | | | | | | | | | | |

O'AHU INVASIVE SPECIES COMMITTEE

# Survey and Control of *Chromolaena odorata* in the Kahuku Training Area, Oʻahu, Hawaiʻi

Annual Progress Report
October 1, 2016—September 30, 2017

(*Chromolaena odorata*) *being removed by hand*

**Summary of Project Objectives:**

*Chromolaena odorata*, commonly known as devil weed, is a state-listed noxious weed that is toxic to livestock, people and other plants. It possesses the ability to root vegetatively, produces up to 800,000 wind-dispersed seeds a year and is a fire promoting species that forms dense, monotypic stands of vegetation. The Oʿahu Army Natural Resources Project (OANRP) discovered *C. odorata* at the Kahuku Training Area (KTA) on the north shore of O'ahu in January 2011 as part of its early detection program. The Biological Opinion for military activities on O'ahu requires the Army to respond immediately to incipient weeds brought in via training operations. What is currently known about *C. odorata* supports the assumptions that the center of the population is the Kahuku Training Area (KTA) and that *C. odorata* was introduced to KTA because of military activities.

*Bagging seeds to prevent further dispersal*

Between 2006 and 2009, botanical surveys of all publicly accessible roads on O'ahu were conducted by OISC's O'ahu Early Detection program. *C. odorata* was not found during these surveys. This means that it is unlikely *C. odorata* was introduced somewhere else and dispersed onto KTA. *C. odorata* is a widely dispersed pest on the island of Guam, and units from Hawai'i sometimes train in Guam. The seeds are wind dispersed and readily attach to clothing. One plant can produce approximately 800,000 seeds a year. Given these factors, it is highly likely the pathway of introduction was military activities.

The aim of this project is to contain or eradicate *Chromolaena odorata,* commonly called devil weed, from the Kahuku Training Area (KTA). Eradication at KTA will reduce the threat of this species spreading to natural areas that may contain protected species. At KTA, OISC conducts sweeps of designated subunits and flags devil weed infestations for later treatment by OANRP. This method allows consistent monitoring of devil weed treatments to ensure that areas that may need re-treatment are noted and any new infestations mapped. OISC's responsibilities are:

- Surveying and monitoring treatment of subunits 3,4,7,8 and 10 within the Alpha 1 Range of Kahuku Training Area (KTA). This includes state land leased by the military and used by the public as a motorcross recreational area on the weekends.
- Flagging areas as "hotspots" for follow-up treatment by OANRP. Hotspots are defined as areas with more than five plants or areas that would be inefficient to treat without a power sprayer or an aerial spray.
- Monitoring hotspot treatment and recording amount of re-growth after treatment.
- Removing outlier *C. odorata* outside of hotspots.
- Treating re-growth inside previously treated hotspots if this can be accomplished without delaying surveying (otherwise area is flagged for follow-up treatment by OANRP).

- Communicating results of all monitoring through a Google Docs spreadsheet.
- Assisting with treatment and acquiring access to private land that makes treating OISC hotspots OISC 022, 024 and 080 more efficient.

**Project Accomplishments: October 1, 2016—September 30, 2017.**

**Fieldwork:**

During the reporting period, OISC conducted eight multi-day trips and also assisted in treating hotspots OISC 022, 024 and 080 during day-trips. In total the OISC fieldcrew:

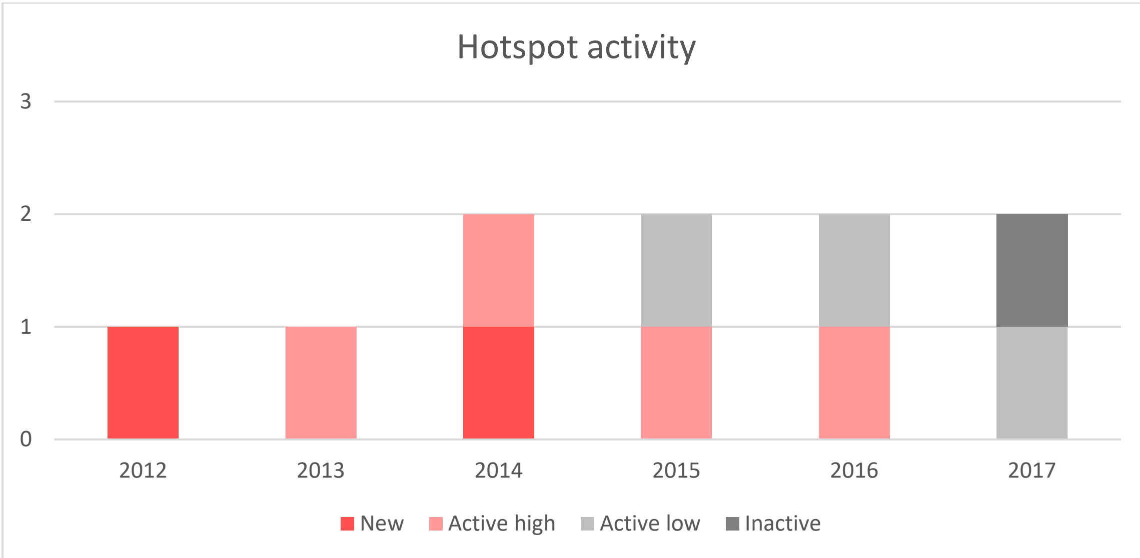
*Spraying a hotspot.*

- Spent 1639 hours and conducted survey sweeps over 1,230 acres in the Kahuku Training Area.
- Treated a total of 367 mature and 3,442 immature plants. It should be noted that these numbers are not a reflection on the total amount of plants detected or that actually exist within the subunits OISC and OANRP manage, just the total that were treated by OISC staff.
- Mapped monotypic fields of guinea grass for possible alternate survey techniques since these areas have a lower confidence level.
- Took points that appeared to be good areas to use gigapan technology—a technique OANRP has begun to use for other species.
- Assisted OANRP staff by acquiring access to adjacent private land and providing labor to power spray hotspots OISC 022, 024 and 080.
- The crew was also able to ground-truth the Gigapan photos that were taken of Kaunala Gulch. They used landmarks from the photos to find the point. The crew noted six new hotspots in the Hotspot Spreadsheet. The crew did not notice seedlings popping up, but the crew thought the terrain would require an aerial spray. The crew saw many mature plants, but not many seedlings. They noted the area would be challenging to monitor due to the terrain.

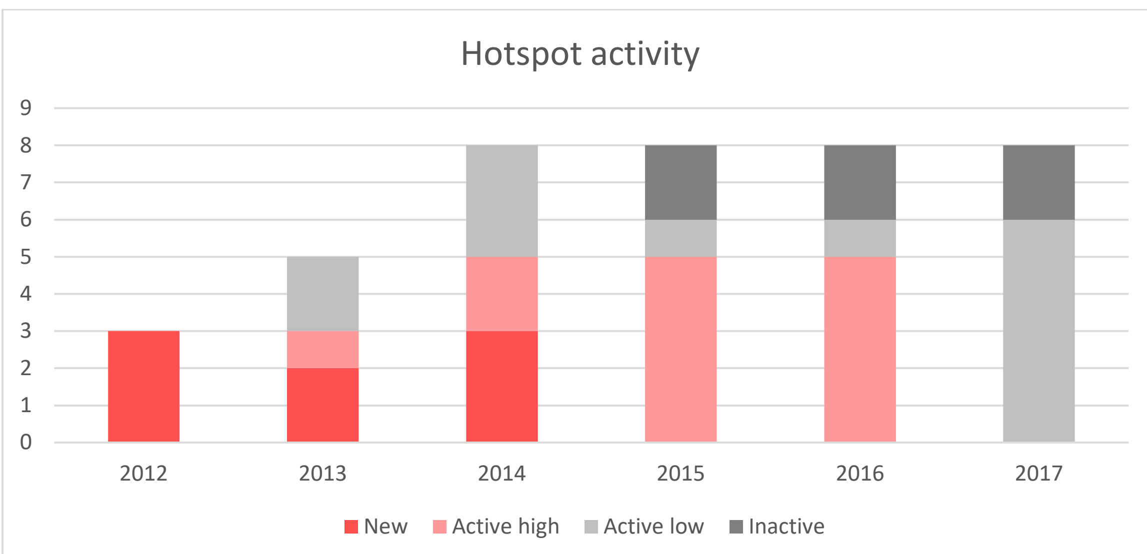
**Observations and Results:**

OISC data alone cannot be analyzed for results since the field crew is responsible for surveys and OANRP is responsible for much of the treatment. OISC and OANRP worked together to come up with metrics to track success with this project. Going forward we will review the number of hotspots annually. A hotspot is defined as five more mature plants. Success will be measured by declining numbers of hotspots over time.  Graphs showing hotspot activity are below:

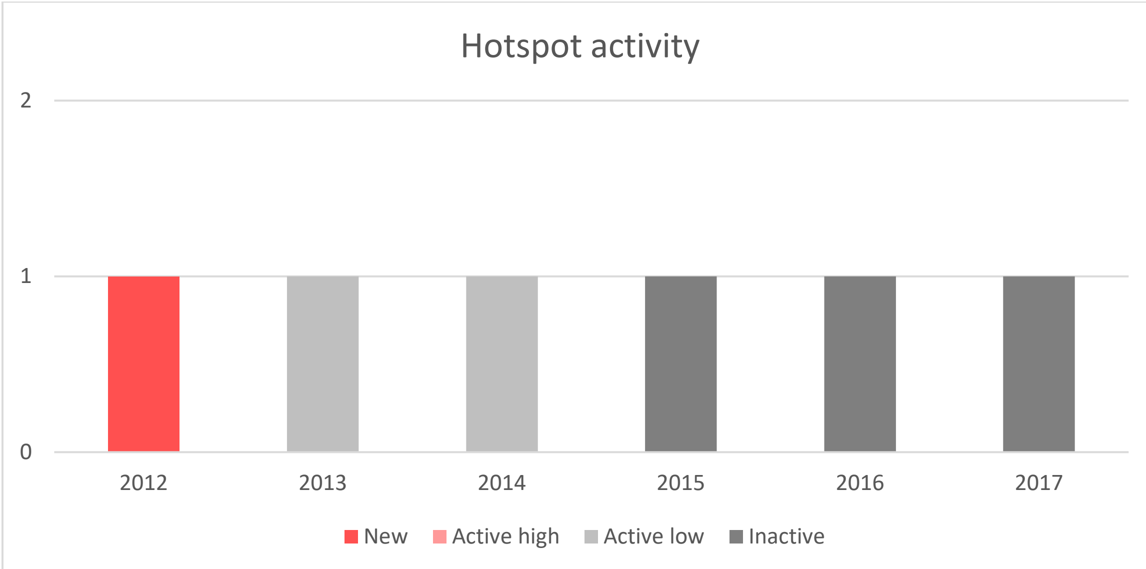
**KTA Subunit 8**



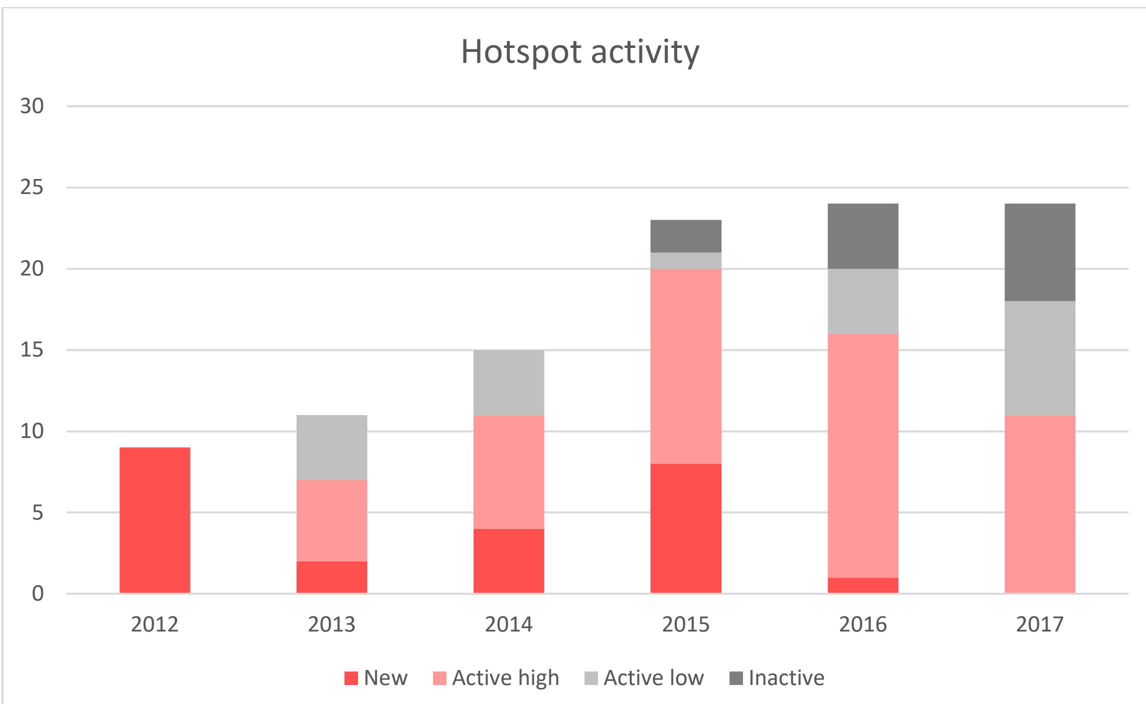

**KTA Subunit 7**



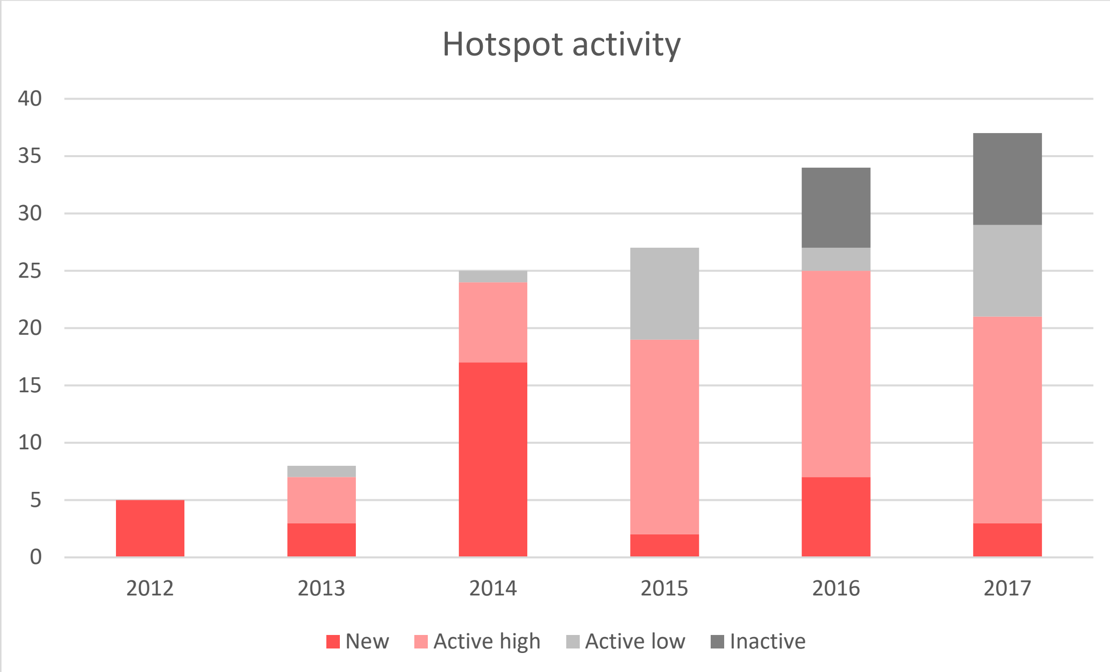
**KTA Subunit 10**




**KTA Subunit 4**



**KTA Subunit 3**




**Data Management and Project Coordination:**

During the reporting period, OISC staff entered observations for each hotspot into the Google Docs Hotspot Spreadsheet and quality controlled data from the field entered into the database.

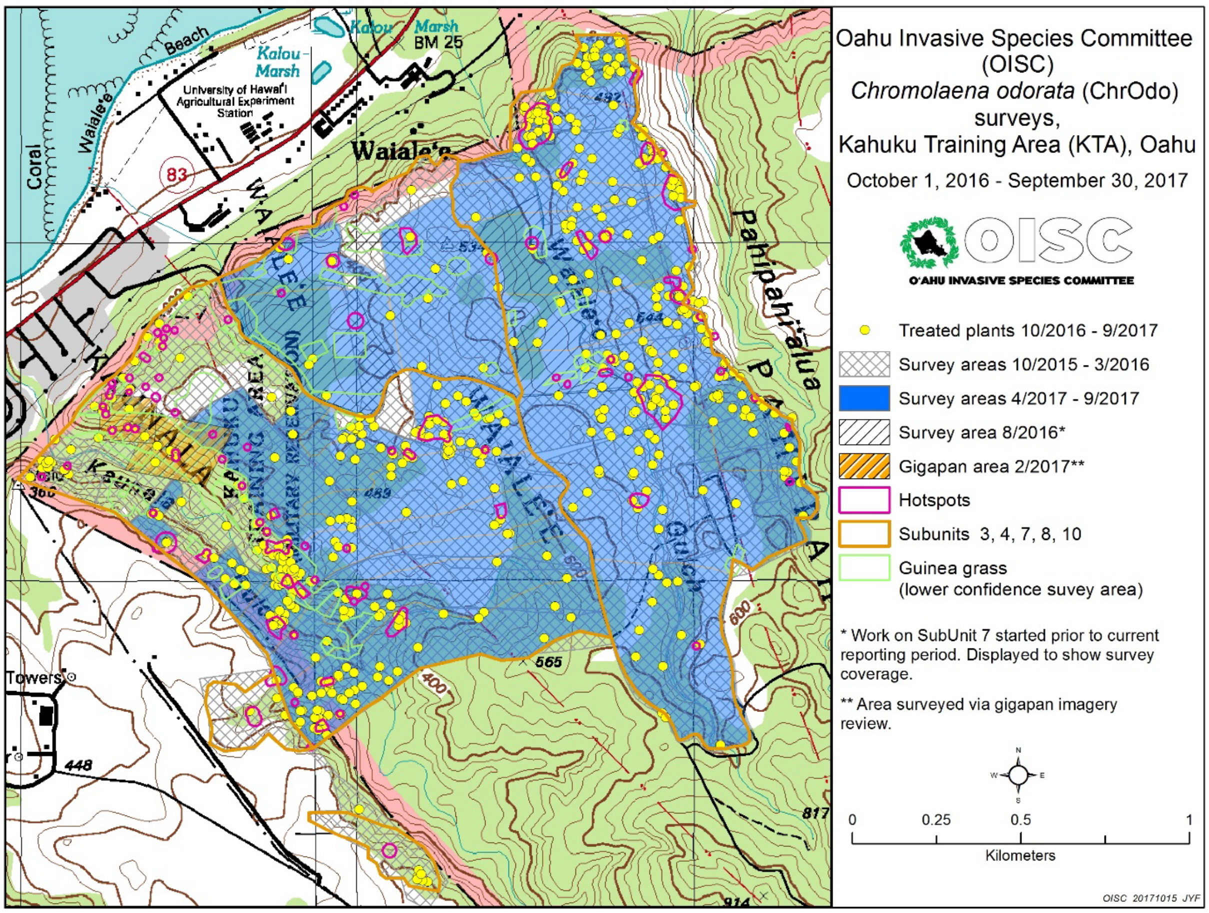
**Challenges:**

During the September trip, one OISC field crew member was stung by 20-30 bees and had to be removed from the field and brought to the emergency room. The incident happened on Kaunala Gulch, a steep area where the crew has mapped numerous beehives. The incident was made worse because the thick vegetation and numerous cliffs in the area made the field crew member feel that she could exit the area safely. OISC has consulted with the Hawaiʻi Department of Agriculture apiary specialists to learn more about how to protect the field crew from bee stings. They advised light colored clothing and so OISC will buy light colored shirts for KTA work. Unfortunately, most of the other advice involves exiting the area quickly which may be difficult to do if there are multiple ledges and thick vegetation.

**Table 1: OISC *Chromolaena odorata* Work Effort Summary at Kahuku Training Area October 1, 2015—September 30, 2016**

| Location | Acres Surveyed | Mature Plants Treated | Immature Plants Treated | Total Plants Treated | Effort (Hours) |
|---|---|---|---|---|---|
| KTA Subunits 3, 4, 7 | 1202.49 | 363 | 3,429 | 3,792 | 1,611 |
| KTA Subunits 8 | 13.69 | 0 | 5 | 5 | 14 |
| KTA Subunits 10 | 13.75 | 4 | 8 | 12 | 14 |
| **Total** | **1229.93** | **367** | **3,442** | **3,809** | **1639** |

**Figure 1: OISC *Chromolaena odorata* Work Effort in Kahuku Training Area October 1, 2016 – September 30, 2017**

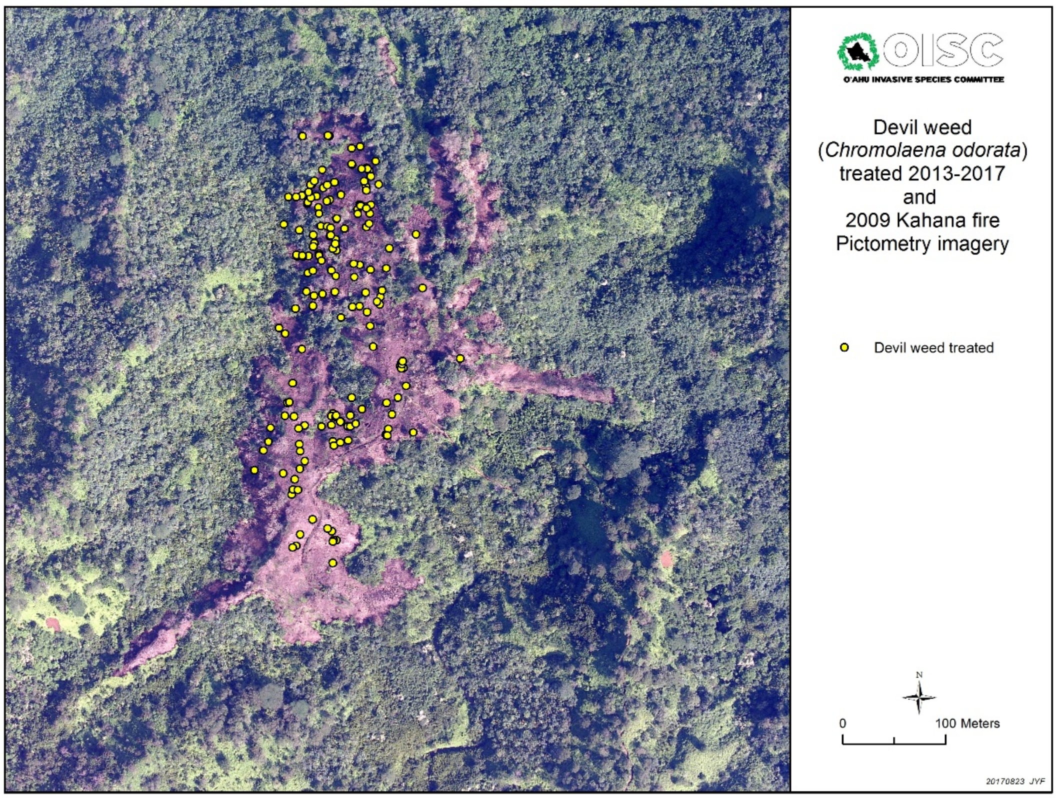



***C. odorata* activites Supported with Other Funds:**

**Surveys and Control for *C. odorata* outside of the Kahuku Training Area (KTA):**
ʽ**Aiea:** OISC continued to delimit around ʽAiea Loop Trail and at Camp Smith. The crew found Range debris on two separate occasions at Camp Smith and so operations in the northern part of Camp Smith have ceased until the Marine Corps EOD can conduct a wider cleanup. OISC sent

a mailer out to approximately 1300 residences located in the search area for *C. odorata* asking them to check their yards and alerting them that OISC may be doing road surveys in their neighborhoods.

**Kahana:** OISC conducted an aerial spray at Kahana State Park. The spray worked well. Mahalo to OANRP for allowing us to borrow their spray rig and an OANRP employee who helped the OISC field crew coordinate the operation. The crew has found a few plants on the edges of the hotspot. The photo below shows Pictometry from 2009 of the burn left by a fire in Kahana. The *C. odorata* points from 2013-2017 fit almost perfectly inside it. OISC has surveyed 200 meters around these points and not found anything. Given that the dispersal pattern seems to fit the burn pattern, OISC reduced the survey area to 50 meters from historical points.




**Bellows Air Force Base:** OISC also assisted with the Marine Corps Base Hawaii Environmental Office MCBH survey of Bellows Air Force Base that was intended to look for fountain grass. *C. odorata* was added as a target due to the individual plant found in Lanikai. No *C. odorata* was found.

**Lāʻie:** OISC crew acquired permission for and surveyed the Lāʻie Falls trail. Some crewmembers had noticed off-road vehicles on this trail during their off-time. The trail is also close to KTA, so it seemed worthwhile to check out. No plants were found, but the crew saw campsites and people riding dirt bikes while they were there.

**Kahuku:** While conducting a road survey along the North Shore, the crew looked under an underpass that spanned the lower part of Kaunala Gulch and found three *C. odorata* plants that had likely been washed downstream from Kahuku Training Area. The stream from the KTA boundary down to the ocean should be surveyed, but at this time, OISC does not have the capacity to acquire the permission from the residences along the stream. The crew also sought permission to survey Keana farms, but has not acquired it yet.

**Table 2: OISC *Chromolaena odorata* Work Effort Summary on non-KTA lands. October 1, 2016–September 30, 2017:**

| Location | Aerial Acres | Ground Acres Surveyed | Mature Plants Treated | Immature Plants Treated | Total Plants Treated | Effort (Hours) |
|---|---|---|---|---|---|---|
| ʻAiea | 2.32 | 1155.74 | 140 | 1833 | 1973 | 1159.5 |
| Hālawa | 0 | 42.87 | 0 | 0 | 0 | 12 |
| Kaʻelepulu | 0 | .68 | 0 | 0 | 0 | 3 |
| Kahana* | 1 | 148.37 | 58 | 516 | 574 | 529 |
| Kahawainui | 0 | 26.95 | 0 | 0 | 0 | 32 |
| Kalauao | 0 | 6.74 | 0 | 0 | 0 | 6 |
| Kaunawaikaala | 0 | 116.79 | 0 | 0 | 0 | 24 |
| Keamanea | 0 | 246.47 | 0 | 0 | 0 | 132 |
| ʻŌiʻo (Haleʻiwa) | 0 | 77.71 | 0 | 0 | 0 | 90 |
| Paumalu (non-KTA) | 0 | 238.30 | 5 | 183 | 188 | 279 |
| Waiawa | 0 | 32.48 | 0 | 0 | 0 | 24 |
| Waimalu | 0 | 137.85 | 0 | 0 | 0 | 32 |
| Waimanalo | 0 | 1201 | 0 | 0 | 0 | 8 |
| **Total** | **3.32** | **4661.96** | **203** | **2,532** | **2,735** | **2330.5** |

**Compliance:**

OISC is a project of the Pacific Cooperative Studies Unit through the Research Corporation of the University of Hawaiʻi, an equal opportunity employer. OISC utilizes RCUH and PCSU standard operating procedures and employee guidelines. OISC employees are trained in wilderness first aid, off-trail hiking safety and pesticide safety.

O'AHU INVASIVE SPECIES COMMITTEE

# Survey and Control of *Chromolaena odorata* in the Kahuku Training Area, O'ahu, Hawai'i

## Annual Progress Report
## October 1, 2017—March 31, 2018

*Clipping off the flowering heads of C. odorata to prevent further seed spread.*

**Summary of Project Objectives:**
The aim of this project is to contain or eradicate *Chromolaena odorata,* commonly called devil weed, from the Kahuku Training Area (KTA). Eradication at KTA will reduce the threat of this species spreading to natural areas that may contain protected species. With other funds, control operations with the aim of eradication are taking place at locations outside of KTA where *C. odorata* has been found.

*Chromolaena odorata*, commonly known as devil weed, is a state-listed noxious weed that is toxic to livestock, people and other plants. It is widespread on Guam and other Pacific territories and under control programs in Australia and several African countries. It poses a threat to natural and agricultural systems due to its ability to form dense thickets and crowd out native plants. It is a threat to ranching because of its toxicity to livestock. *C. odorata* is currently known from three locations on Oʻahu: the Kahuku Training Area, Kahana State Park and Camp H.M. Smith in ʻAiea.

*Chromolaena seedlings*

Between 2006 and 2009, botanical surveys of all publicly accessible roads on Oʻahu were conducted by OISC's Oʻahu Early Detection program. *C. odorata* was not found during these surveys. This means that it is unlikely *C. odorata* was introduced somewhere else and dispersed onto KTA. *C. odorata* is a widely dispersed pest on the island of Guam, and units from Hawaiʻi sometimes train in Guam. The seeds are wind dispersed and readily attach to clothing. One plant can produce approximately 800,000 seeds a year. Given these factors, it is highly likely the pathway of introduction was military activities. The Biological Opinion for military activities on Oʻahu requires the Army to respond immediately to incipient weeds brought in via training operations. What is currently known about *C. odorata* supports the assumptions that the center of the population is the Kahuku Training Area (KTA) and that *C. odorata* was introduced to KTA because of military activities.

At KTA, OISC conducts sweeps of designated subunits and flags patches with a high density of plants that are most efficiently treated with a power or aerial spray. These patches are called "hotspots and are treated at a later date by Army Natural Resources Program. This method allows consistent monitoring of devil weed treatments to ensure that areas that may need re-treatment are noted and any new infestations mapped. OISC's responsibilities are:

- Surveying and monitoring treatment of subunits 3,4,7,8 and 10 within the Alpha 1 Range of Kahuku Training Area (KTA). This includes state land leased by the military and used by the public as a motorcross recreational area on the weekends. Figure 1 shows where the subunits are within KTA.
- Flagging areas as "hotspots" for follow-up treatment by Army Natural Resources Program. Hotspots are defined as areas with more than five plants or areas that would be inefficient to treat without a power sprayer or an aerial spray.
- Monitoring hotspot treatment and recording amount of re-growth after treatment.
- Removing outlier *C. odorata* outside of hotspots.
- Treating re-growth inside previously treated hotspots if this can be accomplished without delaying surveying (otherwise area is flagged for follow-up treatment by Army Natural Resources Program).

- Communicating results of all monitoring through a Google Docs spreadsheet.

**Project Accomplishments: October 1, 2016—March 31, 2017.**
OISC conducted four multi-day trips to control *C. odorata*. During the worktrips the crew:

- Conducted survey sweeps over 570 acres.
- Marked hotspots with flagging or something equivalent for later aerial or ground treatment by Army Natural Resources Program staff.
- Treated a total of 197 mature and 904 immature plants. It should be noted that these numbers are not a reflection on the total amount of plants detected or that actually exist within the subunits OISC and Army Natural Resources Program manage, just the total that were treated by OISC staff.
- Mapped monotypic fields of guinea grass for possible alternate survey techniques since these areas have a lower confidence level due to low visibility.
- Mapped areas that are safe to sweep along vegetated slopes of Kaunala Gulch and mapped access points in order to hike directly to hotspots in areas deemed unsafe.

OISC continued to work with Army Natural Resources Program staff to take GigaPan (extremely high-resolution panoramic photographs) images of the sides of Kaunala Gulch. Visibility on the gulch sides is low because of the thick, overhead vegetation. The low visibility makes other hazards such as drop-offs, ledges and bees more dangerous. With GigaPan images, OISC can find plants using the imagery and hike directly to them, rather than having to do complete sweeps of the hillside.

**Data Management and Coordination:**

During the reporting period, OISC staff entered observations for each hotspot into the Google Docs Hotspot Spreadsheet. The GIS Specialist quality controlled data from the field entered into the database and the spreadsheet. She also worked with Army Natural Resources Program staff to ensure the hotspot spreadsheet makes sense to both organizations.

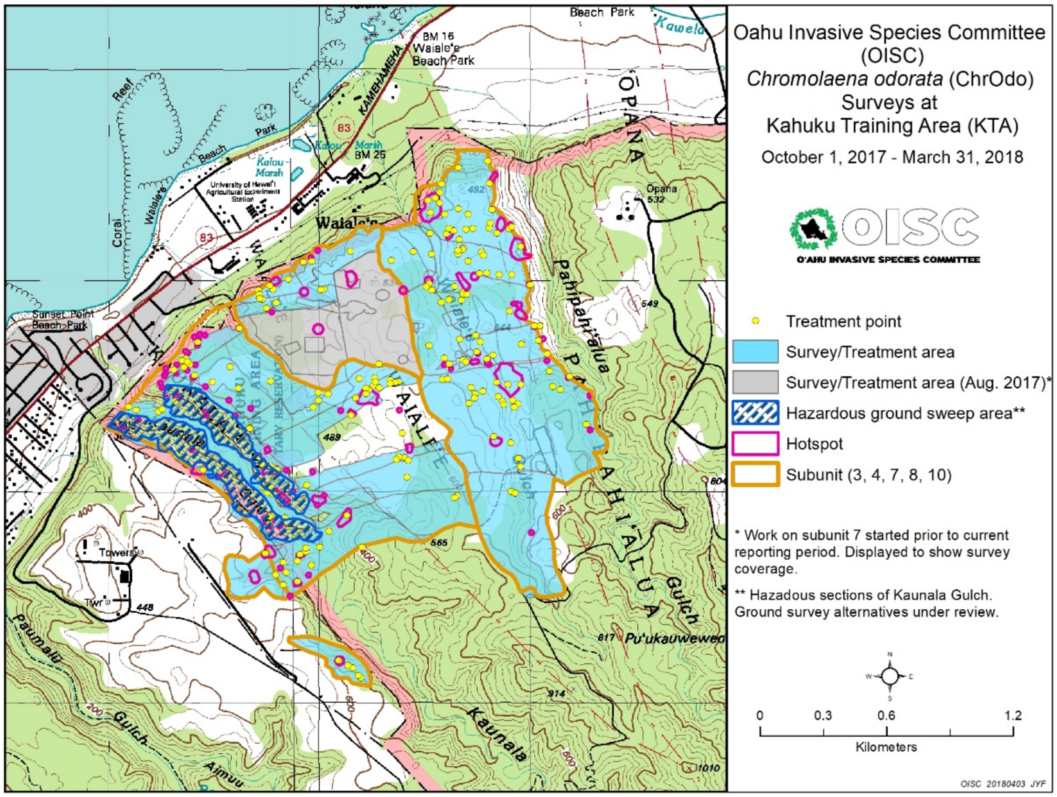
**Challenges:**
As mentioned above, Kaunala Gulch is a challenging area as there are many ledges hidden under the vegetation. However, OISC worked with Army Natural Resources to find a solution. OISC will hike directly to hotspots and Army Natural Resources will aerially spray more of the gulch sides. OISC mapped the areas of the gulch sides that they feel are safe to sweep and will hike directly to hotspots that are outside of the safe area.

**Table 1: OISC *Chromolaena odorata* Work Effort Summary at Kahuku Training Area October 1, 2017—March 31, 2018**

| Location | Acres Surveyed | Mature Plants Treated | Immature Plants Treated | Total Plants Treated | Effort (Hours) |
|---|---|---|---|---|---|
| KTA Subunits 3, 4, 7, 8, 10 | 570 | 197 | 904 | 1,101 | 1,033* |

***This number is higher than the time summary spreadsheets; 14 hours contributed by Army Natural Resources Program staff to take Gigapan photos and 14 hours of OISC staff time for the same was not counted in the monthly time report. A mistake in the amount of 8 cumulative hours was made in the amount of work done in November, December and January.***

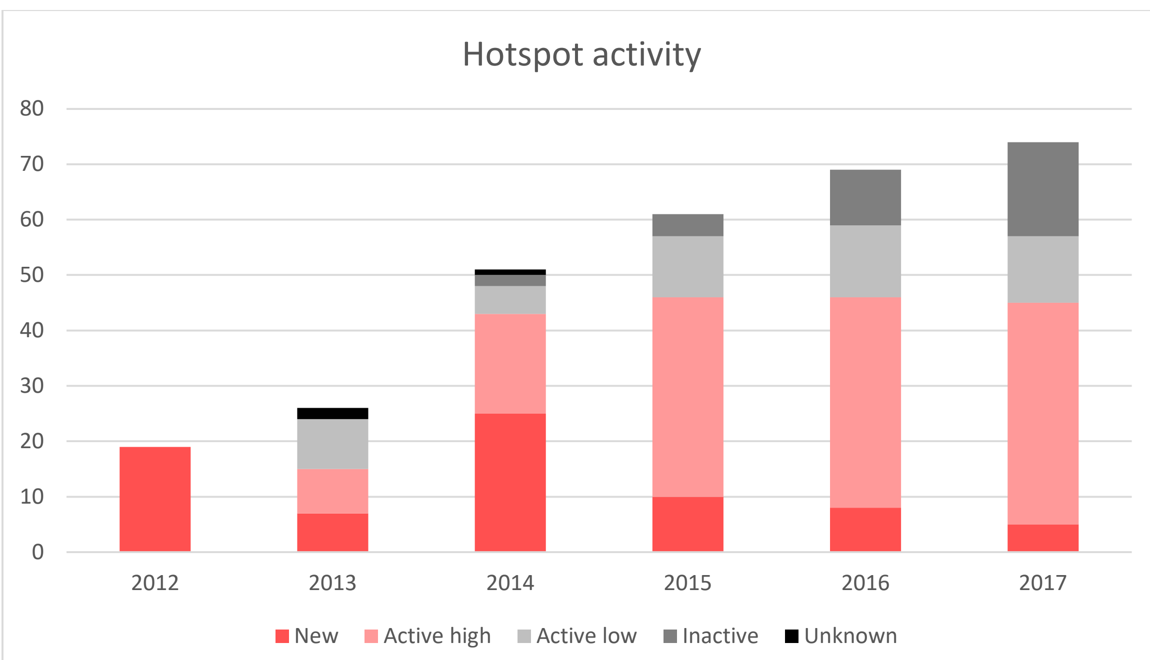
**Figure 1: OISC *Chromolaena odorata* Work Effort in Kahuku Training Area October 1, 2016 – March 31, 2017**



**KTA Annual Hotspot Data:**
OISC worked with Army Natural Resources to come up with a way to track progress on this species. The chart below shows that the number of new hotspots a year is decreasing and the number of inactive hotspots is increasing. Category definitions are explained below:

- *New:* Hotspots with generally five or more mature and/or more than 150 immature. Almost always requires a spray.
- *Active High:* Existing hotspot with at least one mature plant old enough to set seed and/or at least 30 immature. Spray usually needed to address seed bank.
- *Active Low:* Existing hotspot with fewer than 30 immature plants, or containing a small number of seedlings. Usually, active low hotspots were treated within 2 years of "Active High" designation. Spray typically needed on at least the first year classified as low to address seed bank.
- *Inactive:* Hotspot at least two years from the date of an "Active High" designation with "Active low" criteria or less than ten immature found in previous year.

| | New | Active high | Active low | Inactive | Unknown | Total Hotspots |
|---|---|---|---|---|---|---|
| 2012 | 19 | 0 | 0 | 0 | 0 | 19 |
| 2013 | 7 | 8 | 9 | 0 | 2 | 26 |
| 2014 | 25 | 18 | 5 | 2 | 1 | 51 |
| 2015 | 10 | 36 | 11 | 4 | 0 | 61 |
| 2016 | 8 | 38 | 13 | 10 | 0 | 69 |
| 2017 | 5 | 40 | 12 | 17 | 0 | 74 |



***C. odorata* Activites Supported with Other Funds:**

**Surveys and Control for *C. odorata* outside of the Kahuku Training Area (KTA)**
OISC conducted 388 acres of ground surveys in ʽAiea, removing 654 immature and 20 mature plants. Unfortunately, much of the surveys need to be done on private property and acquiring access permission is time-consuming, therefore there are still areas that may contain *C. odorata* but have not been surveyed. 294 of the surveyed acres were done by road since plants have been found in the neighborhood before.

In Kahana Valley, the crew surveyed 27 acres, removed 26 mature plants and 760 immature plants. Unlike the numbers for Kahuku, these numbers reflect all known plants. The area will require another aerial spray in 2018.

The field crew also found an immature plant at the Kahuku Wind Farm, which is significant because it is the first time a plant has ever been found at this location. OISC began checking this location in 2015, because we thought there might be spread from the other wind farm in Keamanea watershed where the species has been controlled by OISC in the past.

A member of the public posted a photo of a flowering *C. odorata* that he had found in Mākaha Valley in December. In response, OISC conducted 2 aerial surveys and five days of ground surveys with the entire crew and did not see any additional plants. This is a very significant range extension as *C. odorata* has never been seen in this valley before. The plant was along an unofficial trail. Although it is very unusual to have a plant that far back in the valley with no other additional plants, there is precedent. The plant in Lanikai that has been reported on previously was growing along a beach access and no additional plants have ever been seen despite extensive surveys. These two incidents are an indication of how easily this species moves around.

**Table 2: OISC *Chromolaena odorata* Work Effort Summary on non-KTA lands. October 1, 2017 – March 31, 2018:**

| Watershed | Aerial Acres Surveyed | Ground Acres Surveyed | Mature Plants Treated | Immature Plants Treated | Total Plants Treated | Effort (Hours) |
|---|---|---|---|---|---|---|
| ʻAiea | 0 | 388 | 20 | 654 | 674 | 412 |
| Hālawa | 0 | .078 | 0 | 100 | 100 | 10 |
| Kaʻelepulu (Lanikai Road Surveys) | 0 | 69 | 0 | 0 | 0 | 24.25 |
| Kahana Valley | 0 | 27 | 26 | 760 | 786 | 110 |
| Keamanea | 0 | 89 | 0 | 0 | 0 | 70 |
| Mākaha | 439 | 380 | 0 | 0 | 0 | 406 |
| ʽŌiʽo (Haleʽiwa) | 0 | 79 | 0 | 1 | 1 | 64 |
| Non-KTA Paumalu | 0 | 113 | 0 | 0 | 0 | 95 |
| **Total** | **439** | **1,145** | **46** | **1514** | **1,561** | **1191.25** |

*Treating Chromolaena odorata*

**Compliance:**
OISC is a project of the Pacific Cooperative Studies Unit through the Research Corporation of the University of Hawaiʻi, an equal opportunity employer. OISC utilizes RCUH and PCSU standard operating procedures and employee guidelines. OISC employees are trained in wilderness first aid, off-trail hiking safety and pesticide safety.

# Informal Herbicide Control Trial Conducted on *Crocosmia crocosmiiflora* at Kaala MU

Introduction: This year an informal trial for chemical treatment of *Crocosmia crocosmiiflora* was conducted at Kaala. This taxon mostly spreads via vegetative growth and is documented to have low seed set. Its vegetative clumps become extremely dense and can exclude all other species. It occurs at the edge of the forest at Kaala where it is treated in several ICAs. The Army natural resource program on Oahu (OANRP) aims to prevent further spread into forested areas and establishment on steep slopes where future control would be impossible. It is also treated in ICAs at Palikea MU. Handpulling has been the standard method of control. However investigations into chemical controls seemed worthwhile in order to address 1) huge patches with too many corms to dig out, where initial sprays could significantly reduce patch biomass both above and below ground (sites 1 and 3), and 2) small populations where hand-digging is likely leaving small corms behind but where chemicals may translocate to corms and result in total elimination (site 2).

OANRP staff identified a promising herbicide mix utilized in New Zealand for control of *C. crocosmiiflora*, a documented invader there (https://www.weedbusters.org.nz/weed-information/weed-list/montbretia/

Purpose: to test efficacy of glyphosate 10ml/L (1%) + Escort XP 0.4g/L + surfactant: 4ml/L (0.4%) in controlling *C. crocosmiiflora*.

Site Description: Test herbicide mix was used at 3 *C. crocosmiiflora* sites. 1) An isolated patch near the landing zone approximately 20m² in size that is surrounded by alien grasses that are mowed/weedwhacked on a regular basis; 2) one of two drainages off the slopes of the Mt. Kaala FAA facility, covered with a dense, continuous infestation, with mixed native plants adjacent to and within the thickets of *C. crocosmiiflora*; 3) a 25 m² patch adjacent to native forest on one side, and the FAA facility on the other. At this third location, in January 2014 the patch was covered with weed mat for a year to determine if live underground corms could be killed via smothering. The weed mat may not have been thick enough, as corms sprouted beneath it, and the patch persisted and sent out new shoots when the mat was removed.

Method: Sites were treated on three occasions: Time 0, 12 months, and 16 months.

All live aboveground growth was treated at all three sites. At site 2, one area of the larger bowl was delineated and targeted for control. Here, more caution was given while spraying to avoid the surrounding native vegetation, however some overspray was inevitable on the interspersed native understory. Plants were sprayed with a backpack sprayer, and in the extremely dense thickets of *C. crocosmiiflora*, the sprayer wand was used to push blades of vegetation around to ensure complete herbicide coverage of all blades. A small amount of blue dye was also used in the mix to ensure thorough spray coverage. Sites were treated a year later, however unfortunately, the wrong mix was used, and only a negligible amount of glyphosate was added to the mix. At site 2, treatment was conducted in the original treatment area and was expanded to adjacent patches due to promising results seen at that time. Treatment was implemented at all sites again at 16 months.

Sites were monitored with anecdotal observations at 6 months post-treatment, at 12 months during the 2nd treatment, and at the 16 month treatment. Comparison photos were taken at Sites 1 and 2 and can be seen in Figures 1-3.

Monitoring observations:

**Table 1.** Observation summaries for each site

<table>
<tr><th></th><th>6 months post-treatment observations</th><th>12 months post-treatment observations</th><th>16 months post-treatment observations</th></tr>
<tr><td>Site 1</td><td rowspan="3">At 6 months post-treatment, staff were surprised to see how effectively the sprays reduced the amount of aboveground biomass at each site. All existing vegetation had died back, and only a few new vegetative shoots occurred sparsely across the sites.</td><td>Dieback still evident and overall re-growth very low.</td><td>Faulty treatment relatively effective. Treated vegetation significantly yellowed and likely to die back completely given more time. No new shoots observed.</td></tr>
<tr><td>Site 2</td><td>Dieback still evident and overall re-growth very low. Sprays expanded here due to promising results and to begin process of vegetative reduction here.</td><td>Original site: Faulty treatment relatively effective. Treated vegetation significantly yellowed and likely to die back completely given more time. Few re-sprouts.<br>Expansion site (4 months post-treatment with faulty mix): vegetation was completely brown and substantial reductions of aboveground biomass were observed, similar to what was seen with the complete cocktail mix. The effects of the Escort XP and the minimal amount of glyphosate was enough to have an impact as seen in Figure 4.</td></tr>
<tr><td>Site 3</td><td>Dieback still evident and overall re-growth very low</td><td>Faulty treatment relatively effective. Treated vegetation significantly yellowed and likely to die back completely given more time. No new shoots observed.</td></tr>
</table>

Discussion of preliminary results:

At 16 months post-treatment, staff were shocked to see the sheer amount of corms present in the soil. Without the vegetative cover, the chain-like growth as seen in Figure 5, became very evident on the original treatment slope at site 2. Hardly any corms had shoots at this time, but there was a range of how plump and fleshy remaining corms looked. Many were shriveled and turning black and were more obviously dead, whereas others were still plump and fleshy. The latter group was difficult to assess if were in the process of dying, or were merely dormant without further detailed study.

Based on the presence of black and shriveling corms on corm ‘chains’, staff ultimately suspect that the herbicide control is effective at killing the corms from which vegetative sprigs were emergent and treated during sprays.. It is likely that new shoots are emerging from corms that did not have vegetative material at the time of control. Therefore, repeated visits will be necessary, but waiting at least 6-12 months between control efforts is best to ensure vegetation has emerged from dormant corms.

This trial was very limited in obtaining quantitative data such as: 1) how effective is the herbicide at killing a single corm, 2) to how many corms in a chain can the herbicide translocate, 3) how long can a corm remain dormant? However, while the efficacy of the herbicide to reduce belowground biomass remains unknown, based on the initial knockdown of aboveground biomass and length of suppression, it has been determined that the trialed treatment of Escort and Glyphosate is worthwhile to pursue operationally. Chemical sprays are much quicker to implement than hand-pulling, and do not require removal/disposal of huge amounts of biomass; in contrast, hand-pulled corms are bagged and taken to the baseyard where they are later sent to H-Power for incineration. Furthermore, chemical control may also be useful for small populations where the majority of the corms have been removed, but remaining ones have been difficult to eradicate because hand-pulling is likely to disrupt chains of corms and leave live ones behind. Total elimination of all associated corms may be more readily achieved by this chemical control.

Escort is an herbicide known for potential of non-target effects, so any control efforts should be closely monitored after treatment. In sensitive areas where there is absolute zero tolerance for non-target effects, handpulling may be the better option. Additionally, staff are currently only able to use this product at Kaala where it occurs at allowable sites according to the label such as utility rights-of way. This would include the sites that occur along the fenceline and on the Landing Zone.

**Figure 1.** Photos at Site 1 during monitoring visits. Top: May 2016, initial spray of this isolated patch of dense plants. Some plants with mature flowers. Bottom left: September 2016, initial knockdown of biomass within 4 months. Bottom right: September 2017, only small shoots remain (colored blue from treatment) in the middle of tall grasses.

**Figure 2.** View one at Site 2. The arrows indicate photos taken through time at monitoring events starting with the top left on May, 2016 and running through September 2016, May 2017 and September 2017. The last photo is a close-up view showing how sparse the remaining vegetation is despite the high density of corms.

**Figure 3.** View two at Site 2. The arrows indicate photos taken through time at monitoring events starting with the top left on May, 2016 and running through September 2016, May 2017 and September 2017. While the photos are not taken from the same vantage point, the significant dieback under the Ohia trees, is evident. Dieback of Ohia in the treatment area was documented before control and was identified in other trees in the surrounding area pre-treatment.

**Figure 4.** Pre- and 4-months post-treatment at Site 2 with 'faulty' spray mix. Dieback was evident, indicating that the Escort component of the mix was effective at reducing aboveground biomass.

**Figure 5.** Photos of numerous corms remaining after 16 months. Some corms were withering while others remained plump. It is unknown if corms will eventually die off. Right photo indicates no adverse impacts to Ohia tree despite treatment of vegetation all around its base.

ARMY NATURAL RESOURCE PROGRAM – OAHU (OANRP)
MONITORING PROGRAM

# KAHANAHAIKI MANAGEMENT UNIT VEGETATION MONITORING, 2018

## INTRODUCTION

Vegetation monitoring was conducted at Kahanahaiki Management Unit (MU) Subunit I in 2018 in association with Implementation Plan (IP) requirements for long term monitoring of vegetation composition and change over time (OANRP 2008) (Figure 1). The primary objective of MU monitoring is to assess if the percent cover of non-native plant species is less than 50% across the MU, or is decreasing towards that threshold requirement. The secondary objective is to assess if native cover is greater than 50% across the MU, or is increasing towards that threshold recommendation. Kahanahaiki MU vegetation monitoring occurs on a on a three-year interval and took place previously in 2009, 2012 and 2015 (OANRP 2009, 2012 and 2015). Previous monitoring in 2015 indicated that cover goals were only met for the non-native understory. The MU fence for Subunit I was completed in 1997. The Subunit II fence was completed in 2013, but monitoring plots were not established due to steep terrain and limited plans for active management in that area.

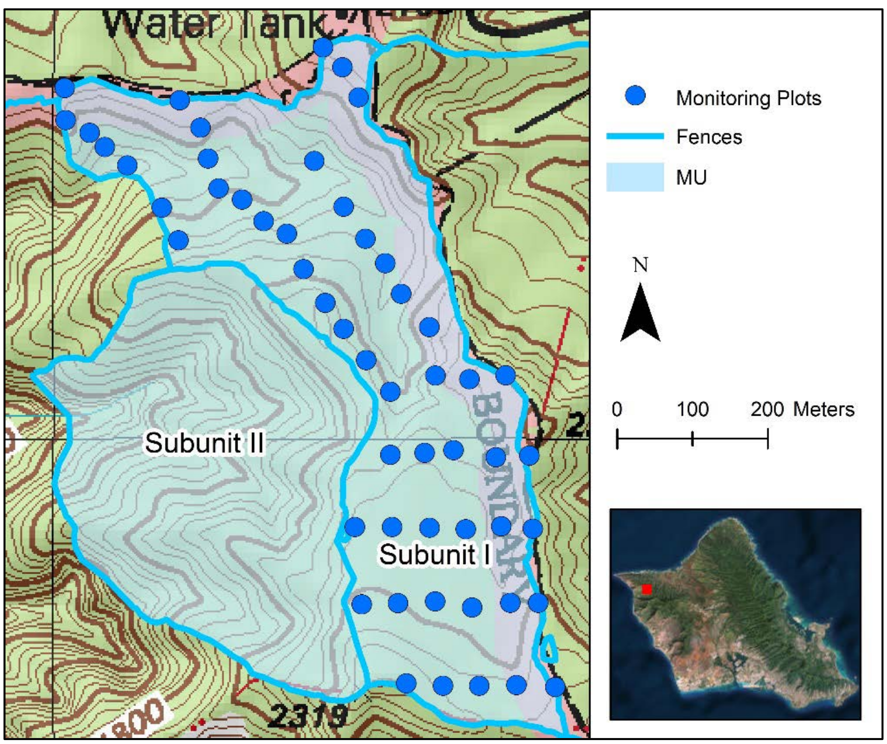



**Figure 1.** Kahanahaiki MU vegetation monitoring plot locations.

## METHODS

In May of 2018, 53 plots along nine transects were monitored in Subunit I of Kahanahaiki MU. Plots measuring 5 x 10 m were generally located every 50 m along transects. Transects were spaced approximately 100 m apart. These same plots were also monitored in 2009 (OANRP 2009), 2012 (OANRP 2012), and 2015 (OANRP 2015). Understory (0 – 2 m above ground level (AGL), including low branches from canopy species) and canopy (> 2 m AGL, including epiphytes) vegetation was recorded by percent cover for all non-native and native species present. Summary percent cover by vegetation type (shrub, fern, grass/sedge) in the understory, overall summary percent cover of non-native and native vegetation in the understory and canopy, and bare ground (non-vegetated < 25 cm AGL), were also documented. Bare ground was not recorded in 2012. Percent cover categories were recorded in 10% intervals between 10 and 100%, and on finer intervals (0-1%, 1-5%, and 5-10%) between 0 and 10% cover. Understory recruitment (defined as seedlings or saplings < 2 m AGL) data for tree species was recorded beginning in 2012. Monitoring results were compared with data from prior years. Inconsistencies with previous recruitment data collection precluded meaningful statistical analyses of frequency change. Based on IP recommendations, p-values < 0.05 were considered significant, and only absolute cover changes ≥ 10% were recognized. Additional methodology information is detailed in Monitoring Protocol 1.2.1 (OANRP 2008). All analyses were performed in IBM SPSS Statistics Version 25. These included Friedman's tests with Bonferroni adjusted post-hoc pairwise comparisons for cover and richness data, McNemar's tests for frequency data, and generalized linear modeling for the influence of weed control efforts on cover change as well as the influence of non-native cover change on native cover.

## RESULTS

### Understory and canopy cover categories

Management objectives of having < 50% non-native understory and canopy and > 50% native understory and canopy cover continued to be met only for the non-native understory (25% median) in 2018 (Table 1). Native understory and canopy cover was low (15% median for both), and non-native canopy was moderate (55% median). Since 2009, there were significant changes in percent cover of vegetation that met the 10% standard for recognized change in cover. Native understory cover declined between 2015 and 2018. Non-native shrubs cover increased from 2009 to 2015. Total non-native understory also increased from 2009 to 2015, but decreased from 2015 to 2018. Bare ground, non-native canopy and total canopy have increased since 2009 (Figure 2). The highest percent cover of native understory and canopy in 2018 primarily occurred in the southern (Maile Flats) portion of the MU (Figure 3). Non-native canopy cover was high throughout much of the northern half of the MU as well as the eastern edge of Maile Flats. Locations of moderate to high percent cover of non-native understory were patchily distributed across the MU. Beneficial changes in native canopy cover occurred primarily in Maile Flats, otherwise, locations of beneficial and worsening conditions were patchily distributed across the MU (Figure 4).

**Table 1**. Median percent cover of native and non-native vegetation categories in the canopy and understory at Kahanahaiki MU from 2009 to 2018 (n = 53). Categories specifically addressed in management objectives are shaded. Statistically significant values for categories that meet the 10% standard for recognized change in cover are in boldface. Arrows indicate increase (↑), decrease (↓), or inconsistent trend (↕) in cover.

| | 2009 | 2012 | 2015 | 2018 | p* | $X^2$ | years that differed significantly | p (post-hoc)** | Management objective currently met? |
|---|---|---|---|---|---|---|---|---|---|
| ***Understory*** | | | | | | | | | |
| Native shrubs | 7.5 | 15 | 7.5 | 7.5 | 0.000↕ | 20.156 | 2009 vs. 2012<br>2009 vs. 2015 | 0.032↑<br>0.029↑ | |
| Native ferns | 7.5 | 3 | 7.5 | 3 | 0.042↕ | 8.205 | | | |
| Native grass/sedges | 0 | 0 | 0.5 | 0 | 0.224 | 4.371 | | | |
| Total native understory | 15 | 25 | 25 | 15 | **0.003↕** | 14.127 | 2015 vs. 2018 | **0.011↓** | No |
| Non-native shrubs | 15 | 25 | 25 | 25 | **0.000↑** | 26.810 | 2009 vs. 2015<br>2009 vs. 2018<br>2012 vs. 2015 | **0.000↑**<br>**0.026↑**<br>0.012↑ | |
| Non-native ferns | 0 | 0.5 | 0.5 | 0.5 | 0.023↑ | 9.516 | | | |
| Non-native grass/sedges | 0.5 | 0.5 | 3 | 0.5 | 0.000↕ | 26.476 | 2012 vs. 2015<br>2015 vs. 2018 | 0.000↑<br>0.026↓ | |
| Total non-native understory | 25 | 25 | 35 | 25 | **0.000↕** | 28.311 | 2009 vs. 2015<br>2012 vs. 2015<br>2015 vs. 2018 | **0.000↑**<br>**0.000↑**<br>**0.026↓** | Yes |
| Bare ground | 45 | NA | 55 | 65 | **0.008↑** | 9.723 | 2009 vs. 2018 | **0.013↑** | |
| ***Canopy*** | | | | | | | | | |
| Native canopy | 15 | 15 | 15 | 15 | 0.031↑ | 8.881 | | | No |
| Non-native canopy | 45 | 55 | 55 | 55 | **0.000↑** | 23.021 | 2009 vs. 2018 | **0.000↑** | No |
| Total canopy | 65 | 95 | 95 | 95 | **0.000↑** | 39.054 | 2009 vs. 2012<br>2009 vs. 2015<br>2009 vs. 2018 | **0.000↑**<br>**0.000↑**<br>**0.000↑** | |

*from Friedman's test, asymptotic significance
**from post-hoc pairwise comparisons with Bonferroni adjustment

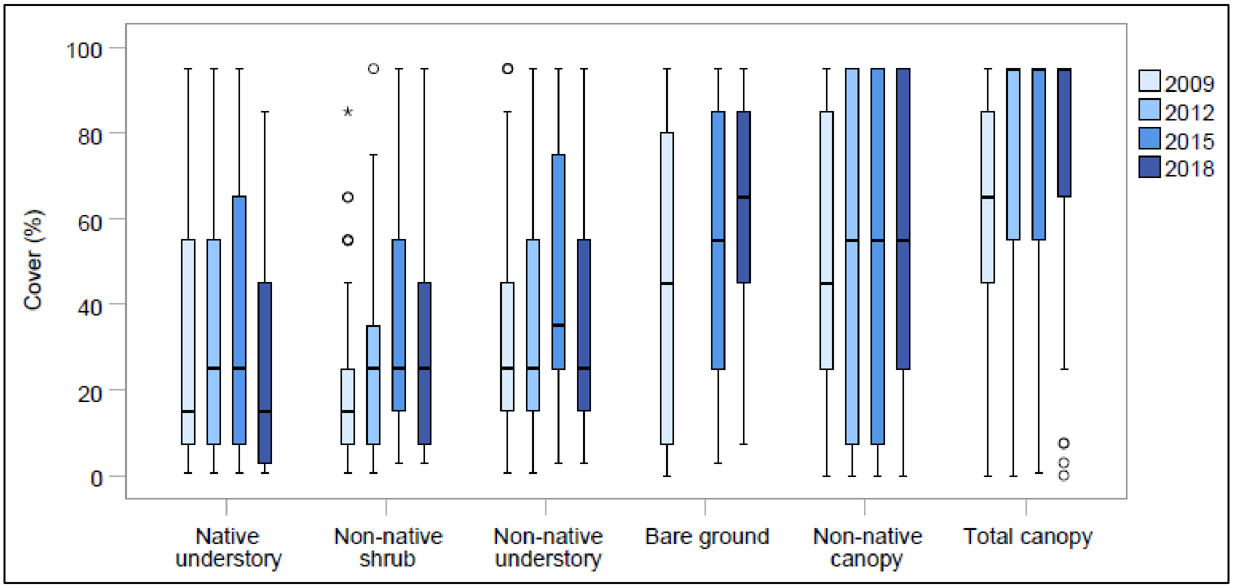



**Figure 2.** Boxplots for vegetation categories with significant change in percent cover that meet 10% standard for recognized change in cover between years 2009 and 2018 in Kahanahaiki MU. [*Note: The boxes depict 50% of the data values, and the horizontal line inside the box represents the median value. Very high or low values relative to the shaded box are indicated by circles (1.5 to 3 times the length of the shaded box) and asterisks (> 3 times the length of the shaded box), while the lines extending above and below the shaded box depict the range in values for all remaining data. Circles and asterisks that appear to be in boldface indicate multiple data points for the same values.*]

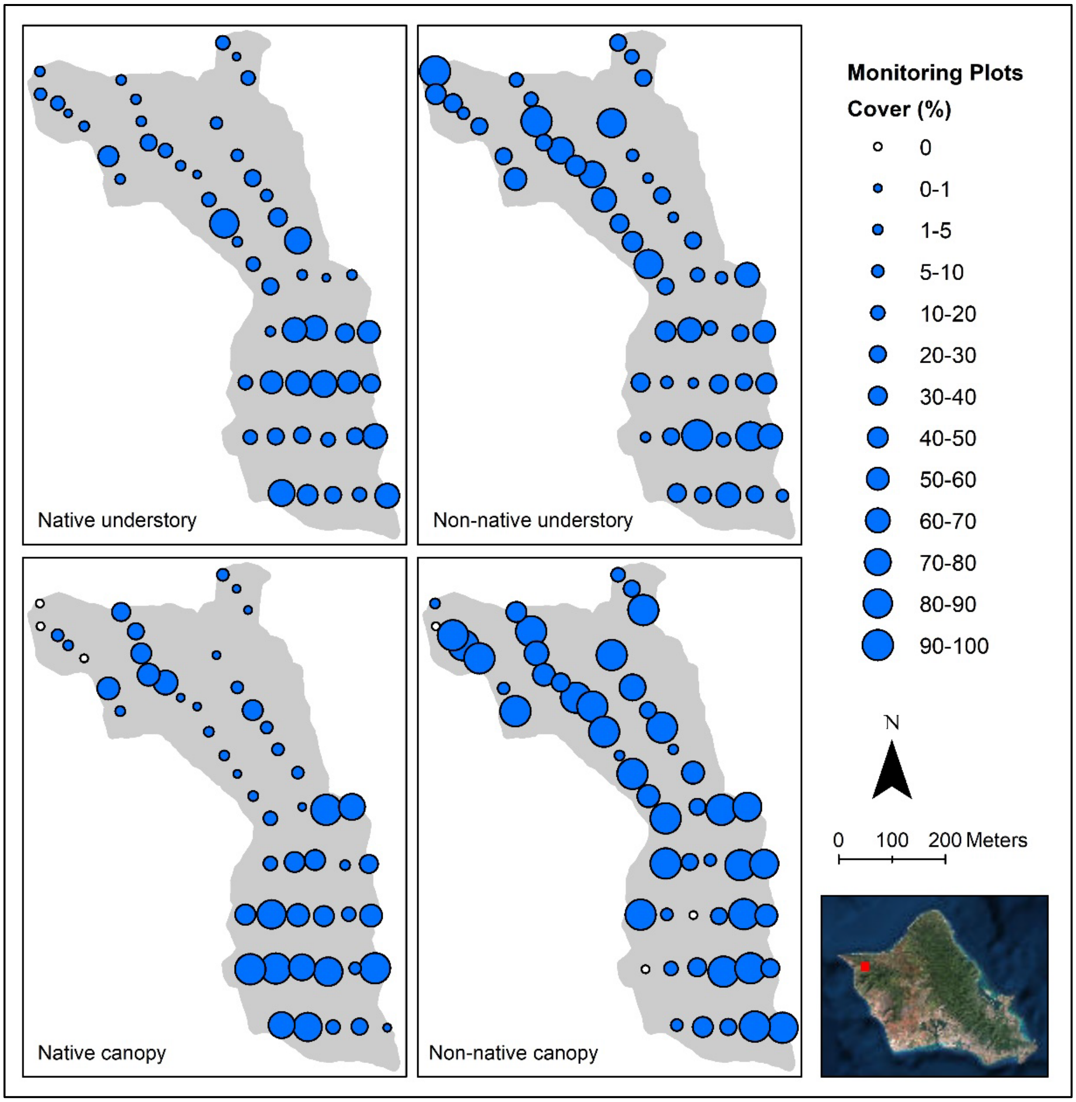



**Figure 3.** Locations of low to high percent cover of native and non-native understory and canopy vegetation among monitored plots at Kahanahaiki MU in 2018. Larger circles denote higher percent cover, while smaller circles represent lower cover.

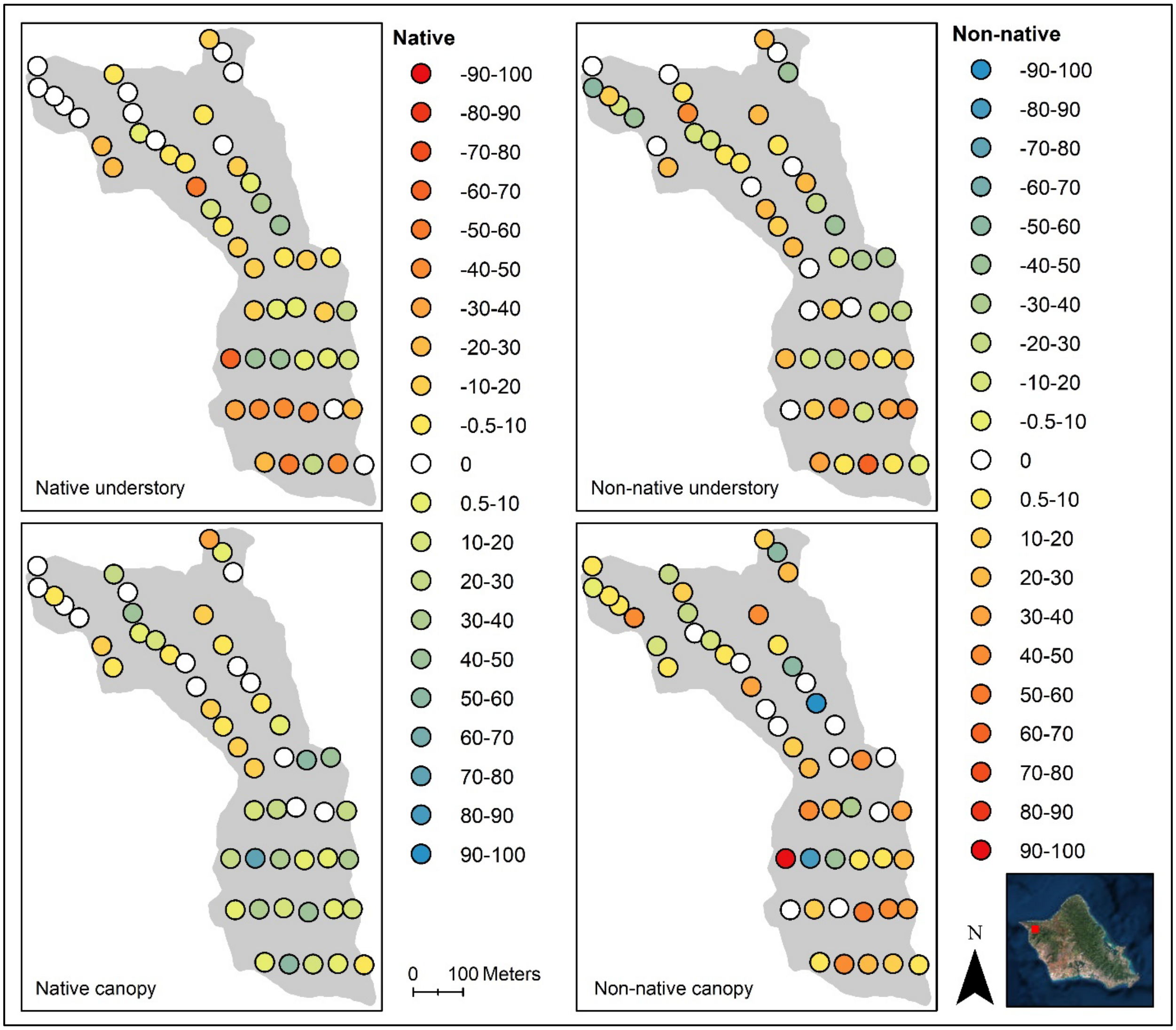



**Figure 4.** Locations of change in native and non-native percent cover for the understory and canopy vegetation in monitored plots in Kahanahaiki MU between 2009 and 2018 in the understory and canopy. Color gradients are inverted for native and non-native vegetation, such that blue indicates beneficial change, red depicts worsening conditions. Cover change of 0 indicates there was no change in percent cover.

## Species richness

During monitoring in 2018, 103 species were recorded in the understory (52% native taxa), and 47 were identified in the canopy (68% native). Most species present in the canopy were also represented in the understory, with the exception of four native species (*Gynochthodes trimera, Hibiscus arnottianus* subsp. *arnottianus*, *Korthalsella cylindrica,* and *Santalum freycinetianum* var. *freycinetianum*) and two non-native (*Eucalyptus urophylla* and *Syzygium cumini*). Native understory and canopy species richness was generally higher in Maile Flats, and lower in the northern gulch portion of the MU (Figure 5). Locations of high and low species richness for the non-native understory and canopy were somewhat patchily distributed across the MU, but more often had higher richness in the northern gulch region. The highest diversity occurred within the native understory, with 54 taxa documented for the MU, and up to 19 species in a single plot. The non-native canopy was the least diverse, with only 15 taxa across the MU, and no more than 4 species in a single plot. Species richness within plots differed significantly between the years monitored, with a small increase in non-native understory between 2009 and 2018 (Table 2).

Seven newly recorded species (29% native), were found in plots in 2018, while 17 species (59% native) were recorded in previous years but not observed in 2018 (Table 3). Aside from natural processes and the direct or indirect result of management actions, the presence or absence of species may be due in part to human error such as misidentification, observer bias regarding plot boundaries or amount of time spent searching, or accidental non-recording. All of the species that were not present in 2018 were uncommon in prior years, with frequencies less than 8%. Similarly, species newly recorded in 2018 had low frequencies, less than 2%.

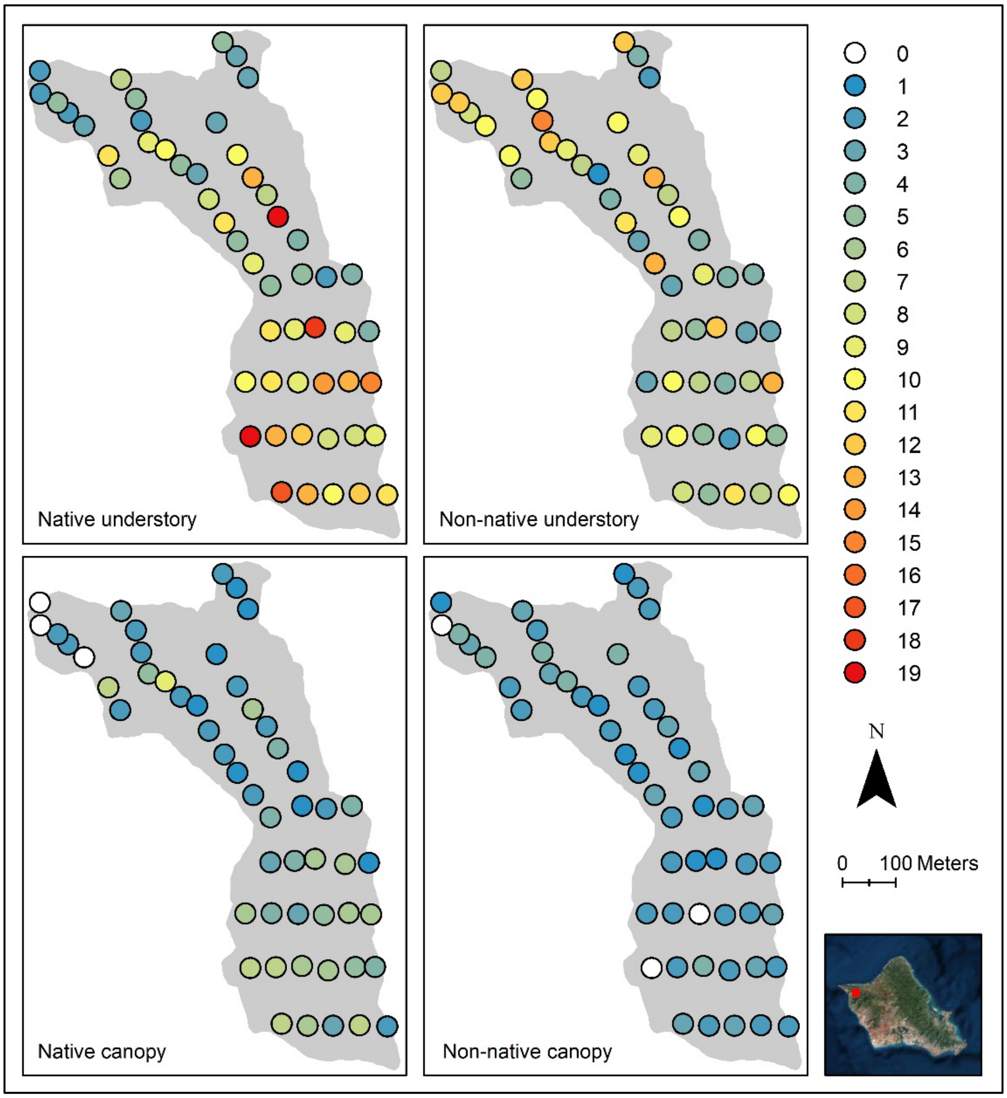



**Figure 5.** Locations of low to high species richness among plots in the native and non-native understory and canopy in Kahanahaiki MU in 2018. Color gradients of blue to red indicate low to high values, respectively, of the number of species occurring in plots (i.e., blue indicates low diversity, while red indicates relatively higher diversity).

**Table 2**. Kahanahaiki MU understory and canopy species richness from 2009 to 2018. Median species richness per plot during vegetation monitoring is shown by year, with the total number of species recorded among all plots in parenthesis (n = 53). Statistically significant values are in boldface. Arrows indicate increase (↑) or decrease (↓) in richness. Post-hoc pairwise comparisons with Bonferroni adjustment did not reveal any years that differed significantly.

| | 2009 | 2012 | 2015 | 2018 | p* | $X^2$ |
|---|---|---|---|---|---|---|
| Native understory | 8 (55) | 8 (55) | 9 (55) | 9 (54) | 0.561 | 2.054 |
| Non-native understory | 6 (44) | 6 (45) | 7 (49) | 8 (49) | **0.012↑** | 11.035 |
| Native canopy | 3 (30) | 3 (28) | 3 (31) | 3 (32) | 0.115 | 5.927 |
| Non-native canopy | 2 (10) | 2 (9) | 2 (12) | 2 (15) | 0.056 | 7.556 |

*from Friedman's test, asymptotic significance

**Table 3.** Taxa no longer present, and newly recorded, from 2018 Kahanahaiki MU monitoring in the understory and/or canopy. Native taxa are in boldface. Frequency (the proportion of plots in which species are present) values are represented (n = 53).*ICA. ‡Rare taxa.

| Species not recorded in 2018, but observed in plots previously | 2015 | 2012 | 2009 | New species recorded in plots in 2018 | 2018 |
|---|---|---|---|---|---|
| *Adiantum hispidulum* | 3.8 | 3.8 | 3.8 | *Angiopteris evecta** | 1.9 |
| ***Asplenium macraei*** | 1.9 | 0.0 | 0.0 | *Arundina gramminifolia* | 1.9 |
| ***Canavalia galeata*** | 1.9 | 0.0 | 0.0 | ***Cyanea superba* subsp. *superba* ‡** | 1.9 |
| *Casuarina equisetifolia** | 0.0 | 1.9 | 0.0 | *Indigofera suffruticosa* | 1.9 |
| ***Coprosma longifolia*** | 1.9 | 0.0 | 0.0 | *Litchi chinensis* | 1.9 |
| *Cyanthillium cinereum* | 3.8 | 1.9 | 0.0 | ***Plectranthus parviflorus*** | 1.9 |
| ***Delissea waianaeensis* ‡** | 1.9 | 1.9 | 0.0 | Unknown sp. | 1.9 |
| ***Doryopteris decipiens*** | 0.0 | 0.0 | 1.9 | | |
| *Emilia fosbergii* | 0.0 | 0.0 | 3.8 | | |
| ***Gahnia beecheyi*** | 1.9 | 1.9 | 0.0 | | |
| *Gamochaeta purpurea* | 0.0 | 0.0 | 1.9 | | |
| *Leucaena leucocephala* | 0.0 | 1.9 | 5.7 | | |
| ***Melicope oahuensis*** | 1.9 | 0.0 | 7.5 | | |
| ***Panicum nephelophilum*** | 1.9 | 0.0 | 0.0 | | |
| *Setaria parviflora* | 0.0 | 0.0 | 1.9 | | |
| ***Streblus pendulinus*** | 0.0 | 1.9 | 1.9 | | |
| ***Waltheria indica*** | 1.9 | 0.0 | 0.0 | | |

## Species frequency

Non-native species that occurred most frequently in plots (present in more than half the plots) in the understory included *Psidium cattleianum*, *Clidemia hirta*, and *Schinus terebinthifolius*, while *P. cattleianum* and *S. terebinthifolius* occurred most commonly in the canopy (Table 4). The most frequent native species included *Alyxia stellata* and *Psydrax odorata*, both in the understory and canopy. Two MIP rare taxa, *Cenchrus agrimonioides* var. *agrimonioides* and *Cyanea superba* subsp. *superba* (Figure 6), were recorded in a single plot each during monitoring in 2018. Numerous target weed taxa (taxa of special concern for weed management, ranging from incipient species to those with widespread distributions) for Kahanahaiki MU were present in monitored plots in either the understory or canopy (Figure 7). Two out of the 16 ICA target species, *Acacia mearnsii* and *Angiopteris evecta*, were present in a single plot each. Five out of 11 limited distribution target taxa were recorded, including, *Grevillea robusta*, *Macrotyloma axillare* var. *glabrum*, *Montanoa hibiscifolia*, *Nephrolepis brownii*, and *Spathodea campanulata*, and over a quarter of the plots included at least one of these. All 45 widespread distribution target taxa were observed, at least one of which was present in all plots.

**Table 4.** Species frequency among plots (percent of plots in which a given species occurs) during 2018 Kahanahaiki MU monitoring (n= 53), in order of most to least frequent. Native species are in bold print. ‡Rare taxa. Target weed taxa: *ICA, **limited distribution.

| TaxonName | Freq | TaxonName | Freq |
|---|---|---|---|
| Understory | | | |
| *Psidium cattleianum* | 96.2 | *Deparia petersenii* | 7.5 |
| *Clidemia hirta* | 88.7 | ***Euphorbia multiformis*** | 7.5 |
| *Schinus terebinthifolius* | 69.8 | *Melinis repens* | 7.5 |
| ***Alyxia stellata*** | 67.9 | *Mesosphaerum pectinatum* | 7.5 |
| ***Psydrax odorata*** | 67.9 | ***Nestegis sandwicensis*** | 7.5 |
| ***Nephrolepis exaltata* subsp. *hawaiiensis*** | 49.1 | ***Pipturus albidus*** | 7.5 |
| ***Doodia kunthiana*** | 41.5 | ***Pisonia brunoniana*** | 7.5 |
| *Blechnum appendiculatum* | 39.6 | ***Pteridium aquilinum*** | 7.5 |
| ***Coprosma foliosa*** | 39.6 | ***Asplenium caudatum*** | 5.7 |
| *Lantana camara* | 39.6 | *Cyclosorus dentatus* | 5.7 |
| ***Acacia koa*** | 37.7 | ***Cyperus hillebrandii* var. *hillebrandii*** | 5.7 |
| ***Dianella sandwicensis*** | 37.7 | ***Dicranopteris linearis*** | 5.7 |
| ***Microlepia strigosa*** | 37.7 | ***Diospyros hillebrandii*** | 5.7 |
| ***Metrosideros polymorpha*** | 35.8 | ***Leptecophylla tameiameiae*** | 5.7 |
| ***Kadua affinis*** | 30.2 | ***Myrsine lessertiana*** | 5.7 |
| *Melinis minutiflora* | 30.2 | *Passiflora edulis* | 5.7 |
| *Rubus rosifolius* | 30.2 | ***Planchonella sandwicensis*** | 5.7 |
| *Cyclosorus parasiticus* | 28.3 | *Youngia japonica* | 5.7 |
| *Passiflora suberosa* | 28.3 | *Ageratina adenophora* | 3.8 |
| ***Cocculus orbiculatus*** | 26.4 | *Ageratum conyzoides* | 3.8 |
| ***Carex meyenii*** | 24.5 | *Buddleja asiatica* | 3.8 |
| ***Carex wahuensis*** | 24.5 | *Castilleja arvensis* | 3.8 |
| ***Diospyros sandwicensis*** | 24.5 | *Chamaecrista nictitans* | 3.8 |
| *Oplismenus hirtellus* | 24.5 | ***Charpentiera tomentosa*** | 3.8 |
| *Paspalum conjugatum* | 24.5 | *Emilia sonchifolia* | 3.8 |
| *Conyza bonariensis* | 22.6 | *Grevillea robusta*** | 3.8 |
| ***Wikstroemia oahuensis* var. *oahuensis*** | 22.6 | *Pluchea carolinensis* | 3.8 |
| ***Sphenomeris chinensis*** | 20.8 | ***Psychotria hathewayi*** | 3.8 |
| *Ageratina riparia* | 18.9 | ***Sapindus oahuensis*** | 3.8 |
| *Stachytarpheta australis* | 18.9 | ***Xylosma hawaiiense*** | 3.8 |
| ***Psilotum nudum*** | 17.0 | *Acacia mearnsii** | 1.9 |
| ***Psychotria mariniana*** | 17.0 | *Aleurites moluccana* | 1.9 |
| ***Bidens torta*** | 15.1 | *Angiopteris evecta** | 1.9 |
| ***Cibotium chamissoi*** | 15.1 | *Arundina gramminifolia* | 1.9 |
| ***Lepisorus thunbergianus*** | 15.1 | ***Bobea elatior*** | 1.9 |
| *Crassocephalum crepidoides* | 13.2 | ***Cenchrus agrimonioides* var. *agrimonioides***‡ | 1.9 |
| *Nephrolepis brownii*** | 13.2 | *Cheilanthes viridis* | 1.9 |
| *Oxalis corniculata* | 13.2 | ***Cyanea superba* subsp. *superba*‡** | 1.9 |
| *Erechtites valerianifolia* | 11.3 | *Desmodium incanum* | 1.9 |
| *Oxalis debilis* | 11.3 | ***Elaphoglossum aemulum*** | 1.9 |
| ***Pisonia sandwicensis*** | 11.3 | *Indigofera suffruticosa* | 1.9 |
| *Spathodea campanulata*** | 11.3 | *Litchi chinensis* | 1.9 |
| *Andropogon virginicus* | 9.4 | *Macrotyloma axillare* var. *glabrum*** | 1.9 |
| ***Antidesma platyphyllum*** | 9.4 | *Montanoa hibiscifolia*** | 1.9 |
| *Cordyline fruticosa* | 9.4 | ***Myrsine lanaiensis*** | 1.9 |
| ***Dodonaea viscosa*** | 9.4 | ***Peperomia tetraphylla*** | 1.9 |
| *Phlebodium aureum* | 9.4 | ***Pisonia umbellifera*** | 1.9 |
| *Psidium guajava* | 9.4 | ***Pittosporum glabrum*** | 1.9 |
| ***Scaevola gaudichaudiana*** | 9.4 | *Pityrogramma austroamericana* | 1.9 |
| ***Asplenium kaulfussii*** | 7.5 | ***Plectranthus parviflorus*** | 1.9 |
| ***Cyperus hypochlorus* var. *hypochlorus*** | 7.5 | | |

**Table 4, cont.**

| TaxonName | Freq | TaxonName | Freq |
|---|---|---|---|
| Understory | | | |
| *Rivina humilis* | 1.9 | Unknown sp.[1] | 1.9 |
| ***Rumex albescens*** | 1.9 | *Urochloa maxima* | 1.9 |
| *Triumfetta semitriloba* | 1.9 | ***Viola chamissoniana* subsp. *tracheliifolia*** | 1.9 |
| Canopy | | | |
| *Psidium cattleianum* | 84.9 | *Passiflora suberosa* | 3.8 |
| ***Psydrax odorata*** | 75.5 | ***Pipturus albidus*** | 3.8 |
| *Schinus terebinthifolius* | 73.6 | ***Santalum freycinetianum* var. *freycinetianum*** | 3.8 |
| ***Alyxia stellata*** | 50.9 | ***Xylosma hawaiiense*** | 3.8 |
| ***Acacia koa*** | 39.6 | ***Bidens torta*** | 1.9 |
| ***Metrosideros polymorpha*** | 32.1 | ***Bobea elatior*** | 1.9 |
| ***Coprosma foliosa*** | 20.8 | ***Charpentiera tomentosa*** | 1.9 |
| *Aleurites moluccana* | 15.1 | ***Dicranopteris linearis*** | 1.9 |
| ***Diospyros sandwicensis*** | 13.2 | *Eucalyptus urophylla* | 1.9 |
| ***Kadua affinis*** | 13.2 | *Grevillea robusta*** | 1.9 |
| ***Psychotria mariniana*** | 11.3 | ***Gynochthodes trimera*** | 1.9 |
| ***Antidesma platyphyllum*** | 9.4 | ***Korthalsella cylindrica*** | 1.9 |
| *Clidemia hirta* | 9.4 | *Lantana camara* | 1.9 |
| *Cordyline fruticosa* | 9.4 | ***Leptecophylla tameiameiae*** | 1.9 |
| ***Nestegis sandwicensis*** | 9.4 | *Montanoa hibiscifolia*** | 1.9 |
| ***Planchonella sandwicensis*** | 9.4 | ***Pittosporum glabrum*** | 1.9 |
| ***Pisonia sandwicensis*** | 7.5 | *Pluchea carolinensis* | 1.9 |
| ***Cibotium chamissoi*** | 5.7 | *Psidium guajava* | 1.9 |
| ***Cocculus orbiculatus*** | 3.8 | ***Psychotria hathewayi*** | 1.9 |
| ***Diospyros hillebrandii*** | 3.8 | ***Scaevola gaudichaudiana*** | 1.9 |
| ***Dodonaea viscosa*** | 3.8 | *Stachytarpheta australis* | 1.9 |
| ***Hibiscus arnottianus* subsp. *arnottianus*** | 3.8 | *Syzygium cumini* | 1.9 |
| ***Lepisorus thunbergianus*** | 3.8 | ***Wikstroemia oahuensis* var. *oahuensis*** | 1.9 |
| *Passiflora edulis* | 3.8 | | |

[1]Immature plant with insufficient diagnostic material for identification, presumed non-native.

**Figure 6.** A vegetation monitoring plot in 2018, now the location of a new reintroduction site for *Cyanea superba* subsp. *superba*, MMR-J, outplanted two months prior to monitoring.

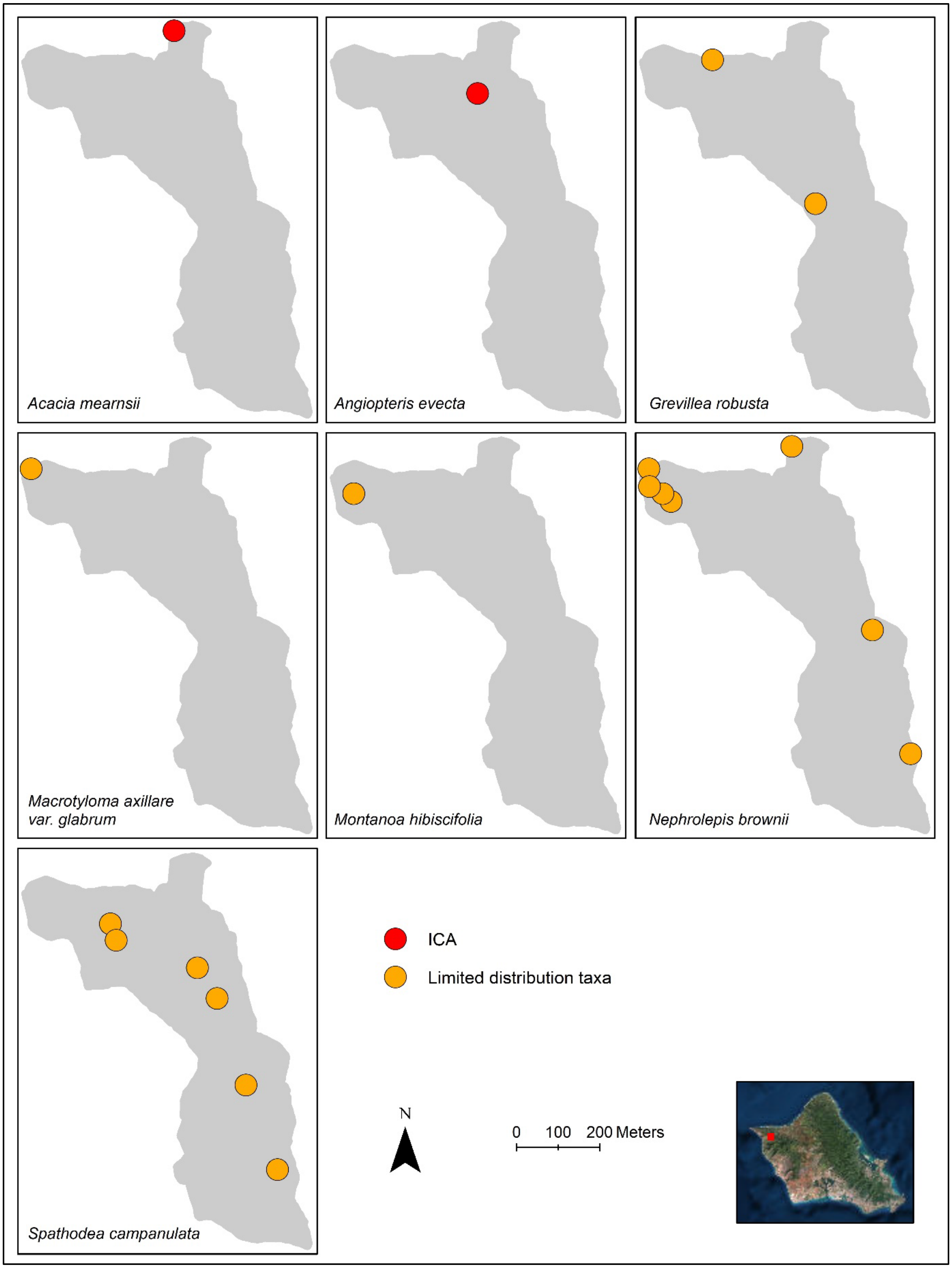



**Figure 7**. Locations of ICA and limited distribution target taxa in the understory and/or canopy found in monitoring plots at Kahanahaiki MU Subunit I.

Analysis of frequency change was limited to taxa with at least ten percent change between 2009 and 2018. There were significant changes in frequency for a number of species (Table 5 and Figure 8). The most noteworthy changes between 2009 and 2018 included increases for one native (*Dianella sandwicensis*) and two non-native (*C. hirta* and *Passiflora suberosa*) species in the understory, and decreases for *G. robusta* both in the understory and canopy.

**Table 5.** Species with significant frequency change at Kahanahaiki MU between 2009 and 2018. Only taxa with at least 10% change in frequency were analyzed. Frequency values represent the proportion of plots in which species are present (n = 53). Native species are in boldface. P-values obtained from McNemar's test (exact significance, binomial distribution, Bonferroni adjusted). Arrows indicate increase (↑) or decrease (↓) in frequency. **Limited distribution target weed taxa.

| | Years that differed | p | 2009 | 2012 | 2015 | 2018 | Freq. change (2018-2009) |
|---|---|---|---|---|---|---|---|
| Understory | | | | | | | |
| *Clidemia hirta* | 2009 vs. 2018 | 0.012↑ | 69.8 | 71.7 | 77.4 | 88.7 | 18.9 |
| | 2012 vs. 2018 | 0.023↑ | | | | | |
| *Conyza bonariensis* | 2009 vs. 2015 | 0.001↑ | 11.3 | 20.8 | 37.7 | 22.6 | 11.3 |
| ***Dianella sandwicensis*** | 2009 vs. 2018 | 0.012↑ | 18.9 | 30.2 | 30.2 | 37.7 | 18.9 |
| *Grevillea robusta*** | 2009 vs. 2018 | 0.038↓ | 22.6 | 11.3 | 17.0 | 3.8 | -18.9 |
| *Passiflora suberosa* | 2009 vs. 2018 | 0.012↑ | 9.4 | 9.4 | 18.9 | 28.3 | 18.9 |
| Canopy | | | | | | | |
| ***Cocculus orbiculatus*** | 2009 vs. 2015 | 0.047↓ | 17.0 | 5.7 | 1.9 | 3.8 | -13.2 |
| *Grevillea robusta*** | 2009 vs. 2018 | 0.023↓ | 18.9 | 7.5 | 13.2 | 1.9 | -17.0 |

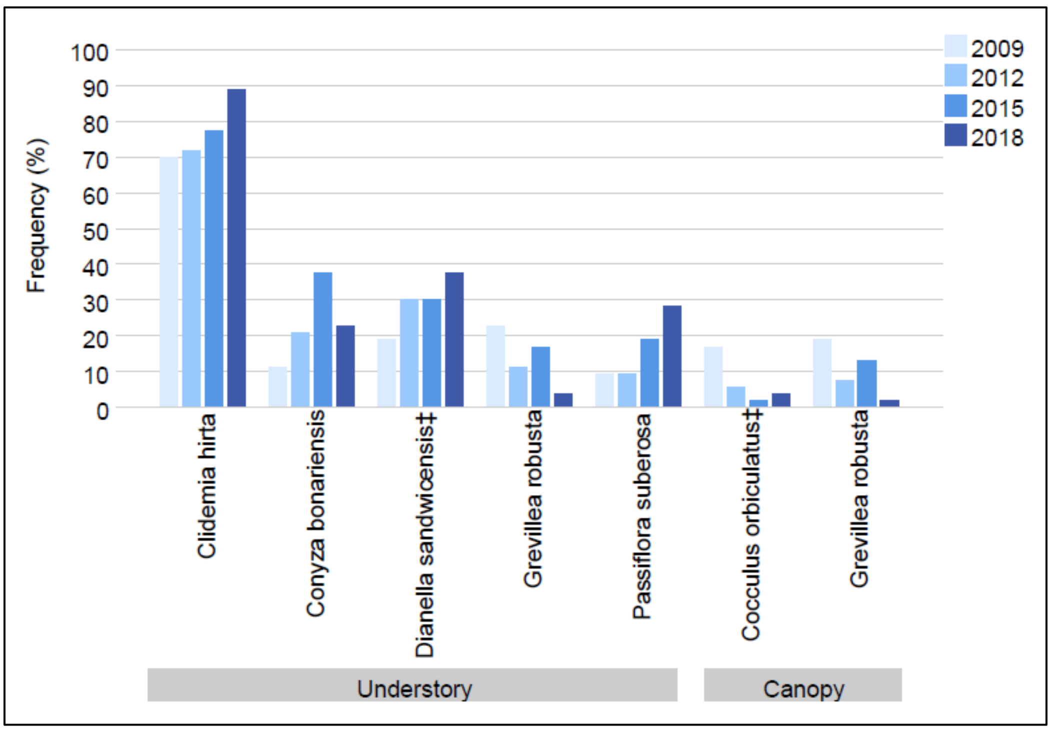



**Figure 8.** Species frequencies at Kahanahaiki MU between 2009 and 2018, among taxa with significant changes over time. Frequency values represent the proportion of plots in which species are present (n=53). ‡Native taxa.

## Species cover

Species with frequencies > 20% in 2018 or 2009 were analyzed. Significant cover changes occurred for several taxa in the understory and canopy (Table 6), however many of these were small (≤ 10% absolute change), inconsistent across years, and/or were of limited management concern. Notable cover changes included increases in one native (*A. stellata*) and two non-native (*C. hirta* and *P. cattleianum*) understory species between 2009 and 2015, and one native (*Acacia koa*) and one non-native (*P. catttleianum*) canopy species between 2009 and 2018 (Figure 9).

**Table 6.** Species with significant cover change at Kahanahaiki MU between 2009 and 2018. Only taxa with > 20% frequency in either 2018 or 2009 were analyzed. Arrows indicate increase (↑), decrease (↓), or inconsistent trend (↕) in cover. Native species are in boldface.

| | p* | $X^2$ | Years with significant differences | p (post-hoc)** |
|---|---|---|---|---|
| Understory | | | | |
| ***Alyxia stellata*** | 0.002↕ | 14.939 | 2009 vs. 2015 | 0.029↑ |
| ***Antidesma platyphyllum*** | 0.034↕ | 8.676 | | |
| ***Bidens torta*** | 0.000↕ | 23.642 | | |
| ***Carex meyenii*** | 0.003↕ | 14.062 | | |
| *Clidemia hirta* | 0.000↑ | 29.025 | 2009 vs. 2015 | 0.005↑ |
| | | | 2009 vs. 2018 | 0.001↑ |
| ***Cocculus orbiculatus*** | 0.017↓ | 10.164 | | |
| *Conyza bonariensis* | 0.000↕ | 19.258 | | |
| ***Dianella sandwicensis*** | 0.000↑ | 22.133 | | |
| *Grevillea robusta* | 0.005↕ | 12.84 | | |
| *Melinis minutiflora* | 0.001↕ | 16.38 | | |
| ***Nephrolepis exaltata* subsp. *hawaiiensis*** | 0.036↓ | 8.55 | | |
| *Passiflora suberosa* | 0.000↑ | 18.333 | | |
| *Psidium cattleianum* | 0.003↑ | 13.793 | 2009 vs. 2015 | 0.014↑ |
| ***Psydrax odorata*** | 0.028↕ | 9.097 | | |
| *Rubus rosifolius* | 0.014↕ | 10.65 | | |
| *Schinus terebinthifolius* | 0.005↕ | 12.845 | | |
| Canopy | | | | |
| ***Acacia koa*** | 0.000↑ | 20.235 | 2009 vs. 2018 | 0.036↑ |
| ***Kadua affinis*** | 0.002↓ | 14.567 | | |
| *Psidium cattleianum* | 0.000↑ | 30.101 | 2009 vs. 2018 | 0.000↑ |
| | | | 2012 vs. 2018 | 0.002↑ |

*from Friedman's test, asymptotic significance
**from post-hoc pairwise comparisons with Bonferroni adjustment

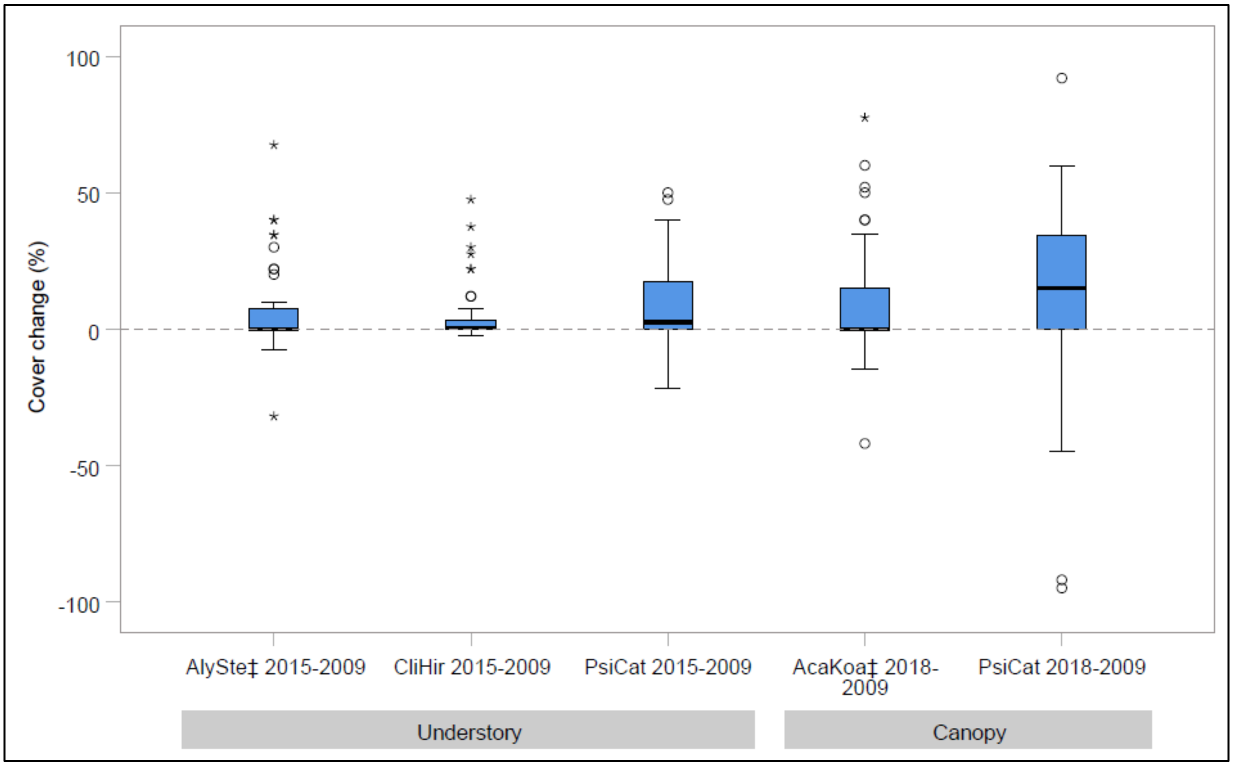



**Figure 9.** Boxplots of cover change for taxa with noteworthy significant changes at Kahanahaiki MU. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change. ‡Native taxa.

## Canopy replacement

Many canopy tree species were found recruiting in the understory, including 18 native and 10 non-native taxa (Table 7). *Psidium cattleianum* was the most commonly recruiting tree species, occurring in nearly every plot. Species with higher frequencies in the canopy generally had higher recruitment frequencies among plots. Native tree species with no recruitment observed in plots were also low in frequency in the canopy. It should be noted that the age of saplings may vary greatly, from less than one year to decades, in accordance with differing species and individual growth rates, complicating interpretations of presence/absence and change over time with respect to concerns over long term canopy replacement.

**Table 7.** Summary of recruitment frequency among plots in the understory for tree taxa observed in monitored plots (understory and/or canopy) at Kahanahaiki MU in 2018. Native species are in boldface. Target weed taxa: *ICA, **limited distribution.

| Species | Recruitment Frequency | Canopy Frequency |
|---|---|---|
| *Psidium cattleianum* | 96.2 | 84.9 |
| *Schinus terebinthifolius* | 56.6 | 73.6 |
| ***Psydrax odorata*** | 41.5 | 75.5 |
| ***Acacia koa*** | 28.3 | 39.6 |
| ***Diospyros sandwicensis*** | 20.8 | 13.2 |
| ***Kadua affinis*** | 20.8 | 13.2 |
| ***Metrosideros polymorpha*** | 18.9 | 32.1 |
| ***Psychotria mariniana*** | 13.2 | 11.3 |
| *Spathodea campanulata*** | 11.3 | 0.0 |
| ***Pisonia sandwicensis*** | 9.4 | 7.5 |
| ***Dodonaea viscosa*** | 7.5 | 3.8 |
| ***Pisonia brunoniana*** | 7.5 | 0.0 |
| *Psidium guajava* | 7.5 | 1.9 |
| ***Myrsine lessertiana*** | 5.7 | 0.0 |
| ***Pipturus albidus*** | 5.7 | 3.8 |
| ***Planchonella sandwicensis*** | 5.7 | 9.4 |
| ***Antidesma platyphyllum*** | 3.8 | 9.4 |
| ***Diospyros hillebrandii*** | 3.8 | 3.8 |
| ***Nestegis sandwicensis*** | 3.8 | 9.4 |
| *Acacia mearnsii** | 1.9 | 0.0 |
| *Aleurites moluccana* | 1.9 | 15.1 |
| *Grevillea robusta*** | 1.9 | 1.9 |
| *Litchi chinensis* | 1.9 | 0.0 |
| *Montanoa hibiscifolia*** | 1.9 | 1.9 |
| ***Myrsine lanaiensis*** | 1.9 | 0.0 |
| ***Pisonia umbellifera*** | 1.9 | 0.0 |
| ***Psychotria hathewayi*** | 1.9 | 1.9 |
| Unknown sp. | 1.9 | 0.0 |
| ***Bobea elatior*** | 0.0 | 1.9 |
| *Eucalyptus urophylla* | 0.0 | 1.9 |
| ***Gynochthodes trimera*** | 0.0 | 1.9 |
| ***Hibiscus arnottianus* subsp. *arnottianus*** | 0.0 | 3.8 |
| ***Pittosporum glabrum*** | 0.0 | 1.9 |
| ***Santalum freycinetianum* var. *freycinetianum*** | 0.0 | 3.8 |
| ***Sapindus oahuensis*** | 0.0 | 0.0 |
| *Syzygium cumini* | 0.0 | 1.9 |
| ***Xylosma hawaiiense*** | 0.0 | 3.8 |

## Weed control

Weed control efforts (WCA) at Kahanahaiki Subunit I between the 2009 and 2012 monitoring intervals were relatively high (including 2555 person hours, with 59% of MU weeded, and occurring in 66% of plots) (Figure 10). Efforts between the 2012 and 2015 monitoring intervals were relatively lower (1948 person hours, 27% of MU weeded, in 28% of plots). Between the 2015 and 2018 intervals, efforts were again relatively high (3328 person hours, 62% of MU weeded, in 66% of plots). Weeding occurred in nearly all plots (94%) between 2009 and 2018 at least once. Much of the weeding efforts over the last nine years consisted of general ecosystem weed control, but some included targeted control of specific widespread distribution target taxa (e.g., *G. robusta* and *M. hibiscifolia*), as well as grass control and trail clearing. Additional weed control efforts occurred for ICA taxa.

Changes in native and non-native understory and canopy cover were not significantly associated with the occurrence of weeding within plots for any of the three-year intervals. Sample sizes for unweeded plots between 2009 and 2018 were deemed insufficient for statistical comparison of cover change in weeded vs. unweeded plots for that time range. However, change in native understory cover between 2009 and 2018 was influenced by changes in both non-native canopy (GLM: $p = 0.000$, $\exp(\beta) = 0.700$) and non-native understory (GLM: marginal significance, $p = 0.052$, $\exp(\beta) = 0.788$) cover resulting from either weed control efforts and/or natural processes. Native understory cover increased with decreasing non-native cover, and decreased with increasing non-native cover. This pattern is most evident in two plots, one that has not been weeded since 2011 and has transitioned from high to low native understory cover as non-native canopy progressed from very low to very high cover (Figure 11), and a second in the Maile Flats "Chipper Site" where native understory cover changed from very low to moderate (and native canopy from very low to high) as non-native canopy cover transformed from very high to very low in association with restoration efforts (Figure 12).

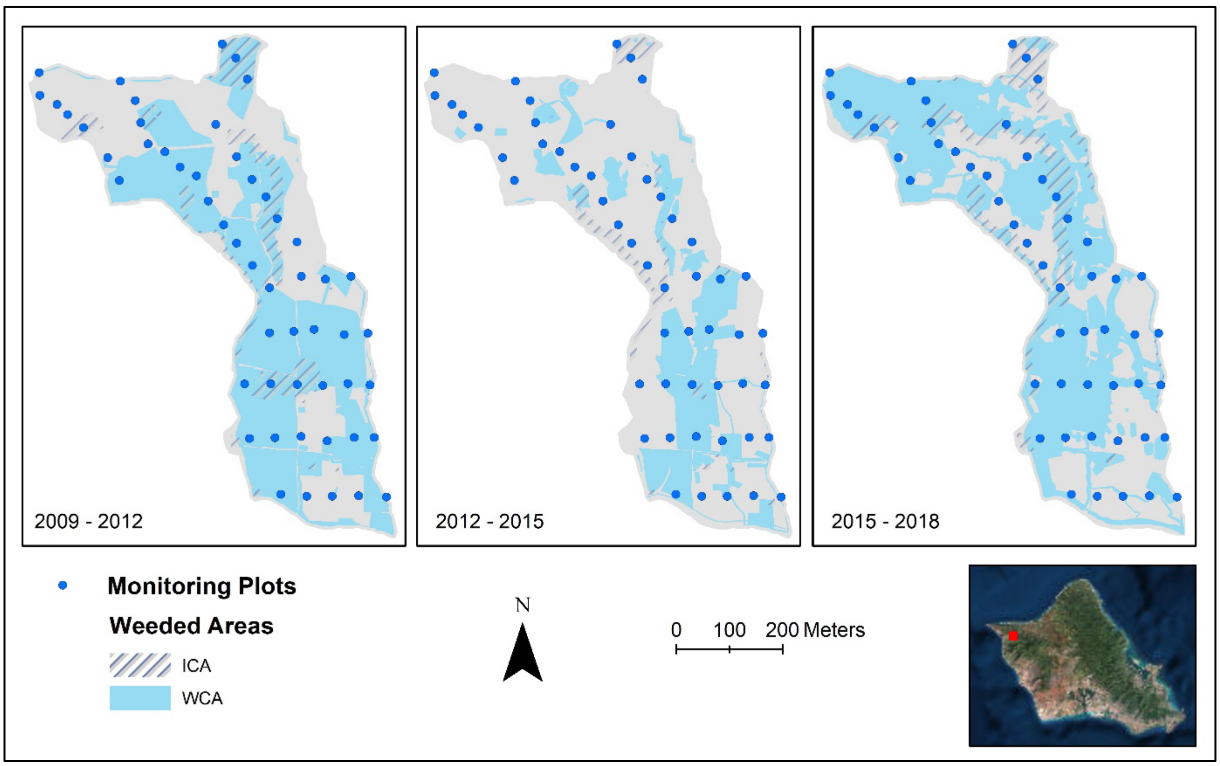



**Figure 10.** Locations of vegetation monitoring plots at Kahanahaiki MU Subunit I in relation to weeded areas (WCA and ICA) between monitoring intervals.

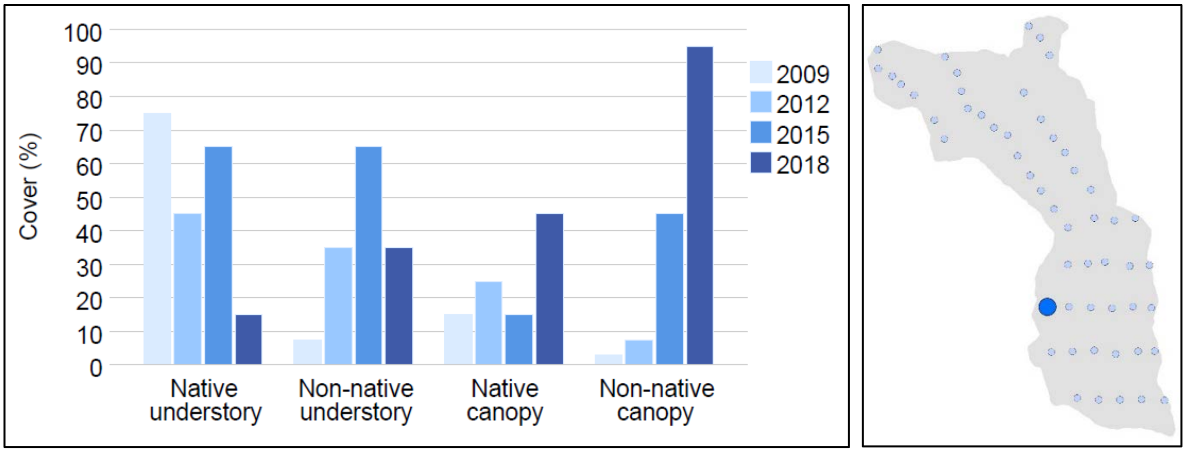



**Figure 11.** Vegetation cover over time in a plot in an area that has not been weeded aside from widespread grass sprays in 2010 and that fell within a *G. robusta* sweep in 2009, demonstrating increased non-native canopy cover paired with decreased native understory.

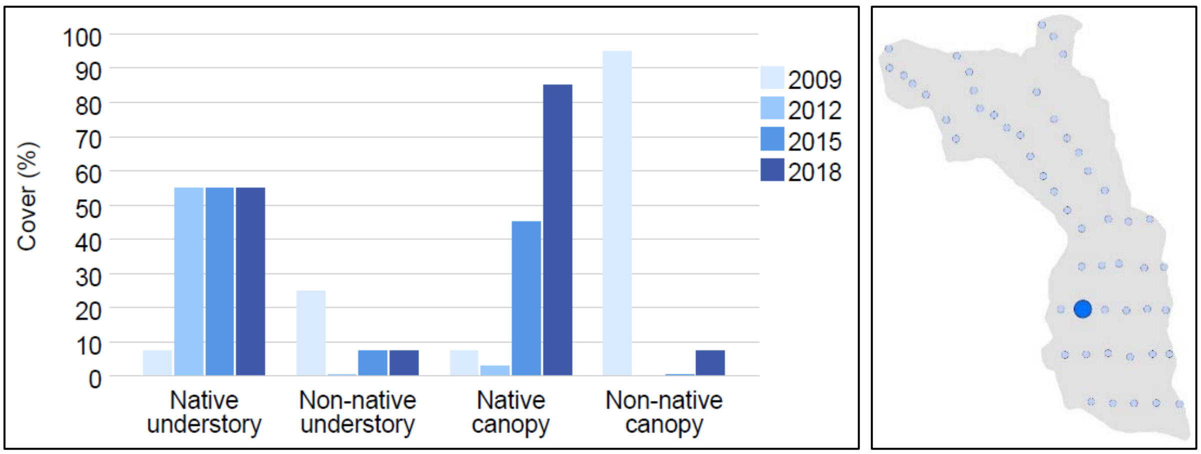



**Figure 12.** Vegetation cover over time in a plot within the Chipper Site restoration area, demonstrating decreased non-native canopy cover paired with increased native understory.

**Native ecosystem restoration efforts**

Native ecosystem restoration efforts began at Kahanahaiki Subunit 1 on a small scale in 2008 with outplantings of common native species (237 plants), and expanded over time to include large scale chainsaw removal of non-native canopy in addition to outplanting, seed sowing, and transplanting of common native taxa (Figures 13 and 14). Between the 2009 and 2012 monitoring intervals, restoration efforts consisted initially of small-scale outplantings, then larger scale efforts began in 2012 with chainsaw clearing and seed sowing in Maile Flats. Between the 2012 and 2015 monitoring intervals, chainsaw clearing and seed sowing continued in Maile Flats, and outplanting began in the northern gulch region as well as at the *Achatinella mustelina* snail enclosure (135 plants total). Between the 2015 and 2018 monitoring intervals, efforts expanded substantially in the northern gulch region, with large-scale chainsaw clearing, along with outplanting, seed sowing, and transplanting common native taxa in several areas. Additional seed sowing occurred, and outplanting in the Maile Flats restoration area also began in 2017. A total of 2604 common native plants were outplanted during this time interval for all restoration sites. Restoration efforts crossed through two plots during the 2009 to 2012 and 2012 to 2015 monitoring intervals, then one additional plot between 2015 and 2018. Sample sizes were insufficient for statistical comparison of cover change in plots for restored vs. unrestored areas to discern the impacts of restoration on the native and non-native understory and canopy. However, vegetation change is documented at individual restoration sites that demonstrates the beneficial changes that are taking place. Dramatic reductions in non-native vegetation and increases in native vegetation were documented from photopoints as well as plots recording frequency, richness and cover at the Chipper Site in Maile Flats (OANRP 2016) and from photopoints at the gulch restoration sites (Chapter 3).

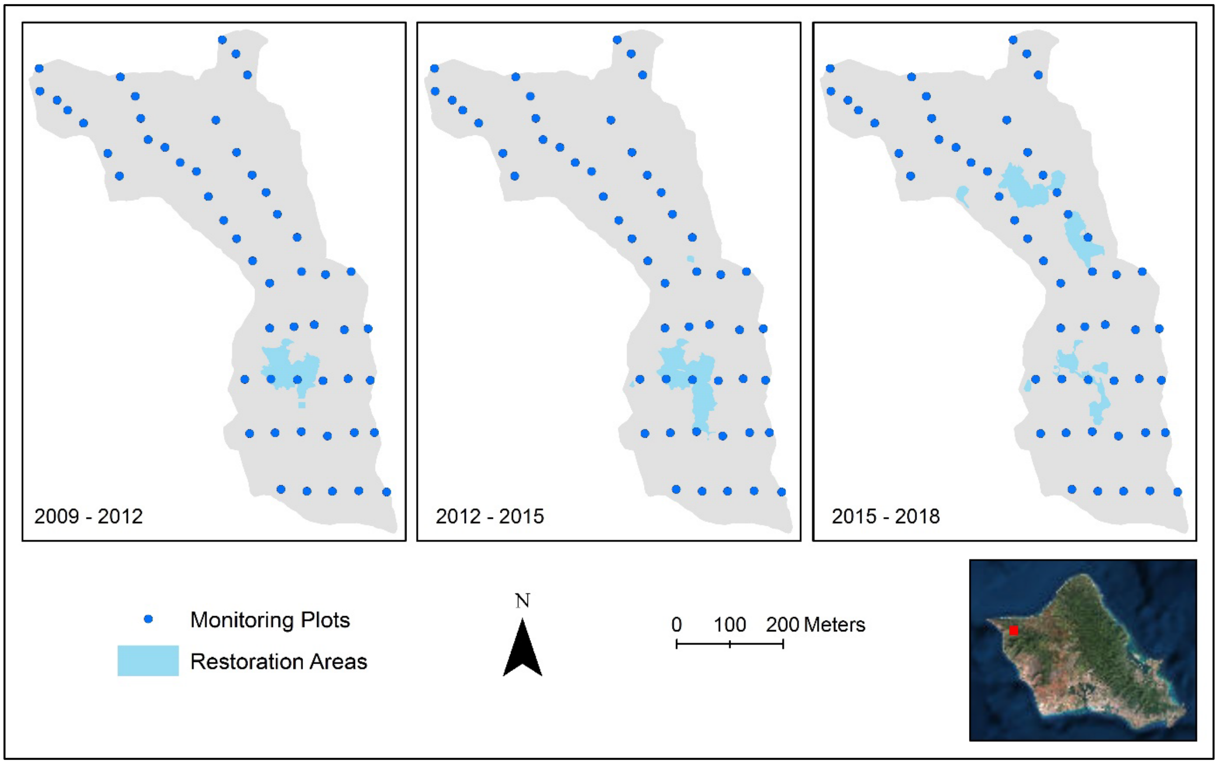



**Figure 13.** Locations of vegetation monitoring plots in relation to native ecosystem restoration actions between monitoring intervals at Kahanahaiki MU.

**Figure 14.** Vegetation change in a monitoring plot at the newly established "Schweppes Extension" restoration site in the northern gulch region, showing when the area was dominated by *Psidium cattleianum* in 2009 (left), then in 2018 (right) after becoming dominated by young *Pipturus albidus* (primarily from seeds sown seven months prior) and common native outplants (planted two months prior).

## SUMMARY AND DISCUSSION

Management objectives continue to be met for percent cover of non-native understory for Kahanahaiki MU Subunit I. Objectives are still not met for native understory, native canopy and non-native canopy cover. There were a number of significant changes in vegetation since 2009, many of which were relatively small, inconsistent, and/or of limited management concern. The most noteworthy changes included:

- **Categorical cover**
  - Increased
    - Non-native shrubs (from 2009 to 2015)
    - Non-native understory (from 2009 to 2015)
    - Non-native canopy (from 2009 to 2018)
  - Decreased
    - Native understory (from 2015 to 2018)
    - Non-native understory (from 2015 to 2018)
- **Frequency** (all from 2009 to 2018)
  - Increased
    - Native understory
      - *D. sandwicensis*
    - Non-native understory

            - *C. hirta*
            - *P. suberosa*
    - Decreased
        - Non-native understory
            - *G. robusta*
        - Non-native canopy
            - *G. robusta*
- **Species cover**
    - Increased
        - Native understory
            - *A. stellata* (from 2009 to 2015)
        - Non-native understory
            - *C. hirta* (from 2009 to 2015)
            - *P. cattleianum* (from 2009 to 2015)
        - Native canopy
            - *A. koa* (from 2009 to 2018)
        - Non-native canopy
            - *P. cattleianum* (from 2009 to 2018)
- **Weed control**
    - Reductions in non-native canopy and understory cover are associated with increases in native understory cover, and increases in non-native canopy and understory cover are associated with declines in native understory cover (from 2009 to 2018)

The many notable changes in vegetation at Kahanahaiki since 2009 include both beneficial and unfavorable ones. Much has been gained presumably from direct (weeding, restoration) and/or indirect (ungulate exclusion, rodent control) management actions, namely the increase in canopy cover of *A. koa* (primarily in Maile Flats, see Figure 15) and *A. stellata* in the understory, the spread of *D. sandwicensis*, the decline of non-native understory (in the last three years), and the decline in *G. robusta* frequency (from targeted control). However, non-native vegetation, particularly the problematic weeds *C. hirta*, *P. suberosa* (Figure 16), and *P. cattleianum*, continues to spread in cover and/or frequency. The association revealed between changes in non-native cover and native understory cover underscores the capacity of weeding and restoration to reverse the trend of decreasing native understory in conjunction with increasing non-native canopy and understory.

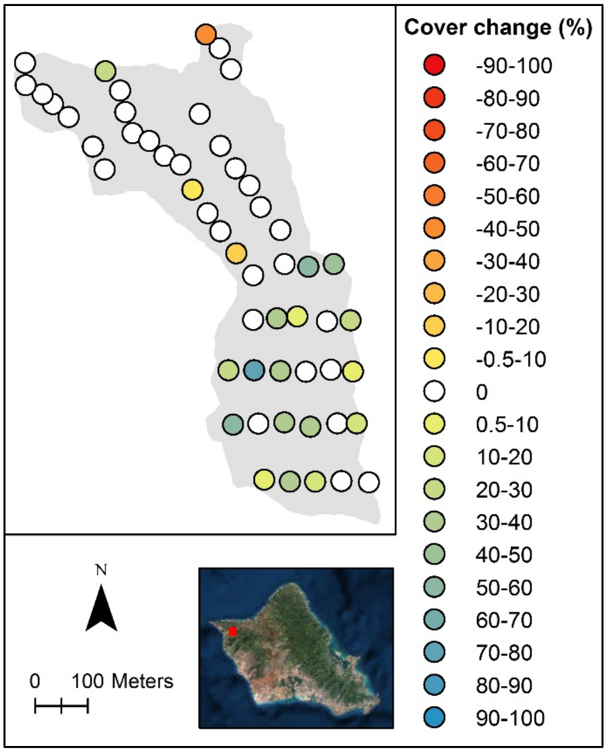



**Figure 15.** Locations of cover change for *Acacia koa* from 2009 to 2018.

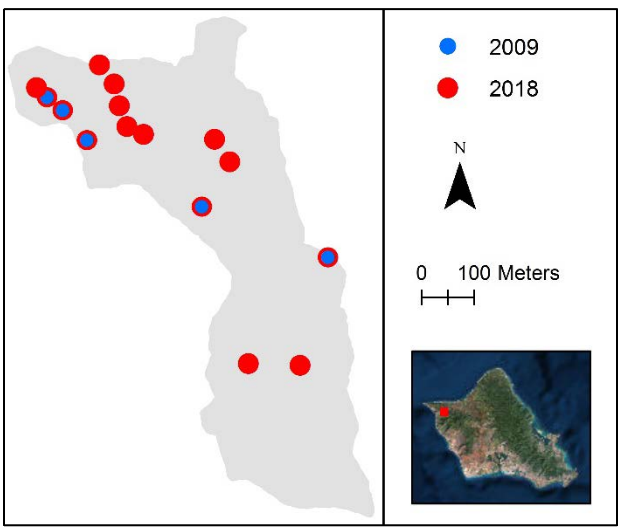



**Figure 16.** Locations of *Passiflora suberosa* in plots in 2009, and locations into which it spread by 2018.

## RECOMMENDATIONS

Based on the results of vegetation monitoring, a number of recommendations were made with the goal of making progress towards meeting management objectives:

- Continued efforts for general ecosystem weeding and grass control
- Continued control of ICA taxa
- Continued targeted sweeps for limited distribution target taxa *M. hibiscifolia* and the few remaining mature *G. robusta* trees
- Conduct general ecosystem weeding sweeps through Maile Flats WCAs in native-dominated areas on a regular rotation (every 3 to 5 years) and map out remaining monotypic stands of *P. cattleianum* for future ecosystem restoration work, with specific actions for the following WCAs:
    - Kahanahaiki-11, SW (Blue Team). Increasing alien cover seen here. Most native-dominated WCA in Maile Flats. This WCA was more or less completely swept in 2002, 2007, 2011, and 2013. It is overdue for another sweep. Blue team started in Q2, 2018, but did not finish. Prioritize finishing by end of 2018.
    - Kahanahaiki-12, SE (Green Team). Increasing alien cover seen here. Some *P. cattleianum* monocultures, some native forest patches, some mixed areas. Need to reinstitute sweeps here. Sweeps should be detailed in native forest patches, and gradual in mixed areas. Map *P. cattleianum* monocultures and target for later removal and restoration.
    - Kahanahaiki-08, -10, -12 (Green Team) have more non-native canopy to the east. Would be good to have some sweeps across parts of -08 and -10 (as well as -12).
    - Kahanahaiki-07, -09 (Blue Team) have more mixed forest. Do sweeps across these areas, targeting understory and slow removal/replacement of canopy.
- Scope *S. terebinthifolius* areas in Maile Flats and consider management options
- Focused efforts on controlling *P. suberosa* during general ecosystem weeding
- Focused efforts for controlling *N. brownii*
- Consider MU-wide IPA sweeps for *P. guajava* and *S. cumini* and find effective control technique for *S. cumini*
- Continued expansion of ecosystem restoration efforts, which may include:
    - "Re-veg" road area and northwest corner of Subunit I, to include removal of *U. urophylla* and outplanting *A. koa* and *D. viscosa*
    - Between "OG chipper" and Ethan's
    - Between Shire and Ethan's
    - Near Generals
    - Remaining stands of *P. cattleianum* in Maile Flats
    - East side of Maile Flats
    - Expand Black Wattle into neighboring *P. cattleianum* zone
    - Use of chipper where appropriate

## REFERENCES

Oahu Army Natural Resources Program. 2008. Appendix 2.0 MIP/OIP Belt Plot Sampling Monitoring Protocol *in* 2008 Status Report for the Makua Implementation Plan. http://manoa.hawaii.edu/hpicesu/DPW/2008_YER/008.pdf.

Oahu Army Natural Resources Program. 2009. MU Vegetation Monitoring *in* Chapter 1.4.4 Kahanahaiki Ecosystem Restoration Management Plan *in* 2009 Status Report for the Makua and Oahu Implementation Plans. http://manoa.hawaii.edu/hpicesu/DPW/ERMUP/2009_Kahanahaiki.pdf

Oahu Army Natural Resources Program. 2012. Chapter 1.1.4 Vegetation Monitoring: Kahanahaiki Three-Year analysis *in* 2012 Status Report for the Makua and Oahu Implementation Plans. http://manoa.hawaii.edu/hpicesu/DPW/2012_YER/02.pdf

Oahu Army Natural Resources Program. 2015. Appendix 1-3 Vegetation monitoring at Kahanahaiki Management Unit, 2015 *in* 2015 Status Report for the Makua and Oahu Implementation Plans. http://manoa.hawaii.edu/hpicesu/DPW/2015_YER/A3.pdf

Oahu Army Natural Resources Program. 2016. Appendix 3-8 Results of Kahanahaiki Chipper Site vegetation monitoring five years after initial clearing *in* 2016 Status Report for the Makua and Oahu Implementation Plans. http://manoa.hawaii.edu/hpicesu/DPW/2016_YER/A3-08.pdf

ARMY NATURAL RESOURCE PROGRAM – OAHU (OANRP)
MONITORING PROGRAM

**KAPUNA UPPER MANAGEMENT UNIT VEGETATION MONITORING, 2011 - 2017**

## INTRODUCTION

Vegetation monitoring was initiated at Kapuna Upper Management Unit (MU) in the Pahole Natural Area Reserve in October through December of 2011, and was conducted a second time in October of 2017, in association with Implementation Plan (IP) requirements for long term monitoring of vegetation composition and change over time (OANRP 2008) (Figures 1 and 2). Because the 2011 data was not previously reported, those results are summarized in full herein along with the 2017 data. The primary objective of MU monitoring is to assess if the percent cover of non-native plant taxa is less than 50% across the MU, or is decreasing towards that threshold requirement. A secondary objective is to assess if native cover is greater than 50% across the MU, or is increasing towards that threshold recommendation. Vegetation monitoring at Kapuna Upper MU will proceed on a five-year interval. The MU fence lines were completed in 2007, though ungulate presence has occurred variously within the MU since that time.

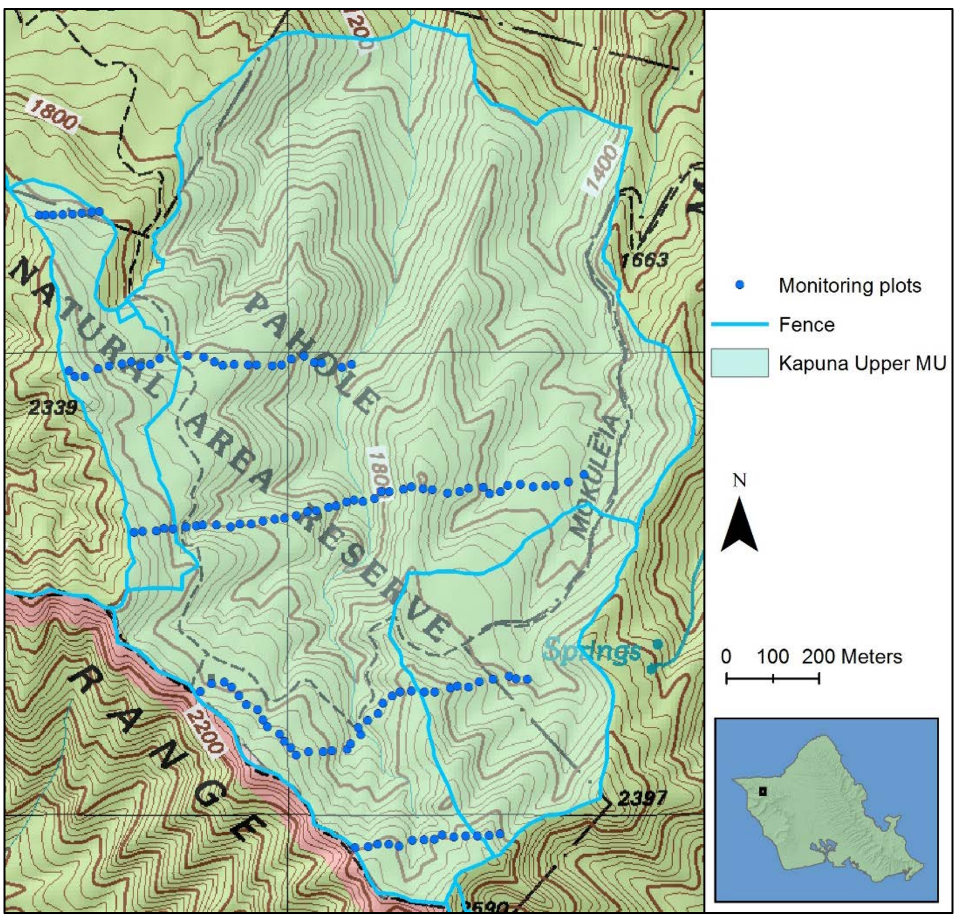



**Figure 1.** Vegetation monitoring plot locations at Kapuna Upper MU.

**Figure 2.** OANRP staff members collecting field data at Kapuna Upper MU in 2011 (left, with Kapua Kawelo and Eli Kimmerle) and 2017 (right, with Melissa Valdez).

## METHODS

In 2011 and 2017, 126 plots along 5 transects were monitored at Kapuna Upper MU. Plots measuring 5 x 10 m were generally located every 20 or 30 m along transects. Transects were spaced approximately 350 m apart. Vegetation monitoring was limited to the higher elevations of the MU, as the lower elevations receive limited direct management, and are largely dominated by non-native vegetation. Understory (0 – 2 m above ground level (AGL), including low branches from canopy species) and canopy (> 2 m AGL, including epiphytes) vegetation was recorded by percent cover for all non-native and native species present. Summary percent cover by vegetation type (shrub, fern, grass/sedge) in the understory, overall summary percent cover of non-native and native vegetation in the understory and canopy, and bare ground (non-vegetated < 25 cm AGL), were also documented. Percent cover categories were recorded in 10% intervals between 10 and 100%, and on finer intervals (0-1%, 1-5%, and 5-10%) between 0 and 10% cover. Understory recruitment (defined as seedlings or saplings < 2 m AGL) presence/absence data for tree species was also recorded. Monitoring results from 2017 were compared with data from 2011. Based on IP recommendations, p-values $< 0.05$ were considered significant, and only absolute cover changes ≥ 10% were recognized. Additional methodology information is detailed in Monitoring Protocol 1.2.1 (OANRP 2008). All analyses were performed in IBM SPSS Statistics Version 24. These included Wilcoxon signed-rank tests for cover and species richness data, and McNemar's tests for frequency data.

# RESULTS

## Understory and canopy cover categories

Management objectives of having < 50% non-native understory and canopy and > 50% native understory and canopy cover were not met in either 2011 or 2017 (Table 1). Native understory and canopy cover were low, non-native understory cover was moderately high, and non-native canopy was very high. There were significant changes in percent cover of vegetation between 2011 and 2017. However, only a subset of those met the 10% standard for recognized change in cover. These included increases in both native and non-native canopy percent cover (Figure 3). In 2017, locations of low to high non-native understory percent cover were patchily distributed across the MU, and consisted of mostly moderate to higher cover (Figure 4). Native understory cover was nearly consistently low throughout, with occasional scattered locations of higher cover. Native canopy cover was wide ranging and quite variable throughout, though primarily moderately low. Non-native canopy cover was nearly consistently high throughout the MU, with occasional scattered locations of lower cover. Locations where beneficial and worsening cover changes occurred were patchily distributed for the native understory and canopy (Figure 5). Changes were mostly +/- 10%, but with scattered locations of moderately worsening change more prevalent in the understory, and moderately beneficial change more frequent in the canopy. Locations of beneficial and worsening cover changes were also patchily distributed for the non-native understory and canopy. These changes were very wide ranging, from highly beneficial to highly undesirable, in the understory. In the canopy, they primarily ranged from minimally beneficial to highly undesirable.

**Table 1.** Median percent cover of native and non-native vegetation categories in the canopy and understory at Kapuna Upper MU from 2011 to 2017 (n = 126). Categories specifically addressed in management objectives are highlighted in blue. Statistically significant values for categories that meet the 10% standard for recognized change in cover are in boldface (Wilcoxon signed-rank test). Arrows indicate increase (↑) or decrease (↓) in cover.

| | 2011 | 2017 | p | Z | Management objective currently met? |
|---|---|---|---|---|---|
| ***Understory*** | | | | | |
| Native shrubs | 3.0 | 3.0 | 0.000↓ | -6.023 | |
| Native ferns | 3.0 | 3.0 | 0.029↓ | -2.181 | |
| Native grass/sedges | 0.0 | 0.0 | 0.074 | -1.789 | |
| Total native understory | 11.3 | 3.0 | 0.000↓ | -4.686 | No, and may be getting worse |
| Non-native shrubs | 35.0 | 25.0 | 0.124 | -1.538 | |
| Non-native ferns | 0.5 | 1.8 | 0.000↑ | -4.201 | |
| Non-native grass/sedges | 0.5 | 0.5 | 0.000↓ | -3.936 | |
| Total non-native understory | 55.0 | 55.0 | 0.067 | -1.829 | No |
| Bare ground | 75.0 | 70.0 | 0.039↓ | -2.068 | |
| ***Canopy*** | | | | | |
| Native canopy | 15.0 | 25.0 | **0.003↑** | -2.982 | No, but getting better |
| Non-native canopy | 85.0 | 95.0 | **0.000↑** | -5.845 | No, and getting worse |
| Total canopy | 95.0 | 95.0 | 0.000↑ | -4.129 | |

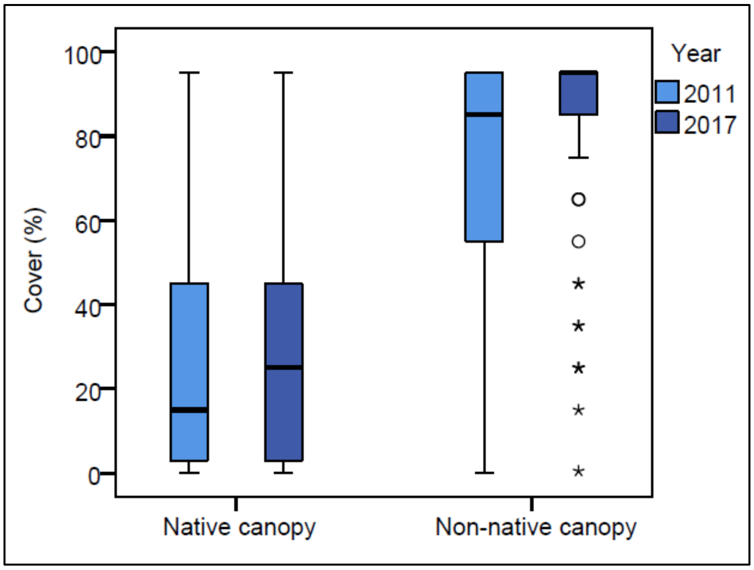



**Figure 3.** Boxplots for vegetation categories with significant change in percent cover that meet 10% standard for recognized change in cover between years 2011 and 2017 in Kapuna Upper MU. [*Note: The boxes depict 50% of the data values, and the horizontal line inside the box represents the median value. Very high or low values relative to the shaded box are indicated by circles (1.5 to 3 times the length of the shaded box) and asterisks (> 3 times the length of the shaded box), while the lines extending above and below the shaded box depict the range in values for all remaining data. Circles and asterisks that appear to be in boldface indicate multiple data points for the same values.*]

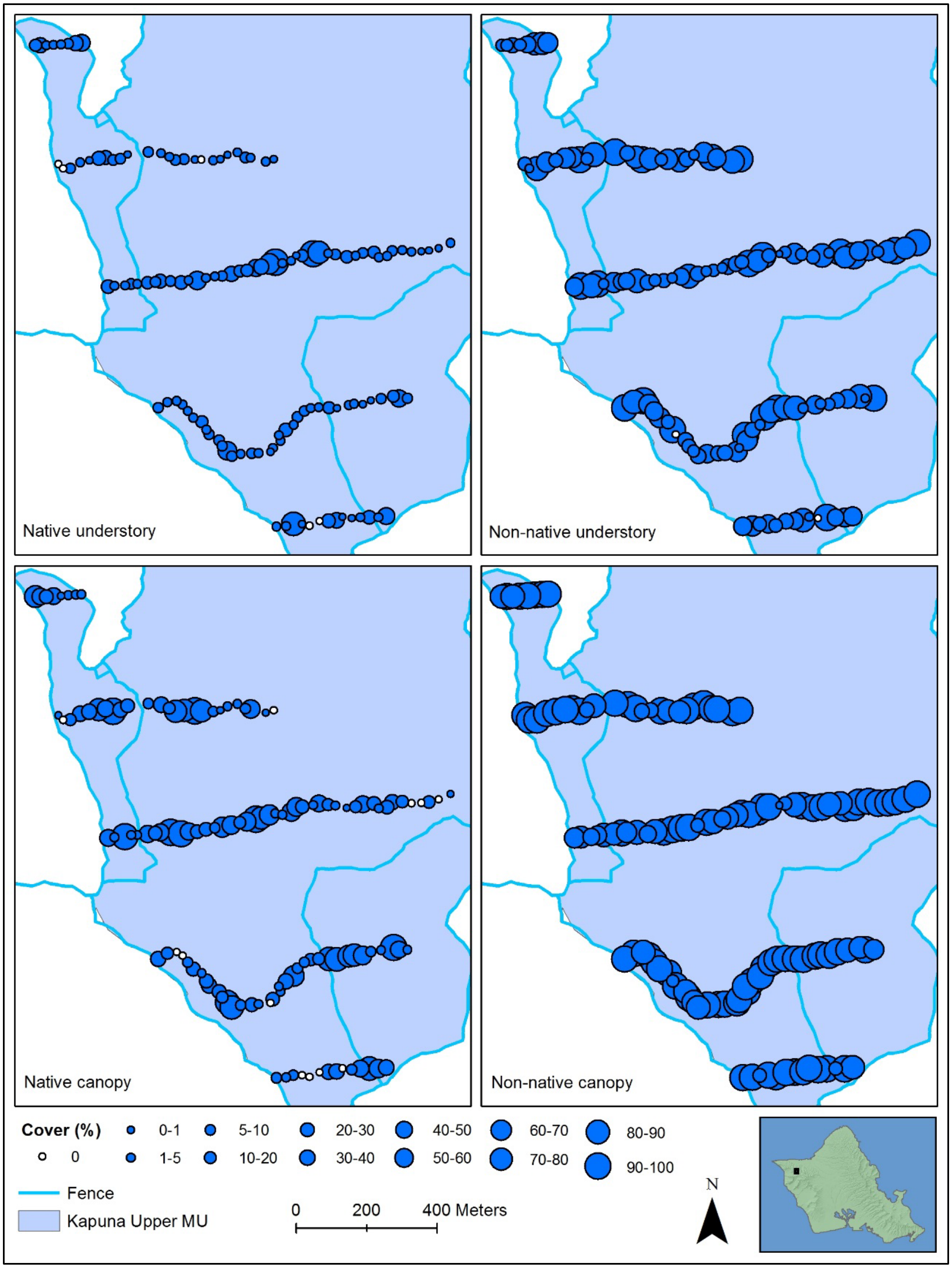



**Figure 4.** Locations of low to high percent cover of native and non-native understory and canopy vegetation among monitored plots at Kapuna Upper MU in 2017. Larger circles denote higher percent cover, while smaller circles represent lower cover.

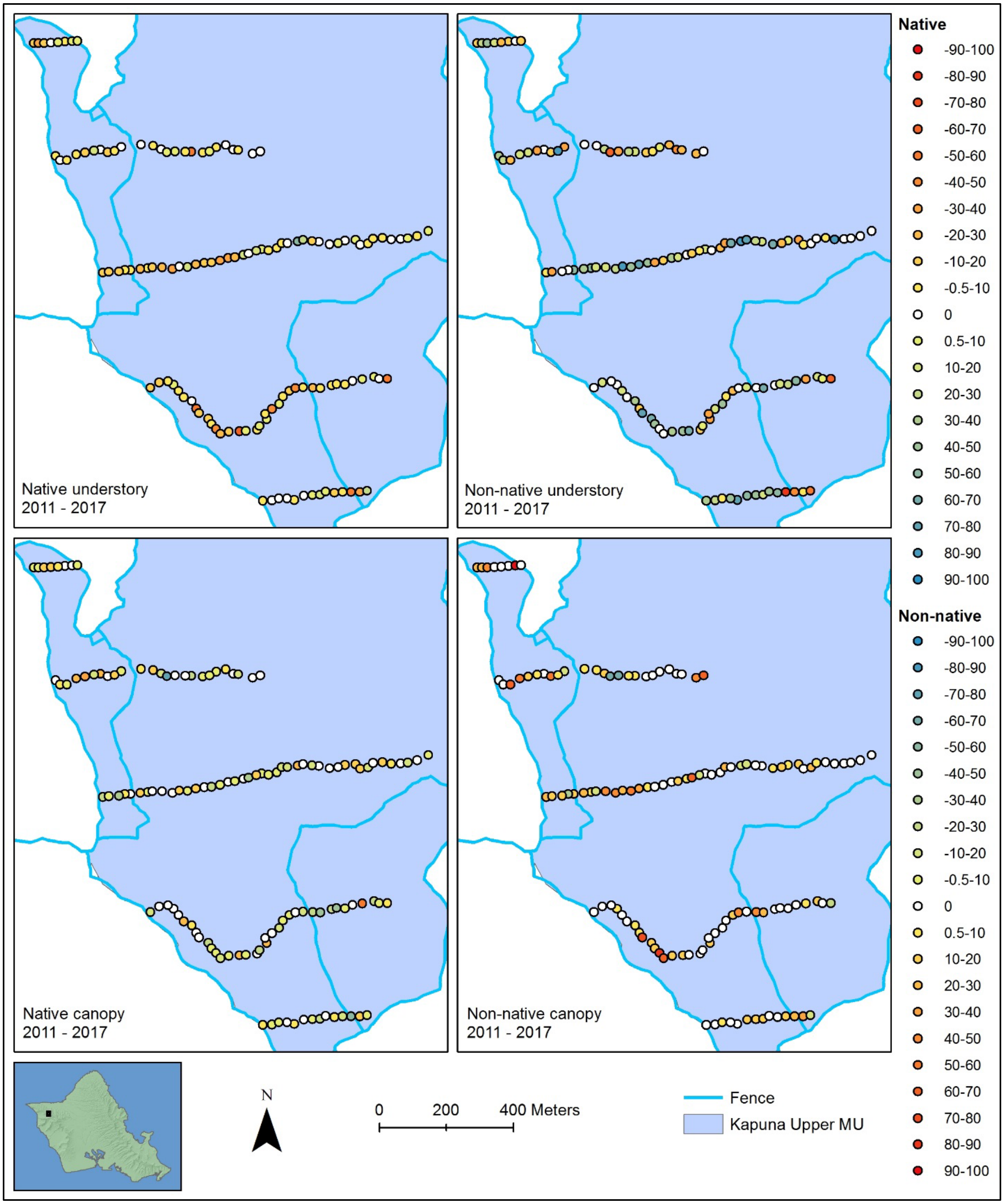



**Figure 5.** Locations of change in native and non-native percent cover for the understory and canopy vegetation in monitored plots in Kapuna Upper MU between 2011 and 2017. Color gradients are inverted for native and non-native vegetation, such that blue indicates beneficial change, red depicts worsening conditions. Cover change of 0 indicates there was no change in percent cover.

## Species richness

During monitoring in 2011, 109 species were recorded in the understory (63% native taxa), and 50 were identified in the canopy (72% native). In 2017, 107 species were recorded in the understory (60% native taxa), and 65 were identified in the canopy (65% native). Most species present in the canopy were also represented in the understory, with the exception of three native taxa (*Gynochthodes trimera*, *Pipturus albidus*, and *Santalum freycinetianum* var. *freycinetianum*) in 2011, and four native (*Bobea elatior*, *Dianella sandwicensis*, *G. trimera*, and *S. freycinetianum* var. *freycinetianum*) and one non-native (*Polystachya concreta*) species in 2017. Species richness differed significantly between the years monitored, with a small decrease in native understory richness along with increases in native and non-native canopy richness within plots (Table 2). The significant changes in richness among plots was in parallel with changes in overall diversity for the MU. Most notable was the increase in overall diversity in the non-native canopy, which was > 1.6 times more speciose in 2017 than in 2011. Locations of low to high species richness within the native and non-native understory and canopy were patchily distributed, though lower elevations typically had relatively low native richness (Figure 6).

**Table 2**. Kapuna Upper MU understory and canopy species richness from 2011 to 2017. Mean species richness per plot during vegetation monitoring is shown by year, with the total number of species recorded among all plots in parentheses (n = 126). Statistically significant values are in boldface (Wilcoxon signed-rank test). Arrows indicate increase (↑) or decrease (↓) in richness.

| | 2011 | 2017 | p | Z |
|---|---|---|---|---|
| Native understory | 5.77 (69) | 5.36 (64) | **0.031**↓ | -2.160 |
| Non-native understory | 5.79 (40) | 5.83 (43) | 0.896 | -0.131 |
| Native canopy | 2.77 (36) | 3.18 (42) | **0.000**↑ | -3.579 |
| Non-native canopy | 2.44 (14) | 2.96 (23) | **0.000**↑ | -4.904 |

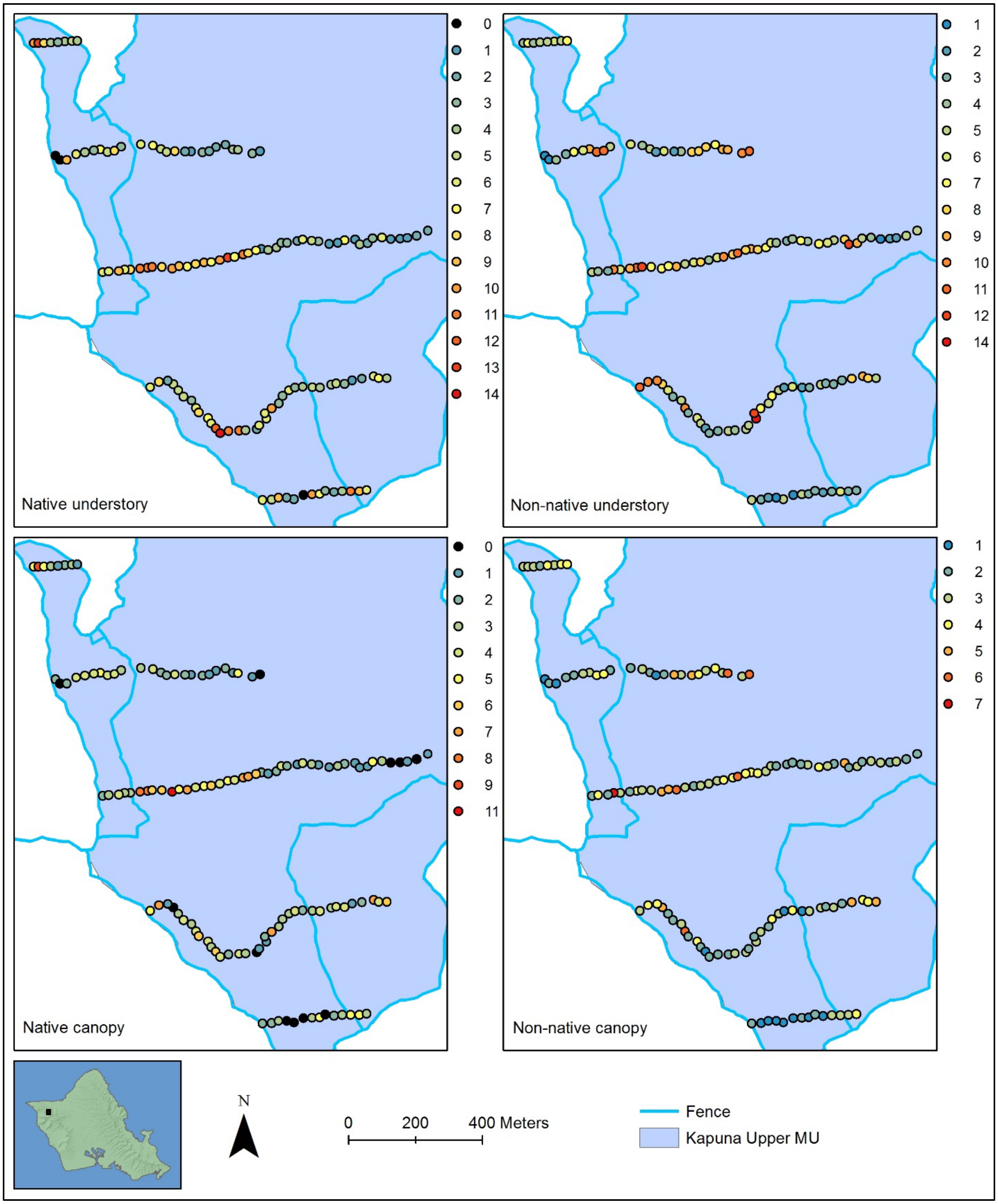



**Figure 6.** Locations of low to high species richness among plots in the native and non-native understory and canopy in Kapuna Upper MU in 2017. Color gradients of blue to red indicate low to high values, respectively, of the number of species occurring in plots (i.e., blue indicates low diversity, while red indicates relatively higher diversity). Plots lacking taxa are indicated in black.

## Species frequency

Non-native species that occurred most frequently in plots (present in more than half the plots) in the understory included *Psidium cattleianum*, *Clidemia hirta*, *Blechnum appendiculatum*, and *Schinus terebinthifolius*, while *P. cattleianum* and *S. terebinthifolius* occurred most commonly in the canopy (Table 3). The most frequent native understory species (in at least a third of the plots) included *Alyxia stellata*, *Nephrolepis exaltata* subsp. *hawaiiensis*, *Microlepia strigosa*, and *Metrosideros polymorpha*, while *M. polymorpha* and *A. stellata* were the most commonly occurring native taxa in the canopy. One out of the 12 IP rare taxa at Kapuna Upper MU (*Cyrtandra dentata*) was recorded in plots during monitoring in 2011 and 2017. One additional non-MIP/OIP rare taxa (*Asplenium dielfalcatum*) was also recorded in 2011. Numerous target weed taxa (taxa of special concern for weed management, ranging from incipient species to those with widespread distributions) for Kapuna Upper MU were present in monitored plots in the understory and/or canopy in both years (Figures 7 and 8). Two out of the eight incipient control area (ICA) target species, *Angiopteris evecta* (a single immature plant within an existing ICA area) and *Rubus argutus* (a new previously undocumented expansive population of > 50 mature plants), were present in a single plot each in 2017. Eight out of the 12 limited distribution target taxa were recorded, including *Adiantum hispidulum*, *Commelina diffusa*, *Montanoa hibiscifolia*, *Nephrolepis brownii*, and *Spathodea campanulata* in both years, *Justicia betonica* and *Schefflera actinophylla* in 2011 only, and *Coffea arabica* in 2017 only, and at least one of these was present in 10% of the plots in 2011, then in 18% of plots by 2017. All 20 widespread distribution target taxa were observed in both years, at least one of which was present in all 126 plots for both years.

Seventeen newly recorded species (53% non-native) were found in plots in 2017, and likewise 17 species (76% native) were recorded in 2011 but not observed in plots in 2017 (Table 4). Aside from the direct or indirect result of management actions, the presence or absence of species may be due in part to human error such as misidentification, observer bias regarding plot boundaries or amount of time spent searching, or accidental non-recording. All of the species that were not present in 2017 were uncommon in 2011, as were those newly recorded in 2017 (all with frequencies < 5%). Most notable among the species newly recorded in in plots in 2017 were *R. argutus* and *Passiflora suberosa*.

Analysis of frequency change was limited to taxa with at least ten percent change between 2011 and 2017. These included two non-native taxa in the understory (*C. hirta* and *Cyclosorus parasiticus*), one native species in the canopy (*Lepisorus thunbergianus*), and one non-native species in the canopy (*C. hirta*), all of which had significant increases in frequency (Table 5 and Figure 9). Most notable were the changes among non-native taxa. Particularly noteworthy among these was the expansion of *C. hirta* (already prevalent in the understory in 2011) into the canopy, occurring in the canopy for only a single plot in 2011, but then in nearly a quarter of the plots by 2017.

**Table 3.** Species frequencies among plots (percent of plots in which a given species occurred) during monitoring in Kapuna Upper MU in 2011 and 2017 (n= 126), in order of most to least frequent in 2017. Native species are in bold print. ‡Rare taxa. Target taxa: *ICA, **Limited distribution.

| Taxon | 2011 | 2017 | Taxon | 2011 | 2017 |
|---|---|---|---|---|---|
| Understory | | | | | |
| *Psidium cattleianum* | 87.3 | 92.9 | *Passiflora suberosa* | 0.0 | 4.8 |
| *Clidemia hirta* | 75.4 | 89.7 | ***Bidens torta*** | 8.7 | 4.0 |
| *Blechnum appendiculatum* | 51.6 | 59.5 | ***Xylosma hawaiiense*** | 6.3 | 4.0 |
| ***Alyxia stellata*** | 54.8 | 52.4 | *Cyclosorus dentatus* | 5.6 | 4.0 |
| ***Nephrolepis exaltata* subsp. *hawaiiensis*** | 52.4 | 52.4 | *Stachytarpheta australis* | 5.6 | 4.0 |
| ***Microlepia strigosa*** | 49.2 | 51.6 | *Conyza bonariensis* | 9.5 | 3.2 |
| *Schinus terebinthifolius* | 52.4 | 50.8 | *Adiantum radianum* | 4.0 | 3.2 |
| *Oplismenus hirtellus* | 45.2 | 42.1 | ***Dryopteris fusco-atra*** | 2.4 | 3.2 |
| *Cyclosorus parasiticus* | 26.2 | 38.9 | ***Cyperus hypochlorus* var. *hypochlorus*** | 6.3 | 2.4 |
| ***Metrosideros polymorpha*** | 42.1 | 33.3 | ***Pisonia sandwicensis*** | 5.6 | 2.4 |
| ***Doodia kunthiana*** | 26.2 | 27.8 | *Toona ciliata* | 5.6 | 2.4 |
| *Rubus rosifolius* | 24.6 | 27.8 | ***Dodonaea viscosa*** | 3.2 | 2.4 |
| ***Kadua affinis*** | 27.0 | 24.6 | ***Melicope oahuensis*** | 3.2 | 2.4 |
| ***Coprosma foliosa*** | 30.2 | 22.2 | ***Tectaria gaudichaudii*** | 3.2 | 2.4 |
| *Paspalum conjugatum* | 31.0 | 21.4 | ***Elaeocarpus bifidus*** | 2.4 | 2.4 |
| *Psidium guajava* | 27.0 | 21.4 | ***Myrsine lessertiana*** | 2.4 | 2.4 |
| ***Psydrax odorata*** | 25.4 | 19.8 | *Oxalis debilis* | 2.4 | 2.4 |
| *Lantana camara* | 20.6 | 19.8 | ***Vandenboschia davallioides*** | 2.4 | 2.4 |
| ***Antidesma platyphyllum*** | 14.3 | 18.3 | *Aleurites moluccana* | 1.6 | 2.4 |
| ***Cocculus orbiculatus*** | 21.4 | 15.1 | ***Elaphoglossum aemulum*** | 0.0 | 2.4 |
| ***Nestegis sandwicensis*** | 14.3 | 13.5 | ***Asplenium caudatum*** | 4.0 | 1.6 |
| ***Psychotria mariniana*** | 11.1 | 13.5 | *Oxalis corniculata* | 4.0 | 1.6 |
| *Melinis minutiflora* | 17.5 | 12.7 | *Montanoa hibiscifolia*** | 1.6 | 1.6 |
| ***Diospyros hillebrandii*** | 15.1 | 12.7 | *Urochloa maxima* | 1.6 | 1.6 |
| ***Psilotum nudum*** | 5.6 | 11.9 | ***Viola chamissoniana* subsp. *tracheliifolia*** | 1.6 | 1.6 |
| ***Wikstroemia oahuensis* var. *oahuensis*** | 9.5 | 11.1 | *Commelina diffusa*** | 0.8 | 1.6 |
| ***Lepisorus thunbergianus*** | 7.1 | 10.3 | ***Cyrtandra dentata*‡** | 0.8 | 1.6 |
| ***Diospyros sandwicensis*** | 10.3 | 9.5 | ***Elaphoglossum crassifolium*** | 0.8 | 1.6 |
| ***Sphenomeris chinensis*** | 12.7 | 8.7 | ***Psychotria hathewayi*** | 0.8 | 1.6 |
| *Triumfetta semitriloba* | 11.9 | 8.7 | *Spathodea campanulata*** | 0.8 | 1.6 |
| ***Carex wahuensis*** | 7.9 | 8.7 | ***Elaphoglossum alatum*** | 2.4 | 0.8 |
| *Adiantum hispidulum*** | 4.8 | 8.7 | *Passiflora edulis* | 2.4 | 0.8 |
| ***Dicranopteris linearis*** | 5.6 | 7.9 | ***Streblus pendulinus*** | 2.4 | 0.8 |
| ***Asplenium macraei*** | 4.8 | 7.9 | ***Charpentiera tomentosa*** | 1.6 | 0.8 |
| ***Acacia koa*** | 8.7 | 7.1 | ***Hibiscus arnottianus* subsp. *arnottianus*** | 1.6 | 0.8 |
| ***Sapindus oahuensis*** | 7.1 | 7.1 | ***Scaevola gaudichaudiana*** | 1.6 | 0.8 |
| *Cordyline fruticosa* | 3.2 | 7.1 | ***Charpentiera obovata*** | 0.8 | 0.8 |
| ***Planchonella sandwicensis*** | 4.8 | 6.3 | ***Dryopteris glabra*** | 0.8 | 0.8 |
| ***Cibotium chamissoi*** | 4.0 | 6.3 | ***Korthalsella cylindrica*** | 0.8 | 0.8 |
| *Syzygium cumini* | 7.9 | 5.6 | ***Pisonia umbellifera*** | 0.8 | 0.8 |
| *Ageratina adenophora* | 7.1 | 5.6 | *Pluchea carolinensis* | 0.8 | 0.8 |
| ***Euphorbia multiformis*** | 7.1 | 5.6 | ***Pteridium aquilinum*** | 0.8 | 0.8 |
| *Buddleja asiatica* | 6.3 | 5.6 | *Andropogon virginicus* | 0.0 | 0.8 |
| ***Freycinetia arborea*** | 4.8 | 5.6 | *Angiopteris evecta** | 0.0 | 0.8 |
| *Nephrolepis brownii*** | 1.6 | 5.6 | ***Asplenium contiguum*** | 0.0 | 0.8 |
| *Grevillea robusta* | 11.1 | 4.8 | ***Asplenium kaulfussii*** | 0.0 | 0.8 |
| ***Carex meyenii*** | 8.7 | 4.8 | *Coffea arabica*** | 0.0 | 0.8 |
| *Ageratina riparia* | 7.1 | 4.8 | ***Dryopteris sandwicensis*** | 0.0 | 0.8 |
| *Deparia petersenii* | 4.0 | 4.8 | ***Gahnia beecheyi*** | 0.0 | 0.8 |
| *Phlebodium aureum* | 3.2 | 4.8 | *Ipomoea cairica* | 0.0 | 0.8 |
| ***Pisonia brunoniana*** | 1.6 | 4.8 | ***Melicope kaalaensis*** | 0.0 | 0.8 |

**Table 3**, continued.

| Taxon | 2011 | 2017 | Taxon | 2011 | 2017 |
|---|---|---|---|---|---|
| Understory | | | | | |
| *Melinis repens* | 0.0 | 0.8 | ***Diplazium sandwichianum*** | 0.8 | 0.0 |
| ***Pipturus albidus*** | 0.0 | 0.8 | ***Doryopteris decipiens*** | 0.8 | 0.0 |
| ***Pittosporum glabrum*** | 0.0 | 0.8 | ***Elaphoglossum paleaceum*** | 0.8 | 0.0 |
| *Rubus argutus** | 0.0 | 0.8 | *Emilia sonchifolia* | 0.8 | 0.0 |
| ***Selaginella arbuscula*** | 0.0 | 0.8 | *Justicia betonica*** | 0.8 | 0.0 |
| *Youngia japonica* | 3.2 | 0.0 | ***Korthalsella complanata*** | 0.8 | 0.0 |
| ***Psilotum complanatum*** | 2.4 | 0.0 | ***Melicope peduncularis*** | 0.8 | 0.0 |
| ***Asplenium dielfalcatum‡*** | 1.6 | 0.0 | ***Myrsine lanaiensis*** | 0.8 | 0.0 |
| ***Asplenium nidus*** | 1.6 | 0.0 | ***Panicum nephelophilum*** | 0.8 | 0.0 |
| ***Leptecophylla tameiameiae*** | 1.6 | 0.0 | *Schefflera actinophylla*** | 0.8 | 0.0 |
| ***Peperomia tetraphylla*** | 1.6 | 0.0 | ***Smilax melastomifolia*** | 0.8 | 0.0 |
| ***Bobea elatior*** | 0.8 | 0.0 | | | |
| Canopy | | | | | |
| *Psidium cattleianum* | 81.7 | 90.5 | *Montanoa hibiscifolia*** | 1.6 | 2.4 |
| *Schinus terebinthifolius* | 73.0 | 78.6 | *Cordyline fruticosa* | 0.0 | 2.4 |
| ***Metrosideros polymorpha*** | 53.2 | 54.8 | *Melinis minutiflora* | 0.0 | 2.4 |
| ***Alyxia stellata*** | 35.7 | 42.1 | ***Pisonia brunoniana*** | 0.0 | 2.4 |
| *Psidium guajava* | 27.0 | 27.0 | *Polystachya concreta* | 0.0 | 2.4 |
| ***Psydrax odorata*** | 23.8 | 27.0 | ***Bidens torta*** | 3.2 | 1.6 |
| *Grevillea robusta* | 19.8 | 23.8 | ***Gynochthodes trimera*** | 2.4 | 1.6 |
| *Clidemia hirta* | 0.8 | 23.0 | *Lantana camara* | 1.6 | 1.6 |
| ***Coprosma foliosa*** | 14.3 | 17.5 | *Spathodea campanulata*** | 1.6 | 1.6 |
| ***Nestegis sandwicensis*** | 15.9 | 15.1 | ***Pipturus albidus*** | 0.8 | 1.6 |
| ***Acacia koa*** | 12.7 | 15.1 | ***Wikstroemia oahuensis*** **var.** ***oahuensis*** | 0.8 | 1.6 |
| ***Antidesma platyphyllum*** | 13.5 | 14.3 | *Nephrolepis brownii*** | 0.0 | 1.6 |
| ***Psychotria mariniana*** | 11.9 | 14.3 | ***Nephrolepis exaltata*** **subsp.** ***hawaiiensis*** | 0.0 | 1.6 |
| ***Lepisorus thunbergianus*** | 3.2 | 14.3 | ***Psychotria hathewayi*** | 0.0 | 1.6 |
| ***Kadua affinis*** | 12.7 | 13.5 | *Rubus rosifolius* | 0.0 | 1.6 |
| ***Diospyros sandwicensis*** | 11.1 | 11.1 | ***Bobea elatior*** | 1.6 | 0.8 |
| *Syzygium cumini* | 17.5 | 9.5 | ***Korthalsella cylindrica*** | 1.6 | 0.8 |
| ***Planchonella sandwicensis*** | 9.5 | 9.5 | ***Euphorbia multiformis*** | 0.8 | 0.8 |
| ***Diospyros hillebrandii*** | 8.7 | 7.1 | ***Santalum freycinetianum*** **var.** ***freycinetianum*** | 0.8 | 0.8 |
| *Toona ciliata* | 2.4 | 7.1 | ***Scaevola gaudichaudiana*** | 0.8 | 0.8 |
| ***Sapindus oahuensis*** | 8.7 | 6.3 | ***Charpentiera tomentosa*** | 0.0 | 0.8 |
| *Aleurites moluccana* | 7.1 | 5.6 | ***Cyrtandra dentata‡*** | 0.0 | 0.8 |
| ***Cocculus orbiculatus*** | 4.0 | 5.6 | ***Dianella sandwicensis*** | 0.0 | 0.8 |
| ***Xylosma hawaiiense*** | 5.6 | 4.8 | ***Melicope kaalaensis*** | 0.0 | 0.8 |
| ***Myrsine lessertiana*** | 1.6 | 4.8 | ***Melicope oahuensis*** | 0.0 | 0.8 |
| *Buddleja asiatica* | 5.6 | 4.0 | *Passiflora suberosa* | 0.0 | 0.8 |
| *Phlebodium aureum* | 2.4 | 4.0 | ***Psilotum nudum*** | 0.0 | 0.8 |
| *Passiflora edulis* | 1.6 | 4.0 | *Stachytarpheta australis* | 0.0 | 0.8 |
| ***Cibotium chamissoi*** | 0.0 | 4.0 | *Triumfetta semitriloba* | 0.0 | 0.8 |
| ***Hibiscus arnottianus*** **subsp.** ***arnottianus*** | 3.2 | 3.2 | *Urochloa maxima* | 0.0 | 0.8 |
| ***Dodonaea viscosa*** | 1.6 | 3.2 | ***Myrsine lanaiensis*** | 1.6 | 0.0 |
| ***Dicranopteris linearis*** | 0.8 | 3.2 | ***Streblus pendulinus*** | 1.6 | 0.0 |
| ***Elaeocarpus bifidus*** | 3.2 | 2.4 | ***Korthalsella complanata*** | 0.8 | 0.0 |
| ***Pisonia sandwicensis*** | 3.2 | 2.4 | ***Smilax melastomifolia*** | 0.8 | 0.0 |
| ***Freycinetia arborea*** | 1.6 | 2.4 | | | |

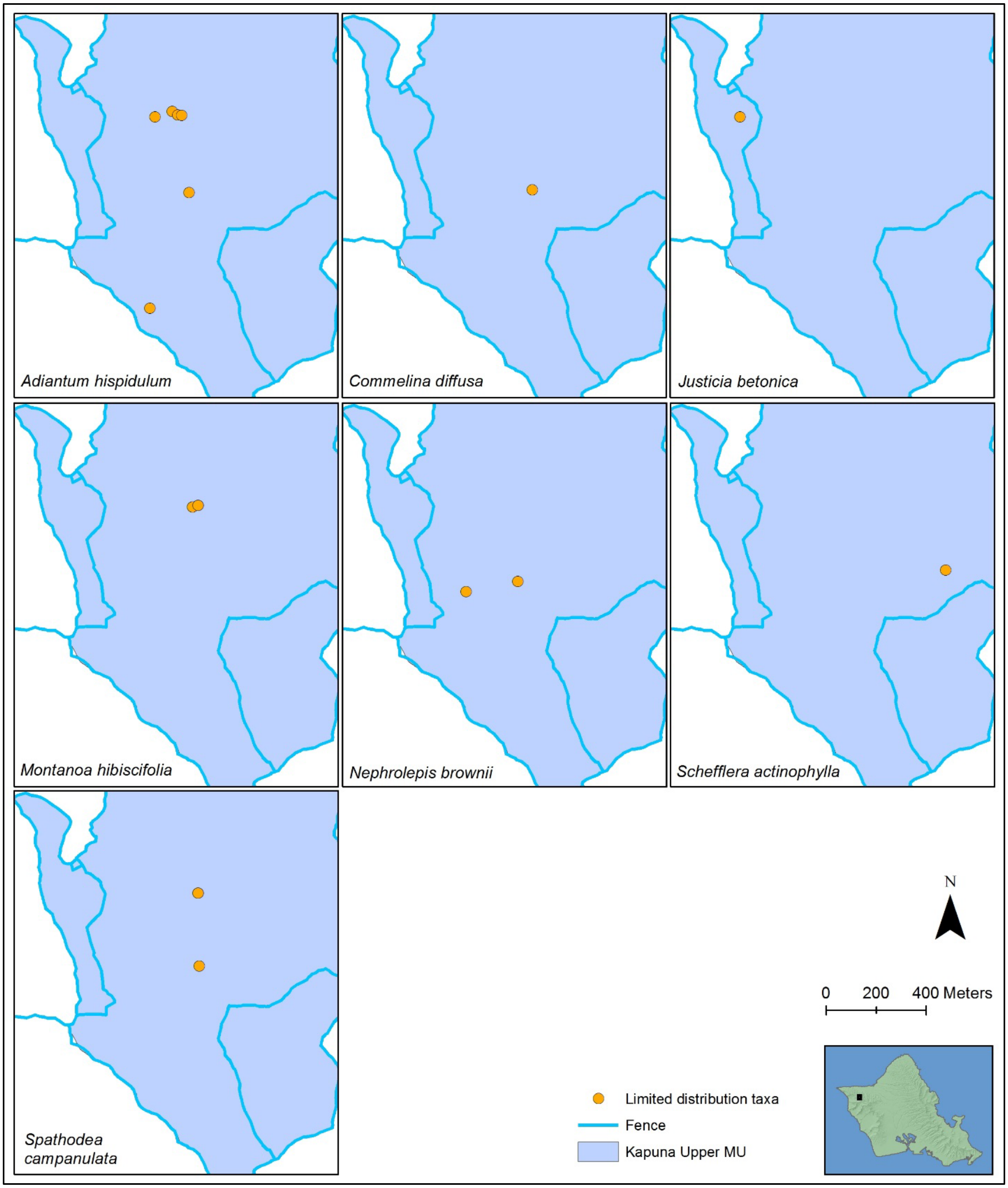



**Figure 7**. Locations of limited distribution target taxa in the understory and/or canopy found in monitoring plots at Kapuna Upper MU in 2011.

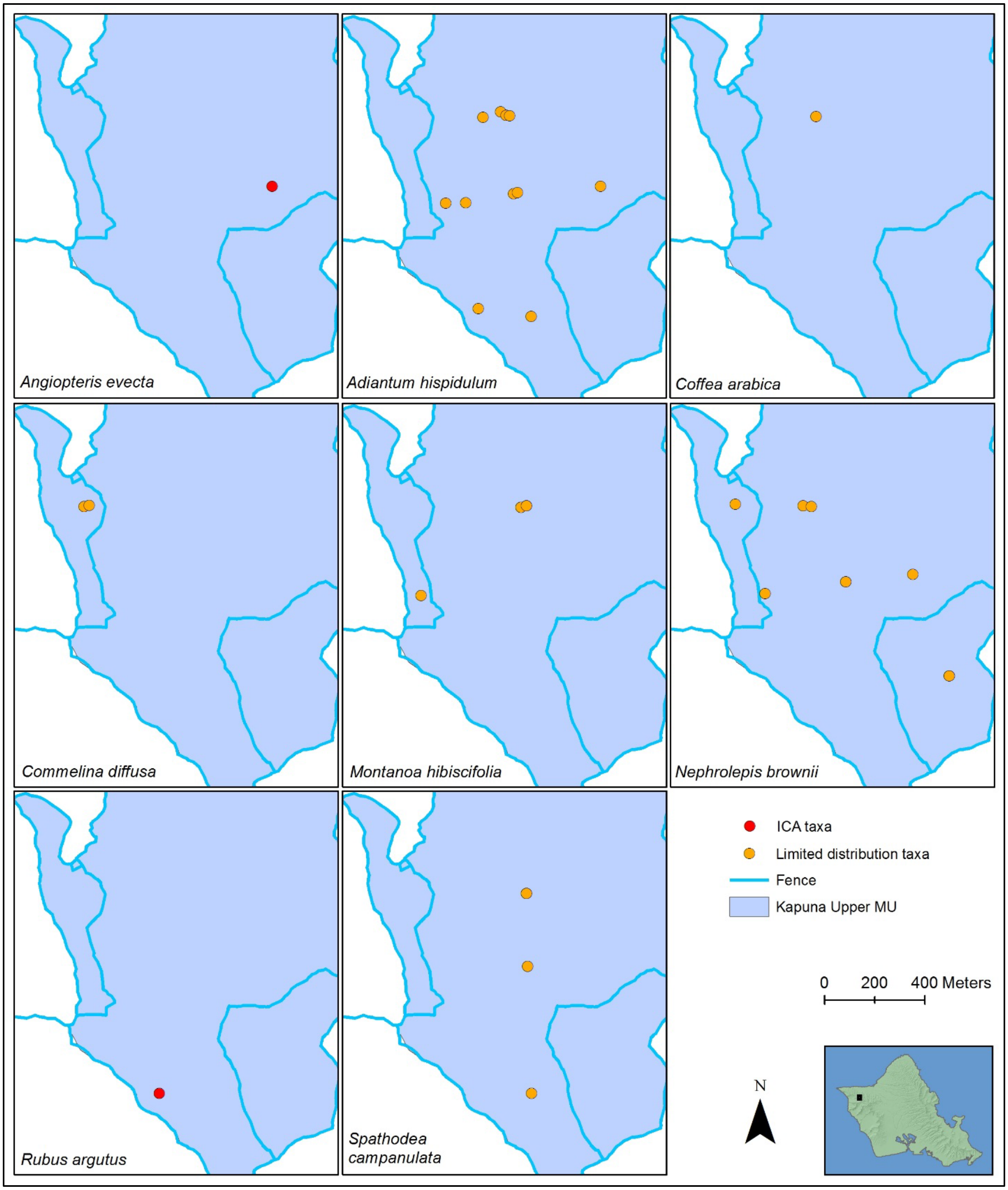



**Figure 8**. Locations of ICA and limited distribution target taxa in the understory and/or canopy found in monitoring plots at Kapuna Upper MU in 2017.

**Table 4.** Newly recorded, and no longer present, species from 2017 Kapuna Upper MU monitoring in the understory and/or canopy. Native taxa are in boldface. Frequency (the proportion of plots in which species are present) values are represented (n = 126). ‡Rare taxa. Target weed taxa: * ICA, **Limited distribution taxa.

| Species not recorded in 2017 but observed in plots previously | Freq. 2011 | New species recorded in plots in 2017 | Freq. 2017 |
|---|---|---|---|
| ***Asplenium dielfalcatum*‡** | 1.6 | *Andropogon virginicus* | 0.8 |
| ***Asplenium nidus*** | 1.6 | *Angiopteris evecta** | 0.8 |
| ***Diplazium sandwichianum*** | 0.8 | ***Asplenium contiguum*** | 0.8 |
| ***Doryopteris decipiens*** | 0.8 | ***Asplenium kaulfussii*** | 0.8 |
| ***Elaphoglossum paleaceum*** | 0.8 | *Coffea arabica*** | 0.8 |
| *Emilia sonchifolia* | 0.8 | ***Dianella sandwicensis*** | 0.8 |
| *Justicia betonica*** | 0.8 | ***Dryopteris sandwicensis*** | 0.8 |
| ***Korthalsella complanata*** | 1.6 | ***Elaphoglossum aemulum*** | 2.4 |
| ***Leptecophylla tameiameiae*** | 1.6 | ***Gahnia beecheyi*** | 0.8 |
| ***Melicope peduncularis*** | 0.8 | *Ipomoea cairica* | 0.8 |
| ***Myrsine lanaiensis*** | 2.4 | ***Melicope kaalaensis*** | 0.8 |
| ***Panicum nephelophilum*** | 0.8 | *Melinis repens* | 0.8 |
| ***Peperomia tetraphylla*** | 1.6 | *Passiflora suberosa* | 4.8 |
| ***Psilotum complanatum*** | 2.4 | ***Pittosporum glabrum*** | 0.8 |
| *Schefflera actinophylla*** | 0.8 | *Polystachya concreta* | 2.4 |
| ***Smilax melastomifolia*** | 0.8 | *Rubus argutus** | 0.8 |
| *Youngia japonica* | 3.2 | ***Selaginella arbuscula*** | 0.8 |

**Table 5.** Species with significant frequency change at Kapuna Upper MU between 2011 and 2017. Only taxa with at least 10% change in frequency were analyzed. Frequency values represent the proportion of plots in which species were present (n = 126). Native species are in boldface. P-values obtained from McNemar's test. Arrows indicate increase (↑) or decrease (↓) in frequency.

| | Freq. 2011 | Freq. 2017 | Freq. change | p | $X^2$ |
|---|---|---|---|---|---|
| Understory | | | | | |
| *Clidemia hirta* | 75.4 | 89.7 | 14.3 | 0.000[a]↑ | 16.056 |
| *Cyclosorus parasiticus* | 26.2 | 38.9 | 12.7 | 0.000[a]↑ | 12.500 |
| Canopy | | | | | |
| *Clidemia hirta* | 0.8 | 23.0 | 22.2 | 0.000[b]↑ | 26.036 |
| ***Lepisorus thunbergianus*** | 3.2 | 14.3 | 11.1 | 0.003[a]↑ | 8.450 |

[a]Exact significance
[b]Asymptotic significance

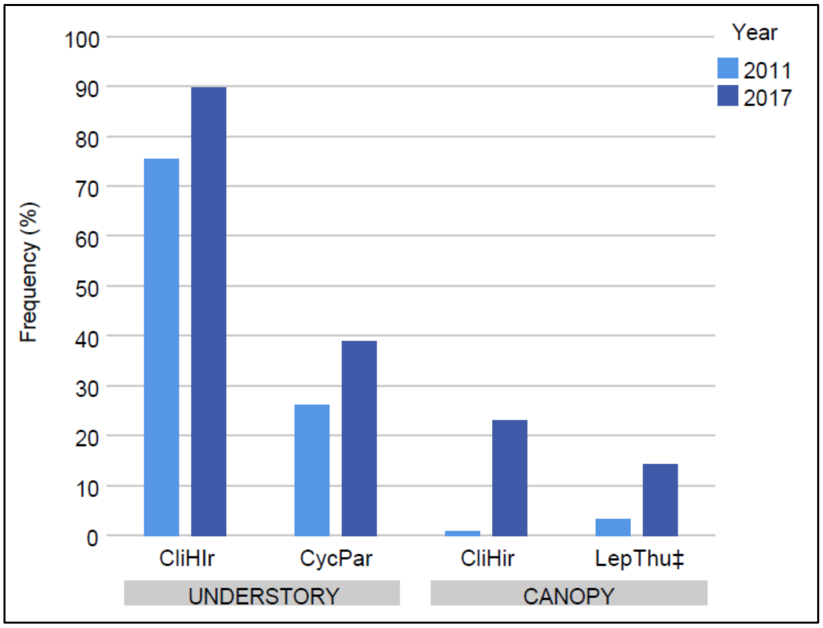



**Figure 9.** Species frequencies at Kapuna Upper MU in 2011 and 2017, among taxa with significant changes over time. Frequency values represent the proportion of plots in which species were present (n=126). ‡Native.

## Species cover

Species with frequencies > 0.20 (present in at least 26 plots) in 2011 and/or 2017 were subjected to analysis of cover change. Significant increases in percent cover occurred for two non-native understory species (*B. appendiculatum* and *C. hirta*), three native canopy species (*A. stellata*, *M. polymorpha,* and *Psydrax odorata*), and four non-native canopy species (*C. hirta*, *Grevillea robusta*, *P. cattleianum* and *S. terebinthifolius*) (Table 6). Significant decreases in percent cover occurred for six native understory taxa (*A. stellata*, *Coprosma foliosa*, *Doodia kunthiana*, *M. polymorpha*, *N. exaltata* subsp. *hawaiiensis*, and *P. odorata*), and four non-native understory species (*Oplismenus hirtellus*, *Paspalum conjugatum*, *P. cattleianum*, and *P. guajava*). However, much of the cover changes noted above were not especially noteworthy, particularly among the native taxa, as differences in cover were predominantly small within plots (≤ 10% absolute change). Notable changes among native taxa included the understory decline for *N. exaltata* subsp. *hawaiiensis.* Noteworthy changes among non-native taxa included the increase in *B. appendiculatum* and *C. hirta* in the understory, and *G. robusta*, *P. cattleianum*, and *S. terebinthifolius* in the canopy, as well as the decrease in *P. cattleianum* in the understory (Figure 10).

**Table 6.** Species with significant cover changes at Kapuna Upper MU from 2011 to 2017. Only species with frequencies > 0.20 (present in > 25 plots) in 2011 or 2017 were analyzed (Wilcoxon signed-rank test, n = 126). Arrows indicate increase (↑) or decrease (↓) in cover. Native taxa are in boldface.

| Understory | p | Z | Canopy | p | Z |
|---|---|---|---|---|---|
| ***Alyxia stellata*** | 0.000↓ | -4.236 | ***Alyxia stellata*** | 0.000↑ | -5.129 |
| *Blechnum appendiculatum* | 0.001↑ | -3.375 | *Clidemia hirta* | 0.000↑ | -4.477 |
| *Clidemia hirta* | 0.000↑ | -4.016 | *Grevillea robusta* | 0.009↑ | -2.601 |
| ***Coprosma foliosa*** | 0.000↓ | -3.729 | ***Metrosideros polymorpha*** | 0.038↑ | -2.079 |
| ***Doodia kunthiana*** | 0.002↓ | -3.127 | *Psidium cattleianum* | 0.000↑ | -6.585 |
| ***Metrosideros polymorpha*** | 0.000↓ | -3.626 | ***Psydrax odorata*** | 0.007↑ | -2.675 |
| ***Nephrolepis exaltata* subsp. *hawaiiensis*** | 0.000↓ | -4.072 | *Schinus terebinthifolius* | 0.000↑ | -4.754 |
| *Oplismenus hirtellus* | 0.004↓ | -2.883 | | | |
| *Paspalum conjugatum* | 0.000↓ | -3.667 | | | |
| *Psidium cattleianum* | 0.000↓ | -3.883 | | | |
| *Psidium guajava* | 0.003↓ | -2.949 | | | |
| ***Psydrax odorata*** | 0.001↓ | -3.248 | | | |

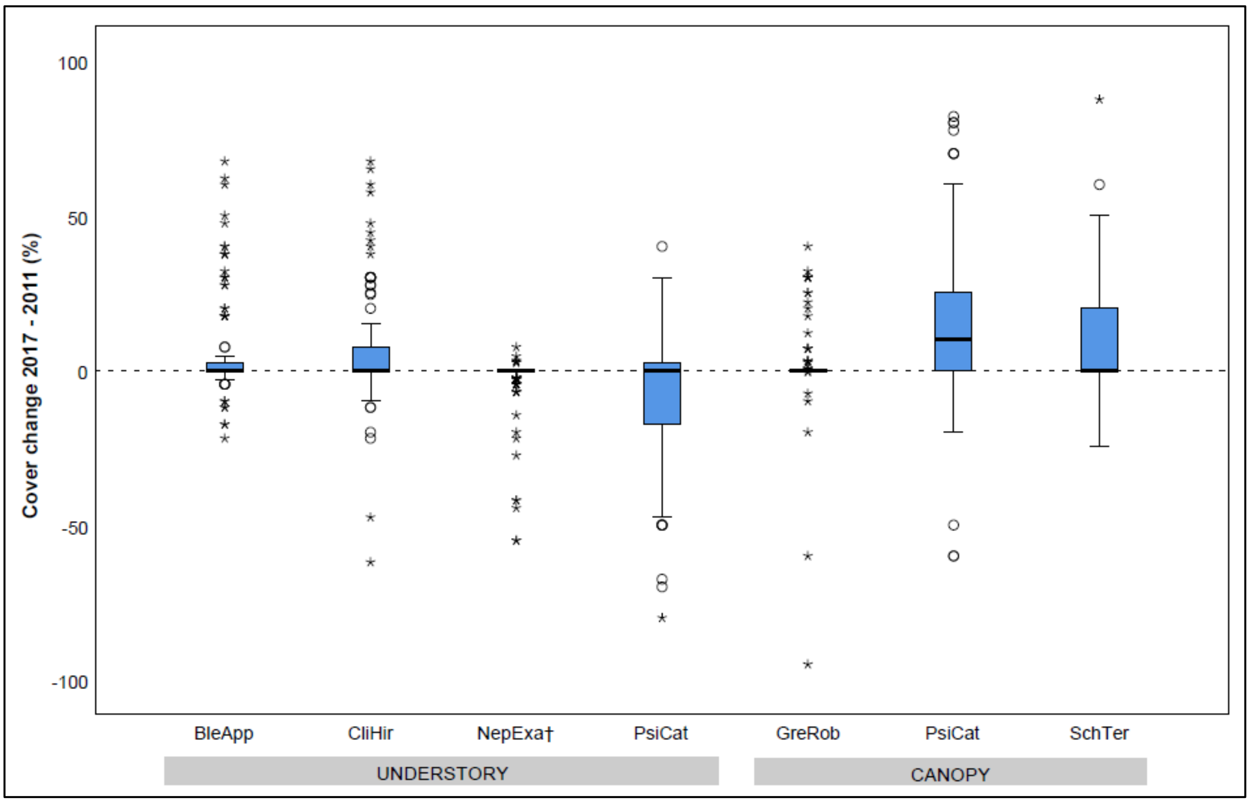


**Figure 10.** Boxplots of cover change among plots for taxa with noteworthy significant differences in percent cover at Kapuna Upper MU. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change. †Native.

## Canopy replacement

Most canopy tree species were found recruiting in the understory, with 28 species observed in each year (71% native taxa in 2011, and 68% native taxa in 2017), and 33 species recorded in at least one of those years (Table 7). Non-native recruiting tree species were primarily *P. cattleianum* and *S. terebinthifolius,* while *Kadua affinis* and *Psydrax odorata* were the most commonly recruiting native tree species. Native trees with no recruitment in the understory in either year were also relatively infrequent in the canopy (with frequencies < 4%), including *Bobea elatior, Elaeocarpus bifidus, Gynochthodes* *trimera, Hibiscus arnottianus* subsp. *arnottianus, Psychotria hathewayi,* and *S. freycinetianum* var. *freycinetianum*. It should be noted that the age of saplings may vary greatly, from less than one year to decades, in accordance with differing species, and individual growth rates and conditions, complicating interpretations of presence/absence and change over time with respect to concerns over long term canopy replacement. Taxa with at least 10% change in frequency between 2011 and 2017 were subjected to analysis. This included a single non-native taxon, *P. cattleianum*, which had a significant increase in recruitment frequency among plots (McNemar's test: $p = 0.000$, $X^2 = 15.848$, asymptotic significance).

**Table 7.** Tree species recruitment frequency at Kapuna Upper MU in 2011 and 2017, in order of most to least frequent in 2017. Frequency values represent the proportion of plots in which recruitment occurred (n = 126). Native species are in boldface. **Limited distribution target taxa.

| Species | 2011 | 2017 | Species | 2011 | 2017 |
|---|---|---|---|---|---|
| *Psidium cattleianum* | 55.6 | 77.8 | ***Melicope oahuensis*** | 2.4 | 0.8 |
| *Schinus terebinthifolius* | 18.3 | 23.8 | ***Streblus pendulinus*** | 1.6 | 0.8 |
| ***Kadua affinis*** | 8.7 | 14.3 | ***Myrsine lessertiana*** | 0.8 | 0.8 |
| ***Psydrax odorata*** | 15.1 | 12.7 | *Syzygium cumini* | 0.8 | 0.8 |
| *Psidium guajava* | 6.3 | 10.3 | *Coffea arabica*** | 0.0 | 0.8 |
| ***Metrosideros polymorpha*** | 7.9 | 7.9 | ***Melicope kaalaensis*** | 0.0 | 0.8 |
| ***Psychotria mariniana*** | 7.9 | 7.9 | ***Pipturus albidus*** | 0.0 | 0.8 |
| ***Acacia koa*** | 5.6 | 7.1 | ***Pittosporum glabrum*** | 0.0 | 0.8 |
| ***Antidesma platyphyllum*** | 5.6 | 7.1 | ***Pisonia sandwicensis*** | 2.4 | 0.0 |
| ***Diospyros hillebrandii*** | 6.3 | 6.3 | ***Dodonaea viscosa*** | 0.8 | 0.0 |
| ***Diospyros sandwicensis*** | 4.8 | 5.6 | ***Myrsine lanaiensis*** | 0.8 | 0.0 |
| ***Sapindus oahuensis*** | 1.6 | 5.6 | ***Pisonia umbellifera*** | 0.8 | 0.0 |
| ***Pisonia brunoniana*** | 1.6 | 4.0 | *Schefflera actinophylla*** | 0.8 | 0.0 |
| ***Planchonella sandwicensis*** | 1.6 | 4.0 | ***Bobea elatior*** | 0.0 | 0.0 |
| *Grevillea robusta* | 5.6 | 3.2 | ***Elaeocarpus bifidus*** | 0.0 | 0.0 |
| ***Xylosma hawaiiense*** | 1.6 | 2.4 | ***Gynochthodes trimera*** | 0.0 | 0.0 |
| *Aleurites moluccana* | 0.0 | 2.4 | ***Hibiscus arnottianus* subsp. *arnottianus*** | 0.0 | 0.0 |
| *Toona ciliata* | 4.8 | 1.6 | *Montanoa hibiscifolia*** | 0.0 | 0.0 |
| *Spathodea campanulata*** | 0.8 | 1.6 | ***Psychotria hathewayi*** | 0.0 | 0.0 |
| ***Nestegis sandwicensis*** | 3.2 | 0.8 | ***Santalum freycinetianum* var. *freycinetianum*** | 0.0 | 0.0 |

## Weed control

OANRP general ecosystem weed control efforts at Kapuna Upper MU between the 2011 and 2017 monitoring intervals included approximately 674 person hours. The total amount of effort varied among the fifteen weed control areas (WCA) that encompass the MU, ranging from 0 to 206 hours per WCA. At least a small amount of weeding occurred at all but 3 WCAs during that time interval. Between the 2011 and 2017 monitoring intervals, 3% of the MU was weeded for general ecosystem weeding, and 11% of the MU for ICA weeding (all single species sweeps, primarily for *A. evecta*) (Figure 11). General ecosystem weed control efforts (WCA efforts) by OANRP crossed through 2% of the plots, while ICA control efforts crossed through 10% of the plots, between the 2011 and 2017 monitoring intervals. Additional weed control has also been conducted by the Natural Area Reserve System (NARS) primarily within Native Ecosystems Protection and Management (NEPM) zones at Kapuna Upper MU. Given the limited amount of weeding that occurred by OANRP, and the lack of complete GIS data for areas weeded by the NARS program, analysis was not conducted of cover change in plots for weeded vs. non-weeded areas to discern the impacts of weed control on the native and non-native understory and canopy.

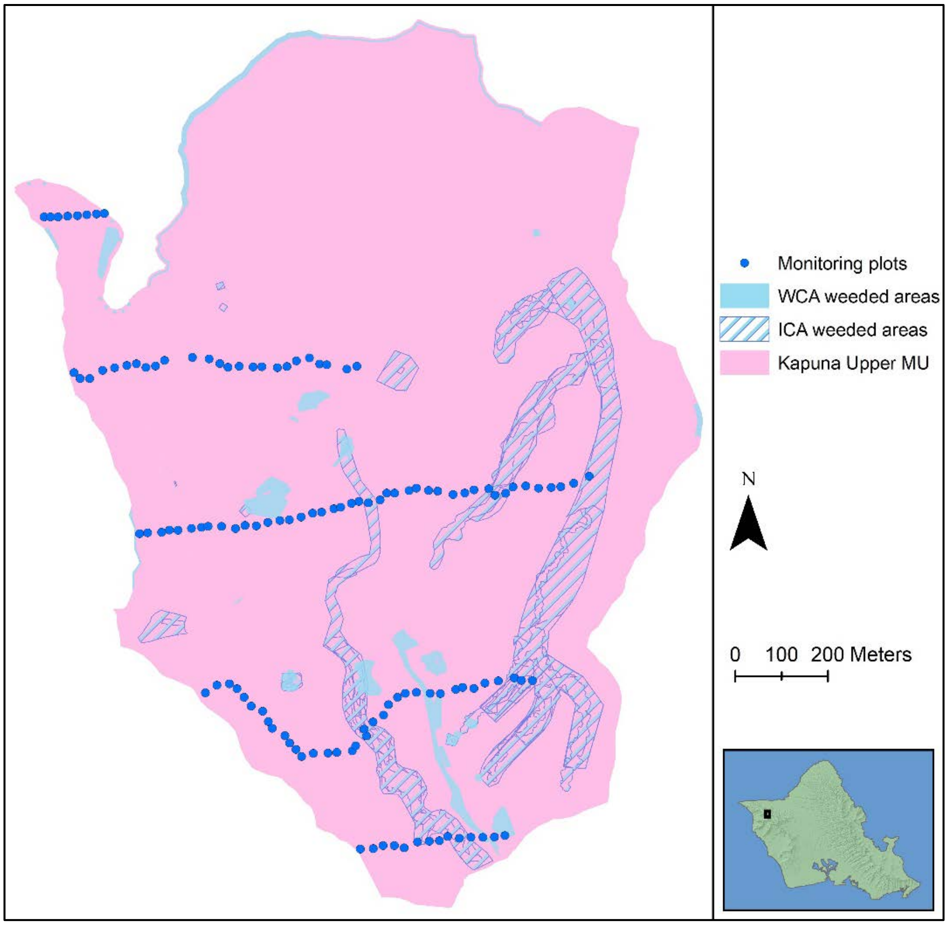



**Figure 11.** Locations of vegetation monitoring plots at Kapuna Upper MU in relation to areas weeded between the 2011 and 2017 monitoring intervals.

## Native ecosystem restoration efforts

Kapuna Upper MU has not been prioritized for native ecosystem restoration by OANRP, as efforts there are focused on rare plant stabilization, ecosystem weed control primarily in the vicinity of rare plants, and ungulate control. However, NARS conducts limited restoration efforts within the NEPM zones in the MU (Figure 12). As such, no analyses of influences of restoration efforts on MU-scale vegetation has been done.

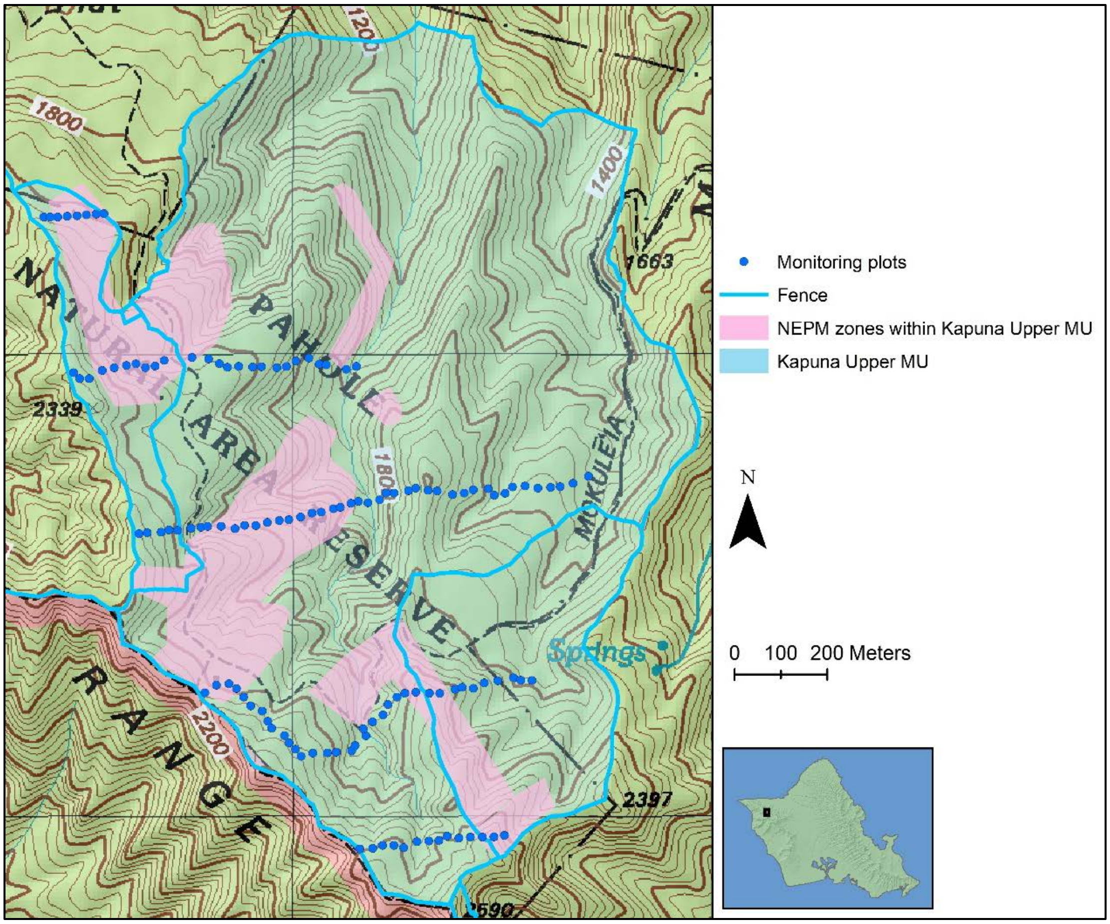


**Figure 12**. Location of NEPM zones in relation to monitoring plots.

## SUMMARY AND DISCUSSION

Management objectives were not met for percent cover of native and non-native understory and canopy for Kapuna Upper MU. However, the extent to which management objectives are applicable to this MU are debatable, as the habitat is heavily degraded, and weed control and restoration efforts are limited. There were a number of significant differences in the 2017 data as compared with six years prior, many of which were relatively small. It should be noted that the analyses involved numerous statistical tests, and it is possible that some of these could have erroneous results (significance is either false or missed). Human error may affect the data, as it is visually based and contingent upon identification skills. The most noteworthy changes included:

- **Categorical cover**
  - <u>Increased</u>
    - Native canopy
    - Non-native canopy
- **Richness**
  - <u>Increased</u>
    - Non-native canopy
- **Frequency**
  - <u>Increased</u>
    - Non-native understory

        - *C. parasiticus*
        - *C. hirta*
    - Non-native canopy
        - *C. hirta*

- **Species cover**
    - Increased:
        - Non-native understory
            - *B. appendiculatum*
            - *C. hirta*
        - Non-native canopy
            - *G. robusta*
            - *P. cattleianum*
            - *S. terebinthifolius*
    - Decreased:
        - Native understory
            - *N. exaltata* subsp. *hawaiiensis*
        - Non-native understory
            - *P. cattleianum*

Aside from the increase in native canopy cover, changes generally reflect worsening conditions, particularly for non-native components. *Clidemia hirta*, already prevalent in the understory in 2011, was present in nearly all plots in 2017, and has grown into the canopy layer in a quarter of the plots. Similarly, non-native canopy cover, already prevalent in 2011, now predominates, as the two most prevalent canopy taxa for the MU, *P. cattleianum* and *S. terebinthifolius*, expanded in cover, and had the most prevalent recruitment by far in comparison with other species. The new appearance of *P. suberosa* in 2017 in several plots is discouraging, as it is considered a high risk weed species (WRA score = 12) due to its ecosystem altering characteristics, as this aggressive bird dispersed weed has the capacity of smothering vegetation (Hawaii-Pacific Weed Risk Assessment 2009). The presence of *A. evecta* in a plot within an existing ICA in 2017 was not surprising or alarming, as ICAs for this taxon are expansive throughout many of the gulches in the MU, with continual recruitment from the residual spore bank that is relatively easy to control. However, the discovery of a new expansive *R. argutus* ICA with numerous plants along a vegetation monitoring transect in 2017 was particularly disheartening, given its rapid growth within six years or less, and as the monitoring transects traverse only a small portion of the MU, it is possible that other unknown emergent populations occur. Further problematic is the presence of ungulates that has occurred variously within the MU, including during both monitoring intervals in 2011 and 2017 (Figure 13), resulting in ground disturbance and the possible spread of weeds.

**Figure 13.** Fresh pig tracks and disturbance observed near a vegetation monitoring plot at Kapuna Upper MU in 2017.

## RECOMMENDATIONS

Based on the results of vegetation monitoring, a number of recommendations were made with the goal of making progress towards meeting management objectives, to be discussed and coordinated with the NARS program:

- Take a more proactive approach to ungulate control
- Add *P. suberosa* to the limited distribution target taxa weed list for Kapuna
- Consider expanding general ecosystem weeding in native dominated and/or recoverable mixed native/non-native areas, particularly in the vicinity of rare plants, to facilitate recovery/expansion of native vegetation
- Consider targeted non-native canopy control by the Ecosystem Restoration crew in recoverable mixed native/non-native areas
- Consider native plant restoration using common taxa via outplanting, seed sowing, and transplanting, to augment recovery/expansion of native vegetation in weeded areas
- Consider initiating volunteer weeding project areas with the Outreach Program in easily accessible and less ecologically sensitive locations in the vicinity of the contour trail
- Consider *R. argutus* management needs regarding locating and controlling incipient populations
- Consider IPA sweeps either throughout the MU or in specific areas for low frequency canopy weeds *G. robusta*, *T. ciliata* (mature trees), *S. campanulata*, *S. actinophylla*, *M. hibiscifolia*, and *S. cumini*
- Consider revisions of WCA boundaries to create more useful divisions within the MU
- Meet with NEPM to discuss monitoring results and determine how to address these results together

## REFERENCES

Hawaii-Pacific Weed Risk Assessment. 2009. *Passiflora suberosa*. www.hpwra.org [Accessed December 2017].

Oahu Army Natural Resource Program. 2008. Appendix 2.0 MIP/OIP Belt Plot Sampling Monitoring Protocol *in* 2008 Status Report for the Makua Implementation Plan. http://manoa.hawaii.edu/hpicesu/DPW/2008_YER/008.pdf.

ARMY NATURAL RESOURCE PROGRAM – OAHU (OANRP)
MONITORING PROGRAM

# PALIKEA MANAGEMENT UNIT VEGETATION MONITORING, 2017

## INTRODUCTION

Vegetation monitoring was conducted at Palikea Management Unit (MU) in 2017 in association with Implementation Plan (IP) requirements for long term monitoring of vegetation composition and change over time (OANRP 2008) (Figure 1 and 2). The primary objective of MU monitoring is to assess if the percent cover of non-native plant species is less than 50% across the MU, or is decreasing towards that threshold requirement. The secondary objective is to assess if native cover is greater than 50% across the MU, or is increasing towards that threshold recommendation. Palikea MU vegetation monitoring occurs on a on a three-year interval and took place previously in 2008, 2011 and 2014 (OANRP 2009, 2011 and 2014). Previous monitoring indicated that cover goals were met for only the non-native understory. The MU fence was completed in 2008.

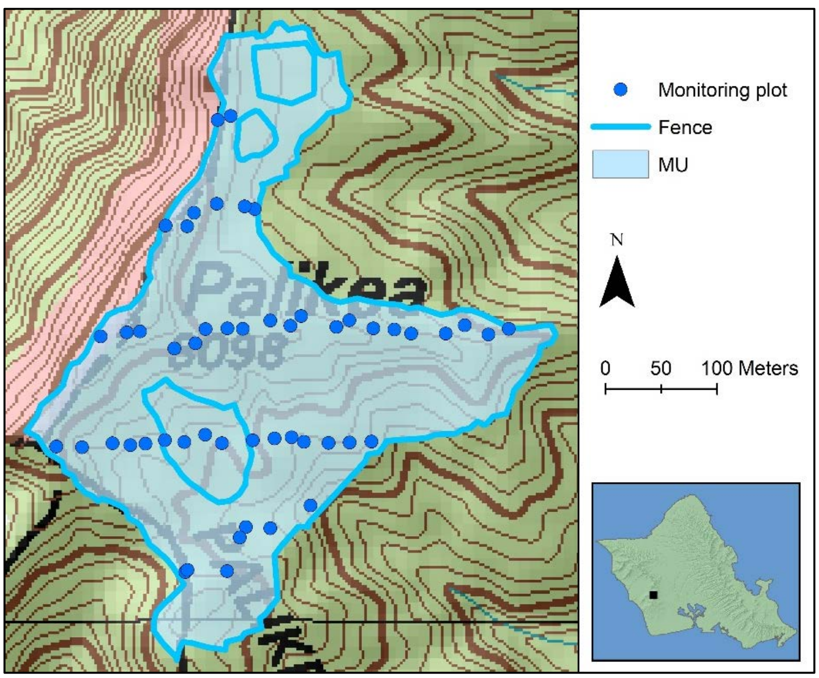



**Figure 1.** Palikea MU vegetation monitoring plot locations.

## METHODS

In June of 2017, 51 plots along five transects were monitored. Plots measuring 5 x 10 m were generally located every 20 m along transects. Transects were spaced approximately 100 m apart. These same plots were also monitored in 2008 (OANRP 2009), 2011 (OANRP 2011), and 2014 (OANRP 2014). Additional plots were monitored in 2008 and 2011, but were not monitored in 2014 or 2017 due to a lack of sampling independence. Understory (0 – 2 m above ground level (AGL), including low branches from canopy species) and canopy (> 2 m AGL, including epiphytes) vegetation was recorded by percent cover for all non-native and native species present. Summary percent cover by vegetation type (shrub, fern, grass/sedge) in the understory, overall summary percent cover of non-native and native vegetation in the understory and canopy, and bare ground (non-vegetated < 25 cm AGL), were also documented. Percent cover categories were recorded in 10% intervals between 10 and 100%, and on finer intervals (0-1%, 1-5%, and 5-10%) between 0 and 10% cover. Understory recruitment (defined as seedlings or saplings < 2 m AGL) data for tree species was recorded in 2014 and 2017, but was not recorded previously. Monitoring results were compared with data from prior years. Canopy percent cover results for 2008 were based on different measurement parameters, and were not comparable with data thereafter. *Youngia japonica* and *Lepisorus thunbergianus* were not recorded consistently in 2008, and data for these species from that year were not included in the analysis. Inconsistencies with recruitment data collection precluded meaningful statistical analyses. Palikea MU boundaries expanded in 2017, and reporting of weed control efforts in relation to monitoring data was based on the current expanded boundary. Based on IP recommendations, p-values < 0.05 were considered significant, and only absolute cover changes ≥ 10% were recognized. Additional methodology information is detailed in Monitoring Protocol 1.2.1 (OANRP 2008). All analyses were performed in IBM SPSS Statistics Version 24. These included Friedman's tests with Bonferroni adjusted post-hoc pairwise comparisons for cover and richness data, McNemar's tests for frequency data, and generalized linear modeling for influence of weed control as well as the influence of non-native cover change on native cover.

**Figure 2**. OANRP staff members Scott Heintzman and Deena Gary collecting field data at a vegetation monitoring plot at Palikea.

## RESULTS

### Understory and canopy cover categories

Management objectives of having < 50% non-native understory and canopy and > 50% native understory and canopy cover were met for the non-native understory (35% median value) and canopy (25% median value) in 2017 (Table 1). Native understory and canopy cover was low (35% and 25% median values, respectively). There were significant changes in percent cover of vegetation from previous monitoring results that met the 10% standard for recognized change in cover. These included decreases in cover for non-native canopy and total canopy, as well as an increase in native canopy (Figure 3). In 2017, locations of low to high native and non-native understory and canopy percent cover were patchily distributed across the MU (Figure 4), as were locations where cover changes occurred (Figure 5). Most notable among cover changes were sizable declines (> 80%) in non-native canopy cover for some plots.

**Table 1.** Median percent cover of native and non-native vegetation categories in the canopy and understory at Palikea MU from 2008 to 2017 (n = 51). Categories specifically addressed in IP management objectives are highlighted in blue. Statistically significant values for categories that meet the 10% standard for recognized change in cover are in boldface. Arrows indicate increase (↑) or decrease (↓) in cover.

| | 2008 | 2011 | 2014 | 2017 | p* | $X^2$ | Years that differed significantly | p (post-hoc)** | Management objective currently met? |
|---|---|---|---|---|---|---|---|---|---|
| ***Understory*** | | | | | | | | | |
| Native shrubs | 7.5 | 7.5 | 15 | 15 | 0.196 | 4.686 | | | |
| Native ferns | 25 | 35 | 25 | 25 | 0.052 | 7.715 | | | |
| Native grass/sedges | 0 | 0 | 0 | 0 | 0.423 | 2.800 | | | |
| Total native understory | 35 | 45 | 35 | 35 | 0.165 | 5.099 | | | No |
| Non-native shrubs | 15 | 25 | 15 | 15 | 0.534 | 2.189 | | | |
| Non-native ferns | 0.5 | 0.5 | 0.5 | 0.5 | 0.019↑ | 9.996 | N/A | | |
| Non-native grass/sedges | 0.5 | 0.5 | 0.5 | 0.5 | 0.328 | 3.443 | | | |
| Total non-native understory | 35 | 35 | 35 | 35 | 0.452 | 2.632 | | | Yes |
| Bare ground | 25 | 25 | 15 | 15 | 0.078 | 6.813 | | | |
| ***Canopy*** | | | | | | | | | |
| Native canopy | N/A | 15 | 25 | 25 | **0.004↑** | 11.143 | 2011-2017 | 0.014 | No |
| Non-native canopy | N/A | 55 | 55 | 25 | **0.000↓** | 18.654 | 2014-2017 | 0.000 | Yes |
| Total canopy | N/A | 85 | 95 | 75 | **0.014↓** | 8.522 | N/A | | |

*from Friedman's test, asymptotic significance

**from post-hoc pairwise comparisons with Bonferroni adjustment

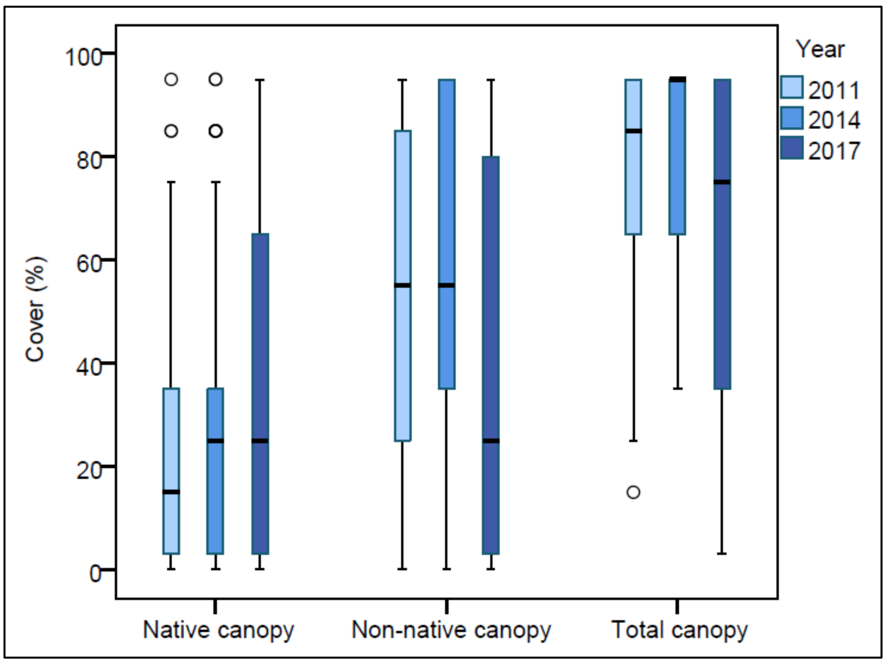



**Figure 3.** Boxplots for vegetation categories with significant change in percent cover that meet 10% standard for recognized change in cover between years 2011 and 2017 in Palikea MU. [*Note: The boxes depict 50% of the data values, and the horizontal line inside the box represents the median value. Very high or low values relative to the shaded box are indicated by circles (1.5 to 3 times the length of the shaded box) and asterisks (> 3 times the length of the shaded box), while the lines extending above and below the shaded box depict the range in values for all remaining data. Circles and asterisks that appear to be in boldface indicate multiple data points for the same values.*]

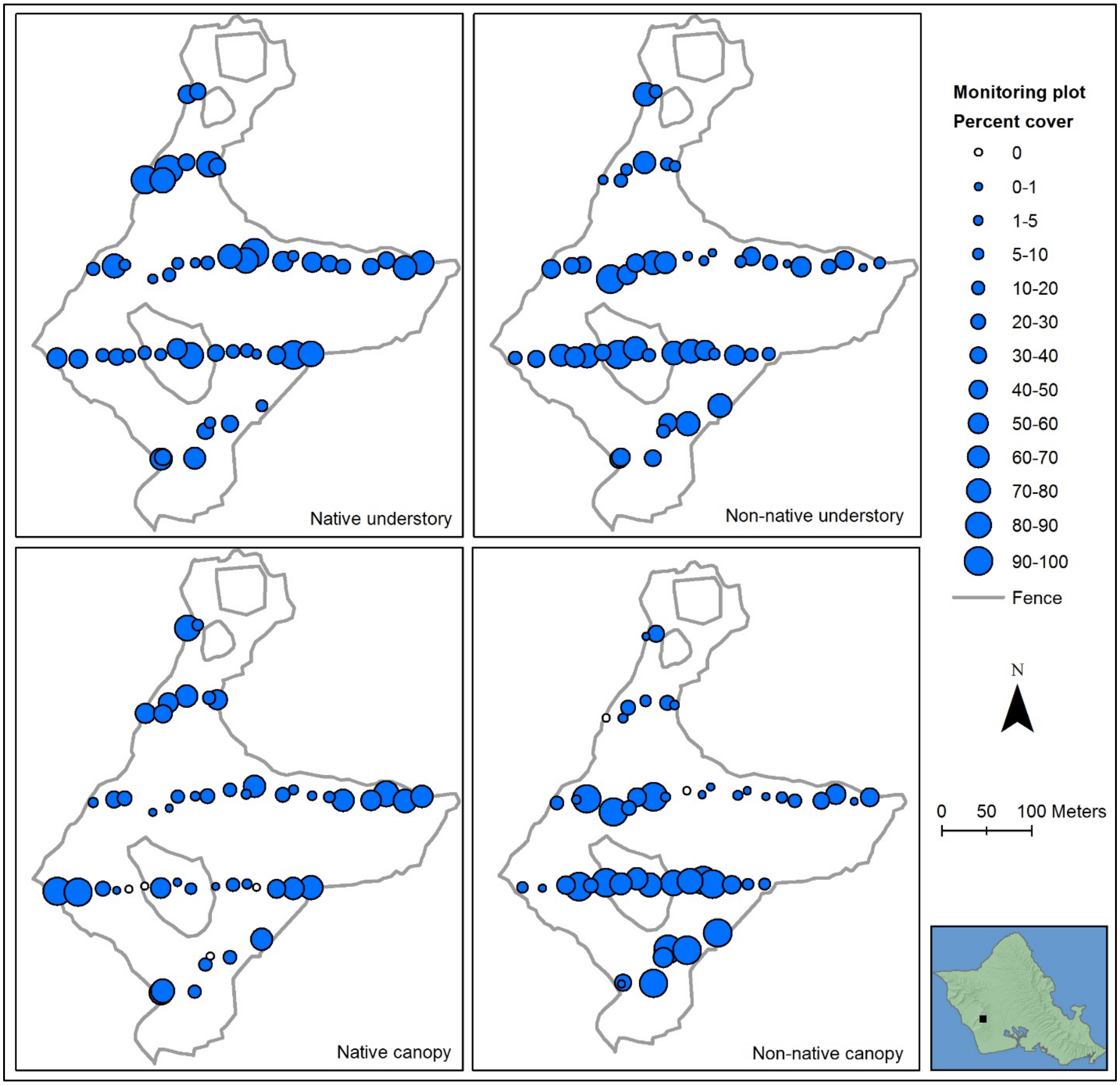



**Figure 4.** Locations of low to high percent cover of native and non-native understory and canopy vegetation among monitored plots at Palikea MU in 2017. Larger circles denote higher percent cover, while smaller circles represent lower cover.

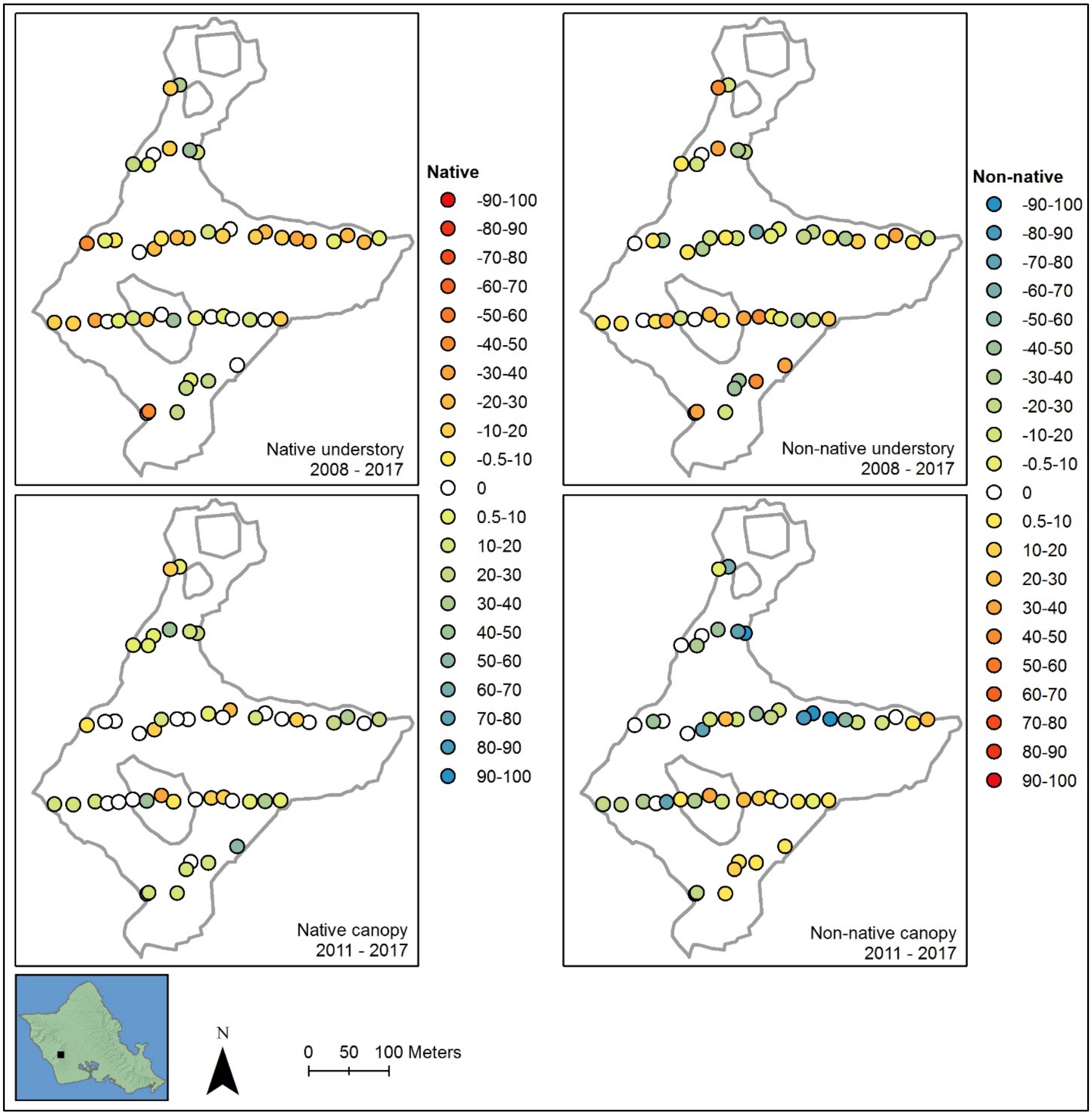



**Figure 5.** Locations of change in native and non-native percent cover for the understory and canopy vegetation in monitored plots in Palikea MU between 2008 and 2017 in the understory, and between 2011 and 2017 in the canopy. Color gradients are inverted for native and non-native vegetation, such that blue indicates beneficial change, red depicts worsening conditions. Cover change of 0 indicates there was no change in percent cover.

## Species richness

During monitoring in 2017, 138 species were recorded in the understory (72% native taxa), and 52 were identified in the canopy (77% native). All species present in the canopy were also represented in the understory, with the exception of one native species (*Sadleria pallida*). Locations of high and low species richness for the native and non-native understory and canopy were patchily distributed across the MU (Figure 6). The highest diversity occurred within the native understory, with 100 taxa documented for the MU, and up to 24 species in a single plot. The non-native canopy was the least diverse, with only

12 taxa across the MU, and no more than 5 species in a single plot. Species richness within plots differed significantly between the years monitored, with a small increase in native understory between 2008 and 2014, as well as a small decrease in native understory between 2014 and 2017 (Table 2). Slight differences among years in overall diversity for the MU were not noteworthy. Ten newly recorded species (80% native), including three rare taxa (*Cyanea membranacea*, *Cyanea superba* subsp. *superba*, and *Silene perlmanii*) were found in plots in 2017, while 24 species (71% native) were recorded in previous years but not observed in 2017 (Table 3). Aside from the direct or indirect result of management actions, the presence or absence of species may be due in part to human error such as misidentification, observer bias regarding plot boundaries or amount of time spent searching, or accidental non-recording. All of the species that were not present in 2017 were uncommon in prior years, with frequencies less than 8%. Similarly, species newly recorded in 2017 had frequencies less than 8%.

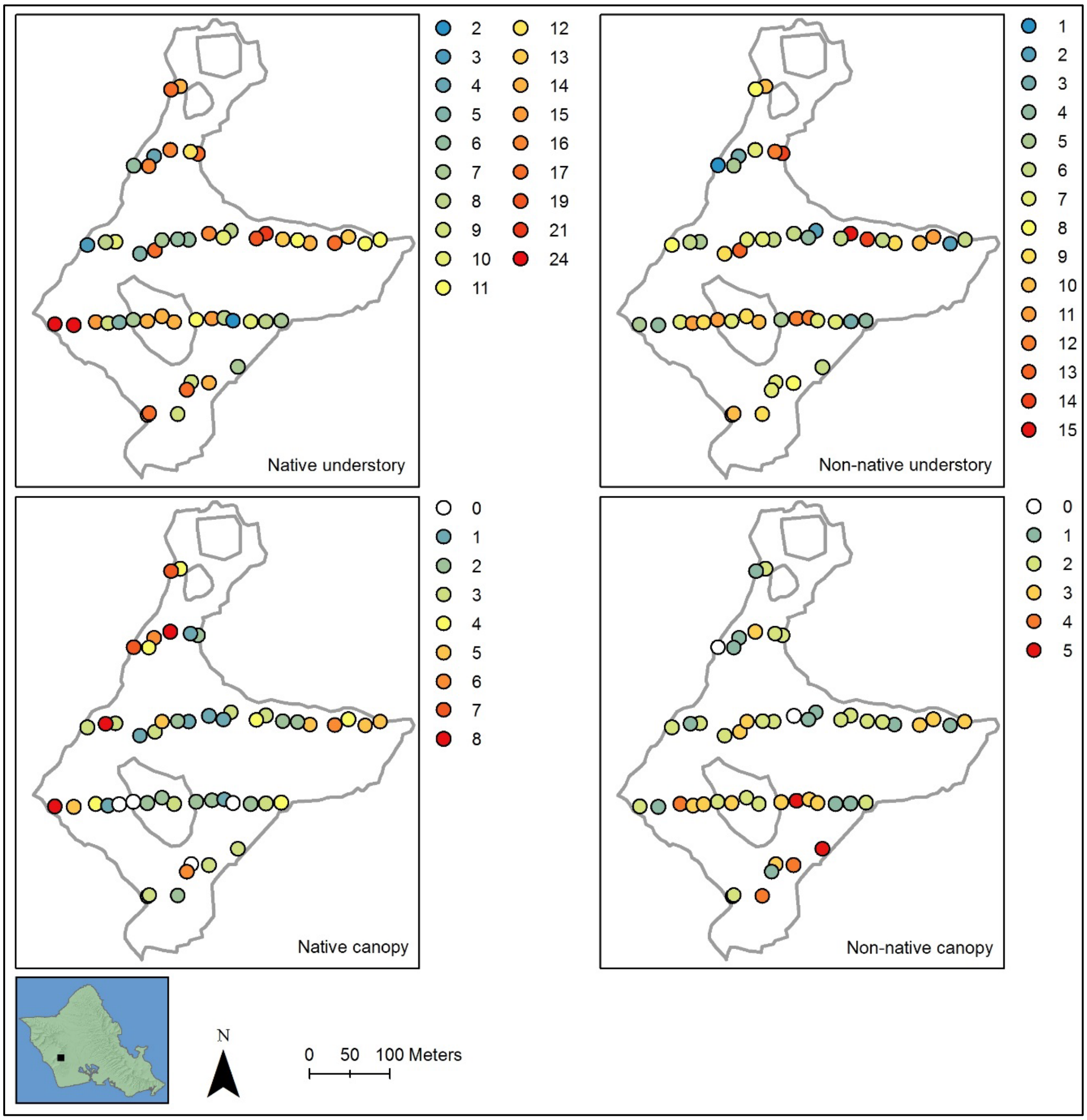



**Figure 6.** Locations of low to high species richness among plots in the native and non-native understory and canopy in Palikea MU in 2017. Color gradients of blue to red indicate low to high values, respectively, of the number of species occurring in plots (i.e., blue indicates low diversity, while red indicates relatively higher diversity).

**Table 2**. Palikea MU understory and canopy species richness from 2008 to 2017. Median species richness per plot during vegetation monitoring is shown by year, with the total number of species recorded among all plots in parentheses (n = 51). Statistically significant values are in boldface. Arrows indicate increase (↑) or decrease (↓) in richness.

| | 2008 | 2011 | 2014 | 2017 | p* | $X^2$ | Years with significant differences | p (post-hoc)** |
|---|---|---|---|---|---|---|---|---|
| Native understory | 13 (99) | 13 (98) | 14 (96) | 11 (100) | **0.010** | 11.346 | 2008-2014<br>2014-2017 | 0.013↑<br>0.009↓ |
| Non-native understory | 7 (36) | 7 (35) | 8 (34) | 7 (38) | 0.199 | 4.649 | | |
| Native canopy | 2 (35) | 3 (39) | 3 (35) | 3 (40) | 0.119 | 5.860 | | |
| Non-native canopy | 2 (9) | 2 (9) | 2 (10) | 2 (12) | 0.554 | 2.091 | | |

*from Friedman's test, asymptotic significance
**from post-hoc pairwise comparisons with Bonferroni adjustment

**Table 3.** Taxa no longer present, and newly recorded, from 2017 Palikea MU monitoring in the understory and/or canopy. Native taxa are in boldface. Frequency (the proportion of plots in which species are present) values are represented (n = 51). ‡Rare taxa. **Limited distribution target weed taxa.

| Species not recorded in 2017 but observed in plots previously | 2008 | 2011 | 2014 | New species recorded in plots in 2017 | 2017 |
|---|---|---|---|---|---|
| *Araucaria columnaris*** | 2.0 | 0.0 | 0.0 | ***Asplenium nidus*** | 2.0 |
| ***Asplenium unilaterale*** | 0.0 | 2.0 | 0.0 | ***Asplenium polyodon*** | 2.0 |
| ***Canavalia galeata*** | 2.0 | 2.0 | 0.0 | ***Clermontia persicifolia*** | 2.0 |
| ***Cibotium glaucum*** | 0.0 | 2.0 | 0.0 | ***Cyanea membranacea*‡** | 2.0 |
| ***Dryopteris wallichiana*** | 2.0 | 0.0 | 0.0 | ***Cyanea superba* subsp. *superba*‡** | 2.0 |
| ***Dubautia laxa*** | 7.8 | 0.0 | 0.0 | *Passiflora edulis* | 2.0 |
| ***Elaeocarpus bifidus*** | 3.9 | 2.0 | 0.0 | ***Pisonia sandwicensis*** | 3.9 |
| *Eleocharis radicans* | 2.0 | 0.0 | 0.0 | ***Sadleria pallida*** | 2.0 |
| *Emilia sonchifolia* | 0.0 | 0.0 | 2.0 | ***Silene perlmanii*‡** | 2.0 |
| ***Gahnia beecheyi*** | 5.9 | 0.0 | 2.0 | *Solanum americanum* | 7.8 |
| ***Korthalsella cylindrica*** | 0.0 | 0.0 | 3.9 | | |
| ***Myoporum sandwicense*** | 2.0 | 0.0 | 0.0 | | |
| ***Nothocestrum longifolium*** | 2.0 | 2.0 | 2.0 | | |
| ***Peperomia sandwicensis*** | 2.0 | 2.0 | 0.0 | | |
| ***Peperomia* sp.** | 0.0 | 0.0 | 2.0 | | |
| *Phyllanthus tenellus* | 2.0 | 0.0 | 0.0 | | |
| *Physalis peruviana* | 0.0 | 2.0 | 2.0 | | |
| ***Polyscias oahuensis*** | 0.0 | 2.0 | 0.0 | | |
| ***Psilotum nudum*** | 5.9 | 3.9 | 0.0 | | |
| ***Scaevola mollis*** | 0.0 | 2.0 | 0.0 | | |
| *Schefflera actinophylla*** | 3.9 | 2.0 | 0.0 | | |
| *Solanum americanum* | 0.0 | 0.0 | 2.0 | | |
| ***Syzygium sandwicense*** | 2.0 | 2.0 | 0.0 | | |
| ***Vaccinium reticulatum*** | 2.0 | 7.8 | 0.0 | | |

## Species frequency

Non-native species that occurred most frequently in plots (present in more than half the plots) in the understory included *Clidemia hirta*, *Rubus rosifolius*, *Psidium cattleianum*, *Passiflora suberosa*, *Cyclosorus parasiticus*, and *Blechnum appendiculatum*, while *Schinus terebinthifolius* occurred most commonly in the canopy (Table 4). The most frequent native understory species (in at least a third of the plots) included *Kadua affinis*, *Dicranopteris linearis*, *Asplenium macraei*, *Metrosideros polymorpha*, *Cibotium chamissoi*, *Microlepia strigosa*, *Dianella sandwicensis*, *Diplazium sandwichianum*, and *Wikstroemia oahuensis*. *Metrosideros polymorpha* occurred most commonly in the canopy. Two out of the three MIP/OIP rare taxa at Palikea MU were recorded in plots during monitoring in 2017, including *Cyanea grimesiana* subsp. *obatae* and *C. superba* subsp. *superba*. Six additional rare taxa (*C. membranacea, Lobelia yuccoides, S. perlmanii, Solanum sandwicense, Urera kaalae,* and *Zanthoxylum dipetalum* var. *dipetalum*) were also recorded. Numerous target weed taxa (taxa of special concern for weed management, ranging from incipient species to those with widespread distributions) for Palikea MU were present in monitored plots in either the understory or canopy (Figure 7). One out of the four ICA target species, *Crocosmia* x *crocosmiifolia*, was present in a single plot. Four out of 16 limited distribution target taxa were recorded, including *Angiopteris evecta*, *Drymaria cordata* var. *pacifica*, *Nephrolepis brownii*, and *Sphaeropteris cooperi*, and a quarter of the plots included at least one of these. All 22 widespread distribution target taxa were observed, at least one of which was present in all 51 plots.

Analysis of frequency change was limited to taxa with at least ten percent change between 2008 and 2017. There were significant increases in frequency for four native species in the understory (*D. sandwichianum*, *M. strigosa*, *Nephrolepis exaltata* subsp. *hawaiiensis* and *Pipturus albidus*) and one in the canopy (*C. chamissoi*), all of which generally increased gradually over time, with the exception of *N. exaltata* subsp. *hawaiiensis*, which increased between 2008 and 2011 (Table 5, Figures 8 and 9). Four non-native taxa in the understory (*C. parasiticus, Deparia petersenii*, *Ehrharta stipoides*, and *Erechtites valerianifolia*) and one in the canopy (*P. suberosa*) increased significantly, all of which also generally increased gradually with the exception of *E. valerianifolia*, which primarily increased between 2014 and 2017. Frequency decreases among non-native taxa occurred for *Morella faya* in both the understory and canopy between 2014 and 2017, and for *S. terebinthifolius* in the understory gradually over time.

**Table 4.** Species frequency among plots (percent of plots in which a given species occurs) during 2017 Palikea MU monitoring (n= 51), in order of most to least frequent. Native species are in bold print. ‡Rare taxa. Target weed taxa: *ICA, **limited distribution.

| Taxon | Freq. | Taxon | Freq. |
|---|---|---|---|
| Understory | | | |
| *Clidemia hirta* | 90.2 | ***Athyrium microphyllum*** | 9.8 |
| *Rubus rosifolius* | 68.6 | *Buddleja asiatica* | 9.8 |
| *Psidium cattleianum* | 62.7 | ***Dodonaea viscosa*** | 9.8 |
| *Passiflora suberosa* | 60.8 | *Lantana camara* | 9.8 |
| ***Kadua affinis*** | 56.9 | ***Pittosporum confertiflorum*** | 9.8 |
| *Cyclosorus parasiticus* | 54.9 | ***Pteridium aquilinum*** | 9.8 |
| *Blechnum appendiculatum* | 52.9 | ***Sphenomeris chinensis*** | 9.8 |
| ***Dicranopteris linearis*** | 52.9 | ***Carex meyenii*** | 7.8 |
| *Deparia petersenii* | 45.1 | ***Charpentiera obovata*** | 7.8 |
| ***Asplenium macraei*** | 43.1 | *Conyza bonariensis* | 7.8 |
| ***Metrosideros polymorpha*** | 43.1 | *Cryptomeria japonica* | 7.8 |
| ***Cibotium chamissoi*** | 37.3 | ***Doodia kunthiana*** | 7.8 |
| ***Microlepia strigosa*** | 37.3 | ***Elaphoglossum alatum*** | 7.8 |
| *Schinus terebinthifolius* | 37.3 | *Morella faya* | 7.8 |
| ***Dianella sandwicensis*** | 35.3 | *Phytolacca octandra* | 7.8 |
| ***Diplazium sandwichianum*** | 35.3 | ***Polypodium pellucidum* var. *pellucidum*** | 7.8 |
| ***Wikstroemia oahuensis*** | 35.3 | *Solanum americanum* | 7.8 |
| *Youngia japonica* | 35.3 | ***Antidesma platyphyllum*** | 5.9 |
| *Paspalum conjugatum* | 33.3 | ***Asplenium caudatum*** | 5.9 |
| ***Alyxia stellata*** | 31.4 | ***Asplenium kaulfussii*** | 5.9 |
| ***Elaphoglossum paleaceum*** | 31.4 | ***Bidens torta*** | 5.9 |
| ***Nephrolepis exaltata* subsp. *hawaiiensis*** | 31.4 | ***Dryopteris fuscoatra*** | 5.9 |
| *Melinis minutiflora* | 31.4 | ***Elaphoglossum aemulum*** | 5.9 |
| ***Dryopteris glabra*** | 29.4 | ***Euphorbia multiformis*** | 5.9 |
| *Ehrharta stipoides* | 29.4 | ***Hymenophyllum recurvum*** | 5.9 |
| ***Cocculus orbiculatus*** | 27.5 | ***Labordia kaalae*** | 5.9 |
| ***Asplenium contiguum*** | 25.5 | ***Leptecophylla tameiameiae*** | 5.9 |
| ***Carex wahuensis*** | 25.5 | ***Melicope oahuensis*** | 5.9 |
| ***Coprosma longifolia*** | 25.5 | *Phlebodium aureum* | 5.9 |
| *Erechtites valerianifolia* | 23.5 | ***Psychotria mariniana*** | 5.9 |
| ***Kadua cordata*** | 23.5 | ***Vaccinium calycinum*** | 5.9 |
| ***Peperomia membranacea*** | 21.6 | *Adiantum radianum* | 3.9 |
| ***Pipturus albidus*** | 21.6 | *Ageratum conyzoides* | 3.9 |
| ***Cheirodendron trigynum*** | 19.6 | ***Cyanea grimesiana* subsp. *obatae*‡** | 3.9 |
| ***Nephrolepis cordifolia*** | 19.6 | *Cyclosorus dentatus* | 3.9 |
| ***Vaccinium dentatum*** | 19.6 | ***Cyperus polystachyos*** | 3.9 |
| ***Asplenium acuminatum*** | 17.6 | ***Dryopteris sandwicensis*** | 3.9 |
| ***Cyrtandra waianaeensis*** | 17.6 | ***Ilex anomala*** | 3.9 |
| *Ageratina riparia* | 15.7 | ***Kadua acuminata*** | 3.9 |
| ***Coprosma foliosa*** | 15.7 | ***Melicope clusiifolia*** | 3.9 |
| ***Freycinetia arborea*** | 15.7 | ***Myrsine lessertiana*** | 3.9 |
| ***Lepisorus thunbergianus*** | 15.7 | ***Myrsine sandwicensis*** | 3.9 |
| ***Psychotria hathewayi*** | 15.7 | *Nephrolepis brownii*** | 3.9 |
| *Ageratina adenophora* | 13.7 | *Oxalis corniculata* | 3.9 |
| ***Broussaisia arguta*** | 13.7 | ***Pisonia brunoniana*** | 3.9 |
| *Crassocephalum crepidoides* | 13.7 | ***Pisonia sandwicensis*** | 3.9 |
| ***Elaphoglossum crassifolium*** | 13.7 | ***Pteris excelsa*** | 3.9 |
| ***Peperomia tetraphylla*** | 13.7 | ***Scaevola gaudichaudiana*** | 3.9 |
| ***Perrottetia sandwicensis*** | 13.7 | ***Selaginella arbuscula*** | 3.9 |
| ***Diplopterygium pinnatum*** | 11.8 | ***Acacia koa*** | 2.0 |
| ***Sadleria cyatheoides*** | 11.8 | ***Adenophorus tamariscinus*** | 2.0 |

**Table 4,** continued.

| Taxon | Freq. | Taxon | Freq. |
|---|---|---|---|
| Understory | | | |
| *Angiopteris evecta*** | 2.0 | *Passiflora edulis* | 2.0 |
| ***Asplenium excisum*** | 2.0 | ***Planchonella sandwicensis*** | 2.0 |
| ***Asplenium lobulatum*** | 2.0 | *Psidium guajava* | 2.0 |
| ***Asplenium nidus*** | 2.0 | ***Psilotum complanatum*** | 2.0 |
| ***Asplenium polyodon*** | 2.0 | ***Pteris irregularis*** | 2.0 |
| ***Clermontia kakeana*** | 2.0 | ***Rumex albescens*** | 2.0 |
| ***Clermontia persicifolia*** | 2.0 | ***Silene perlmanii*‡** | 2.0 |
| *Crocosmia* x *crocosmiifolia** | 2.0 | ***Smilax melastomifolia*** | 2.0 |
| ***Cyanea membranacea*‡** | 2.0 | ***Solanum sandwicense*‡** | 2.0 |
| ***Cyanea superba* subsp. *superba*‡** | 2.0 | *Sphaeropteris cooperi*** | 2.0 |
| ***Cyrtandra garnotiana*** | 2.0 | ***Tectaria gaudichaudii*** | 2.0 |
| *Drymaria cordata* var. *pacifica*** | 2.0 | ***Urera glabra*** | 2.0 |
| ***Dubautia plantaginea*** | 2.0 | ***Urera kaalae*‡** | 2.0 |
| *Epidendrum* x *obrienianum* | 2.0 | ***Vandenboschia cyrtotheca*** | 2.0 |
| *Grevillea robusta* | 2.0 | ***Vandenboschia davallioides*** | 2.0 |
| ***Huperzia phyllantha*** | 2.0 | ***Viola chamissoniana* subsp. *tracheliifolia*** | 2.0 |
| ***Lobelia yuccoides*‡** | 2.0 | ***Zanthoxylum dipetalum* var. *dipetalum*‡** | 2.0 |
| ***Microlepia speluncae*** | 2.0 | | |
| Canopy | | | |
| ***Metrosideros polymorpha*** | 70.6 | ***Cyanea grimesiana* subsp. *obatae*‡** | 3.9 |
| *Schinus terebinthifolius* | 58.8 | *Grevillea robusta* | 3.9 |
| *Psidium cattleianum* | 49.0 | *Phlebodium aureum* | 3.9 |
| *Passiflora suberosa* | 45.1 | ***Adenophorus pinnatifidus*** | 2.0 |
| *Cryptomeria japonica* | 21.6 | ***Adenophorus tenellus*** | 2.0 |
| ***Cibotium chamissoi*** | 19.6 | *Buddleja asiatica* | 2.0 |
| *Morella faya* | 19.6 | ***Diplazium sandwichianum*** | 2.0 |
| ***Cheirodendron trigynum*** | 17.6 | ***Elaphoglossum alatum*** | 2.0 |
| ***Pipturus albidus*** | 17.6 | ***Elaphoglossum crassifolium*** | 2.0 |
| ***Dicranopteris linearis*** | 15.7 | *Epidendrum* x *obrienianum* | 2.0 |
| ***Broussaisia arguta*** | 13.7 | ***Leptecophylla tameiameiae*** | 2.0 |
| ***Coprosma longifolia*** | 13.7 | ***Lobelia yuccoides*‡** | 2.0 |
| ***Lepisorus thunbergianus*** | 13.7 | ***Melicope clusiifolia*** | 2.0 |
| ***Perrottetia sandwicensis*** | 13.7 | ***Melicope oahuensis*** | 2.0 |
| ***Alyxia stellata*** | 11.8 | *Passiflora edulis* | 2.0 |
| ***Kadua affinis*** | 11.8 | ***Peperomia tetraphylla*** | 2.0 |
| ***Coprosma foliosa*** | 9.8 | ***Pisonia brunoniana*** | 2.0 |
| ***Freycinetia arborea*** | 9.8 | ***Planchonella sandwicensis*** | 2.0 |
| ***Pittosporum confertiflorum*** | 9.8 | ***Polypodium pellucidum* var. *pellucidum*** | 2.0 |
| ***Acacia koa*** | 5.9 | *Psidium guajava* | 2.0 |
| *Clidemia hirta* | 5.9 | ***Psychotria hathewayi*** | 2.0 |
| ***Dodonaea viscosa*** | 5.9 | ***Sadleria pallida*** | 2.0 |
| ***Ilex anomala*** | 5.9 | ***Smilax melastomifolia*** | 2.0 |
| ***Psychotria mariniana*** | 5.9 | ***Solanum sandwicense*‡** | 2.0 |
| ***Adenophorus tamariscinus*** | 3.9 | ***Wikstroemia oahuensis*** | 2.0 |
| ***Cocculus orbiculatus*** | 3.9 | ***Zanthoxylum dipetalum* var. *dipetalum*‡** | 2.0 |

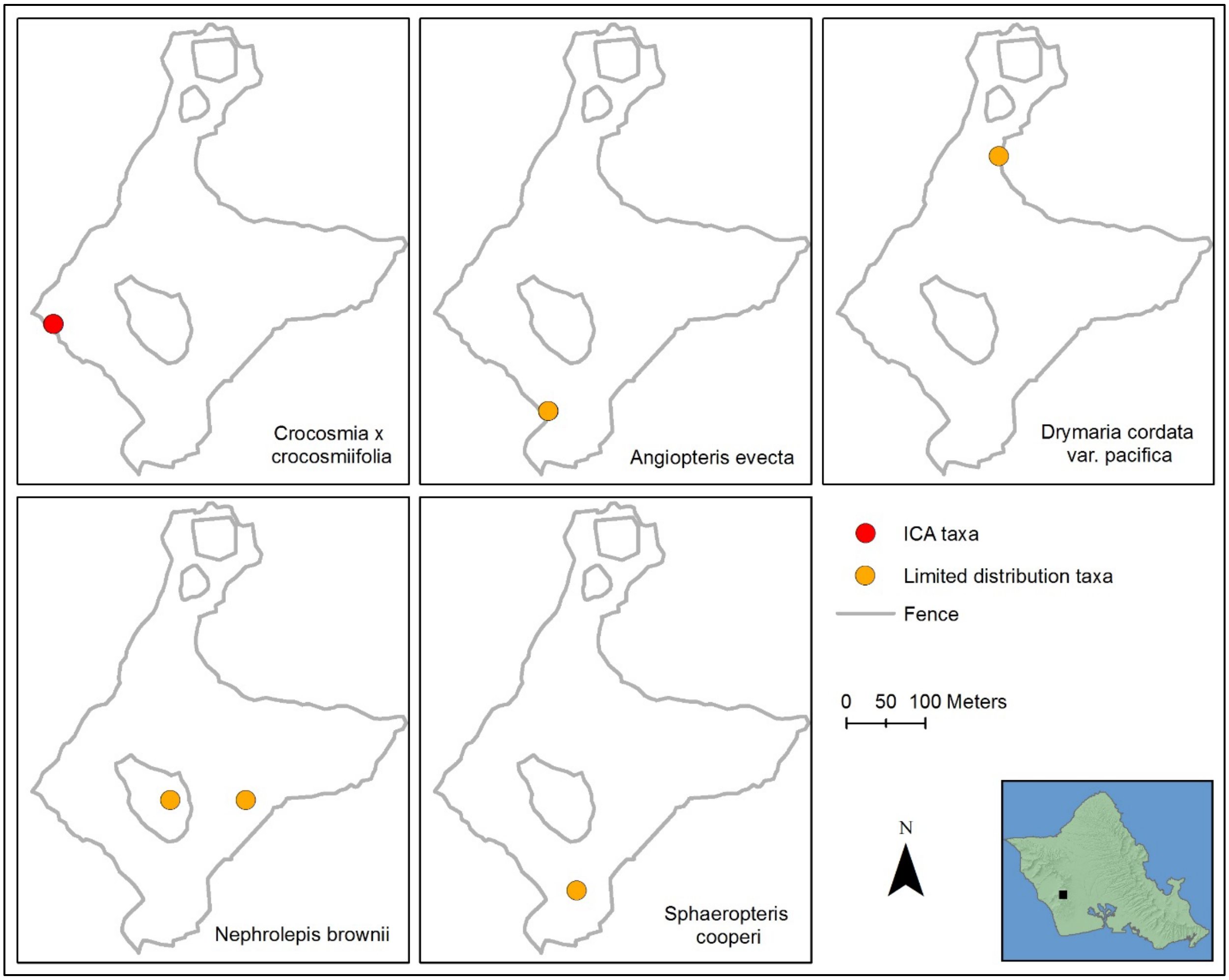



**Figure 7**. Locations of ICA and limited distribution target taxa in the understory and/or canopy found in monitoring plots at Palikea MU.

**Table 5.** Species with significant frequency change in the understory at Palikea MU between 2008 and 2017. Only taxa with at least 10% change in frequency were analyzed. P-values obtained from McNemar's test (exact significance, binomial distribution). Arrows indicate increase (↑) or decrease (↓) in frequency. Native species are in boldface.

| | Years with significant differences | p |
|---|---|---|
| Understory | | |
| *Cyclosorus parasiticus* | 2008-2017 | 0.031↑ |
| | 2011-2017 | 0.031↑ |
| *Deparia petersenii* | 2008-2014 | 0.021↑ |
| | 2008-2017 | 0.002↑ |
| ***Diplazium sandwichianum*** | 2008-2017 | 0.012↑ |
| *Ehrharta stipoides* | 2008-2014 | 0.001↑ |
| | 2008-2017 | 0.016↑ |
| | 2011-2014 | 0.012↑ |
| *Erechtites valerianifolia* | 2008-2017 | 0.003↑ |
| | 2011-2017 | 0.001↑ |
| | 2014-2017 | 0.022↑ |
| ***Microlepia strigosa*** | 2008-2017 | 0.016↑ |
| *Morella faya* | 2008-2017 | 0.016↓ |
| | 2011-2017 | 0.008↓ |
| | 2014-2017 | 0.039↓ |
| ***Nephrolepis exaltata* subsp. *hawaiiensis*** | 2008-2011 | 0.008↑ |
| | 2008-2014 | 0.039↑ |
| | 2008-2017 | 0.039↑ |
| ***Pipturus albidus*** | 2008-2017 | 0.008↑ |
| | 2014-2017 | 0.031↑ |
| *Schinus terebinthifolius* | 2008-2011 | 0.012↓ |
| | 2008-2017 | 0.001↓ |
| | 2014-2017 | 0.001↓ |
| Canopy | | |
| ***Cibotium chamissoi*** | 2008-2017 | 0.016↑ |
| *Morella faya* | 2008-2017 | 0.003↓ |
| | 2011-2017 | 0.000↓ |
| | 2014-2017 | 0.000↓ |
| *Passiflora suberosa* | 2008-2014 | 0.003↑ |
| | 2008-2017 | 0.000↑ |
| | 2011-2017 | 0.022↑ |

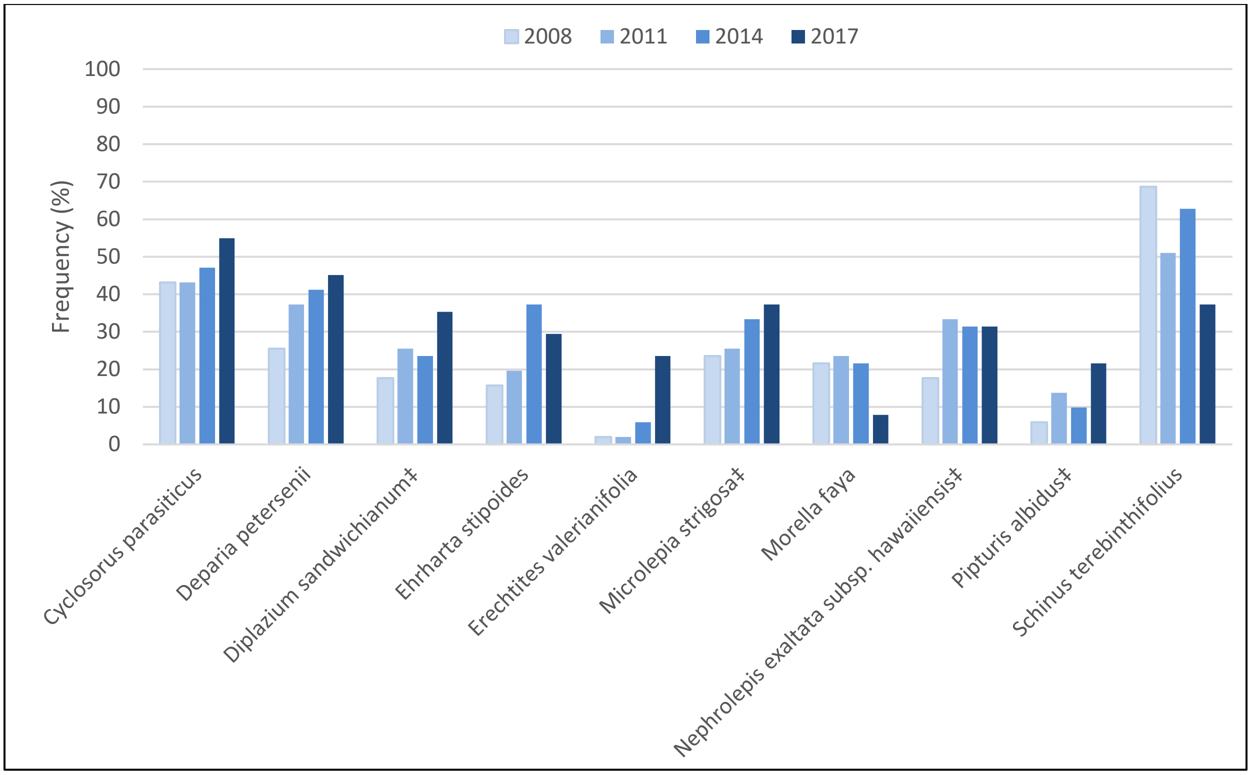



**Figure 8.** Species frequencies at Palikea MU between 2008 and 2017, among understory taxa with significant changes over time. Frequency values represent the proportion of plots in which species are present (n=51). ‡Native taxa.

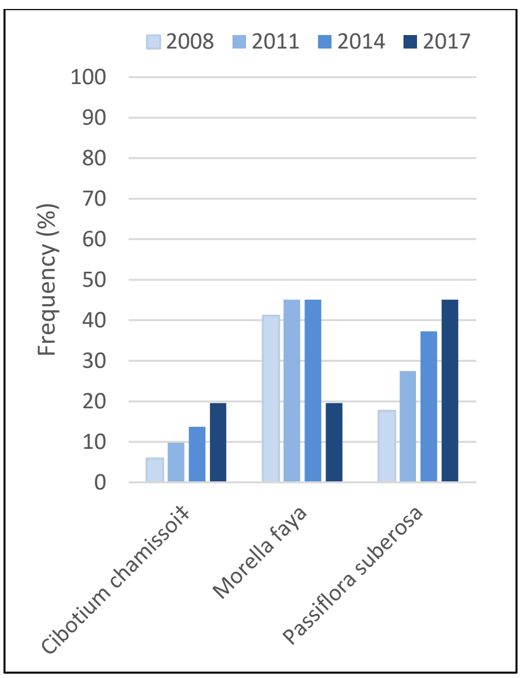



**Figure 9.** Species frequencies at Palikea MU between 2008 and 2017, among canopy taxa with significant changes over time. Frequency values represent the proportion of plots in which species are present (n=51). ‡Native taxa.

## Species cover

Species with frequencies > 20% (present in >10 plots) in 2017 or 2008 (for understory)/2011 (for canopy) were analyzed. Significant native cover changes included increases in four understory taxa (*Asplenium contiguum*, *D. sandwichianum*, *M. strigosa*, and *N. exaltata* subsp. *hawaiiensis*), and declines among four species in the understory (*Alyxia stellata*, *Dryopteris glabra*, *Elaphoglossum paleaceum*, and *M. polymorpha*) and one in the canopy (*K. affinis*) (Table 6 and Figure 10). Significant non-native cover changes included increases in five species in the understory (*B. appendiculatum*, *C. hirta*, *E. stipoides*, *E. valerianifolia*, and *R. rosifolius*) and one in the canopy (*Cryptomeria japonica*), and declines among five non-native species in the understory (*Melinis minutiflora*, *M. faya*, *P. cattleianum*, *S. terebinthifolius*, and *Y. japonica*) and one in the canopy (*M. faya*) (Figure 11). However, much of the cover changes noted above were not especially noteworthy, particularly among the native taxa, as differences in cover were predominantly small within plots (≤ 10% absolute change). Notable changes in the non-native understory included the increased cover for *C. hirta* and *R. rosifolius*, and the decreased cover for *M. minutiflora* and *M. faya*. Noteworthy changes in the non-native canopy included the decreased *M. faya* cover.

**Table 6.** Species with significant cover change at Palikea MU between 2008 and 2017. Only taxa with > 20% frequency in either 2017 or 2008 (for understory)/2011 (for canopy) were analyzed. Arrows indicate increase (↑) or decrease (↓) in cover. Native species are in boldface.

| | p* | $X^2$ | Years with significant differences | p (post-hoc)** |
|---|---|---|---|---|
| Understory | | | | |
| ***Alyxia stellata*** | 0.027↓ | 9.213 | N/A | |
| ***Asplenium contiguum*** | 0.035↑ | 8.614 | N/A | |
| *Blechnum appendiculatum* | 0.008↑ | 11.756 | N/A | |
| *Clidemia hirta* | 0.000↑ | 30.058 | 2008-2014 | 0.004 |
| | | | 2008-2017 | 0.000 |
| ***Diplazium sandwichianum*** | 0.003↑ | 14.194 | N/A | |
| ***Dryopteris glabra*** | 0.001↓ | 17.589 | N/A | |
| *Ehrharta stipoides* | 0.001↑ | 15.760 | N/A | |
| ***Elaphoglossum paleaceum*** | 0.011↓ | 11.155 | N/A | |
| *Erechtites valerianifolia* | 0.000↑ | 22.067 | N/A | |
| *Melinis minutiflora* | 0.024↓ | 9.450 | N/A | |
| ***Metrosideros polymorpha*** | 0.000↓ | 23.904 | 2011-2017 | 0.031 |
| ***Microlepia strigosa*** | 0.000↑ | 19.347 | N/A | |
| *Morella faya* | 0.012↓ | 11.040 | N/A | |
| ***Nephrolepis exaltata* subsp. *hawaiiensis*** | 0.012↑ | 11.000 | N/A | |
| *Psidium cattleianum* | 0.000↓ | 27.857 | 2008-2017 | 0.002 |
| | | | 2011-2017 | 0.019 |
| *Rubus rosifolius* | 0.000↑ | 25.318 | 2008-2017 | 0.001 |
| | | | 2014-2017 | 0.031 |
| *Schinus terebinthifolius* | 0.000↓ | 24.020 | 2008-2017 | 0.006 |
| | | | 2014-2017 | 0.010 |
| *Youngia japonica* | 0.032↓ | 6.907 | N/A | |
| Canopy | | | | |
| *Cryptomeria japonica* | 0.013↑ | 8.706 | N/A | |
| ***Kadua affinis*** | 0.036↓ | 6.638 | N/A | |
| *Morella faya* | 0.000↓ | 25.419 | 2014-2017 | 0.004 |

*from Friedman's test, asymptotic significance

**from post-hoc pairwise comparisons with Bonferroni adjustment

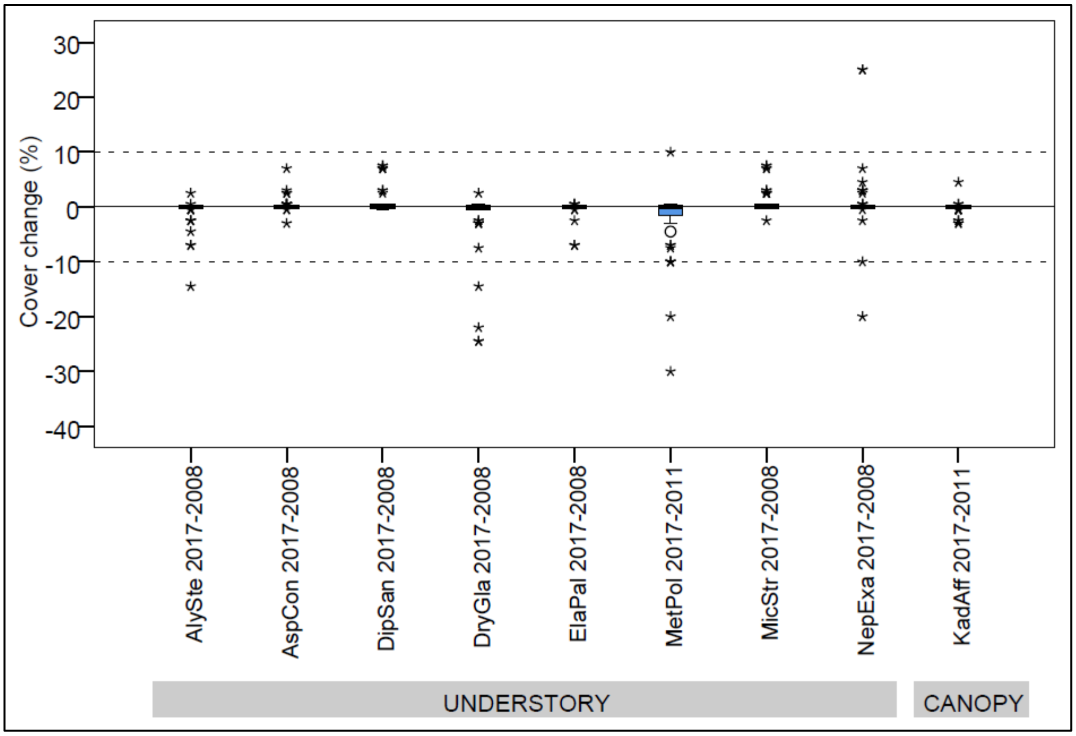



**Figure 10.** Boxplots of cover change for native taxa with significant changes in percent cover at Palikea MU. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change.

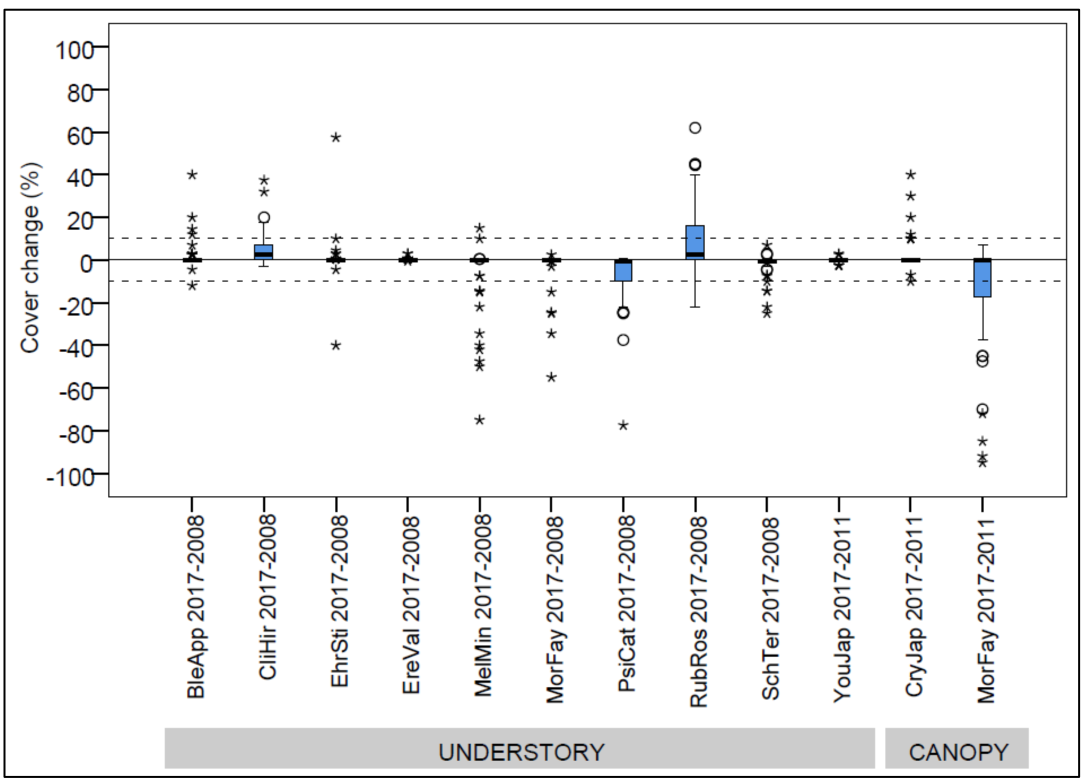



**Figure 11.** Boxplots of cover change for non-native taxa with significant changes in percent cover at Palikea MU. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change.

## Canopy replacement

Many canopy tree species were found recruiting in the understory, including 11 native and two non-native taxa (Table 7). *Psidium cattleianum* was the most commonly recruiting tree species. It should be noted that the age of saplings may vary greatly, from less than one year to decades, in accordance with differing species and individual growth rates, complicating interpretations of presence/absence and change over time with respect to concerns over long term canopy replacement.

**Table 7.** Summary of tree species found recruiting in the understory in monitored plots at Palikea MU in 2017. Native species are in boldface.

| Species |
|---|
| ***Acacia koa*** |
| ***Cheirodendron trigynum*** |
| ***Kadua affinis*** |
| ***Metrosideros polymorpha*** |
| *Morella faya* |
| ***Pipturus albidus*** |
| ***Pisonia brunoniana*** |
| ***Pittosporum confertiflorum*** |
| *Psidium cattleianum* |
| *Schinus terebinthifolius* |

## Weed control

Weed control efforts at Palikea MU between the 2014 and 2017 monitoring interval included approximately 2,340 hours and covered 65% of the MU. The time spent weeding between the 2014 and 2017 monitoring intervals was nearly double that spent weeding between the 2011 and 2014 monitoring intervals (1300 person hours, 53% of MU), and more than five times more than spent weeding between the 2008 and 2011 monitoring intervals (440 person hours, 37% of MU). The total amount of effort varied among the ten weed control areas (WCA) that encompass Palikea MU, ranging from 3 to 92 hours per WCA between 2008 and 2011, from 4 to 423 hours per WCA between 2011 and 2014, and from 12 to 721 hours per WCA between 2014 and 2017. Types of weed control were variable, including general ecosystem weeding, grass control, and single species targets. Some single species control efforts covered large areas. Nearly a third of the weeding hours that took place between 2014 and 2017 occurred in the newly expanded portion at the northern end of the MU, in association with the installation of a new *Achatinella mustelina* enclosure. In concert with the increase in hours spent weeding, weed control efforts crossed through more plots (75%) between the 2014 and 2017 monitoring intervals as compared with 2011 and 2014 intervals (71% plots), and the 2008 to 2011 intervals (59% plots) (Figure 12). Over the last nine years, weed control efforts have crossed through nearly all plots (90%) at least once, as 81% of the MU was weeded throughout that time. Sample sizes for unweeded plots were deemed insufficient for statistical comparison of cover change in weeded vs. unweeded plots to discern the impacts of weeding efforts on the native and non-native understory and canopy between 2008 and 2017. Generalized linear modeling did not reveal any significant influences of changes in non-native canopy on native understory, native canopy, or non-native understory, nor was there a significant influence of change in non-native understory on native understory.

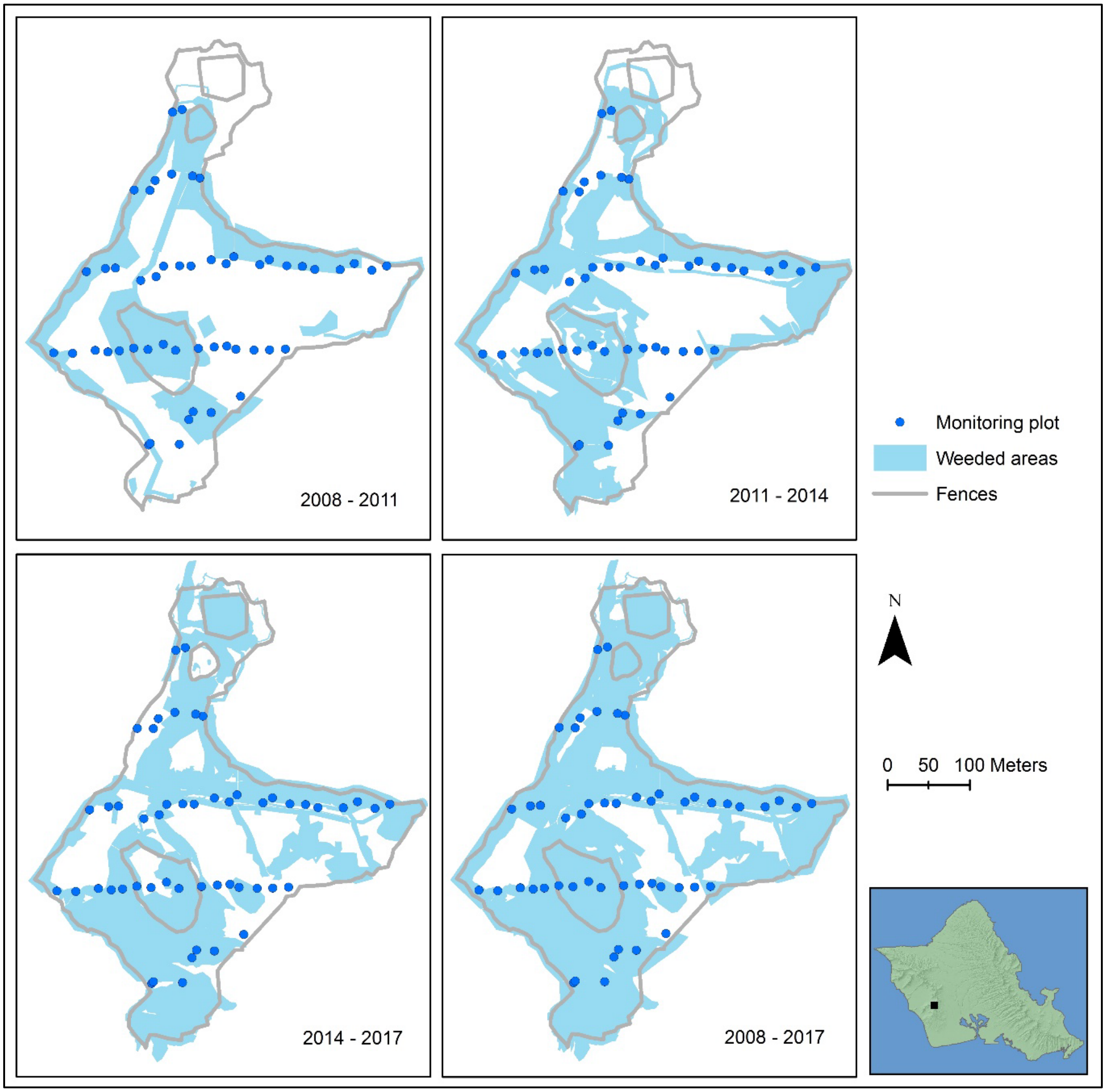



**Figure 12.** Locations of vegetation monitoring plots at Palikea MU in relation to areas weeded between monitoring intervals.

Much of the weeding efforts between 2014 and 2017 consisted of general ecosystem weed control, but some included specific actions for ICA taxa, targeted control of specific widespread distribution target taxa (*C. japonica*, *M. faya*, *P. cattleianum*, and *S. terebinthifolius*), sometimes covering large areas, as well as grass control. The decline in non-native canopy was influenced by the reduction in *M. faya* (Generalized linear model: $p = 0.000$), which was in turn attributed to targeted treatment of that taxon. Approximately 150 large *M. faya* trees were selectively treated using IPA in November of 2015 within Palikea MU (Figure 13). This was done following recommendations from the last Palikea MU vegetation monitoring report (OANRP 2014) for partial thinning/removal of this species, as it was the second most frequently encountered non-native tree within the MU after *S. terebinthifolius*, and is one of the more easily managed canopy weeds. Understory vegetation change in association with IPA treatment of *M. faya* was documented (baseline and one year post-treatment) to address concerns over the potential for weedy ingress in response to increased light levels following *M. faya* defoliation, the results of which were detailed in the 2017 Status Report for the Makua and Oahu Implementation Plans (OANRP 2017).

*Rubus rosifolius* cover increased significantly below treated trees, however MU vegetation monitoring data from 2017 revealed that the observed increase in *R. rosifolius* cover below IPA treated trees was due to MU-wide change in *R. rosifolius* cover unrelated to IPA control, as *R. rosifolius* cover increased both in plots with decreased *M. faya* canopy cover as well as in plots with no change in *M. faya* canopy cover, and statistical modeling indicated *M. faya* canopy cover change from 2014 to 2017 did not influence *R. rosifolius* understory cover change within plots (Figure 14). While *R. rosifolius* increased in cover, the frequency did not change, indicating that it is not spreading to new areas within the MU. The locations with the largest increases in *R. rosifolius* cover in the IPA study were generally off of ridge crests, and similar results were found in the 2017 MU monitoring data (Figure 15). The targeted control of *C. japonica*, *P. cattleianum*, and *S. terebinthifolius* did not result in significantly reduced frequency or cover of those species in the canopy, however there was a small reduction in *P. cattleianum*, and *S. terebinthifolius* cover in the understory. Though there was not a significant decline in non-native grass cover in general, there was a significant decline in *M. minutiflora* cover, and the steady expansion of *E. stipoides* from 2008 to 2014 appears to have abated between the 2014 and 2017 monitoring intervals.

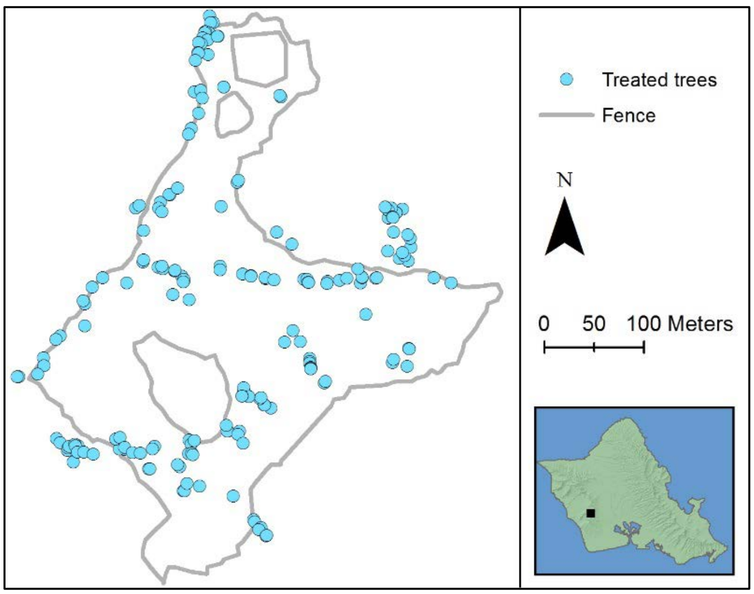



**Figure 13.** Locations of IPA controlled *M. faya* at Palikea.

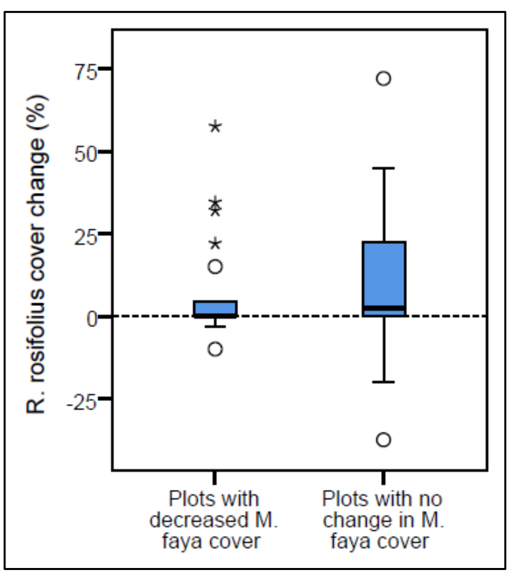



**Figure 14.** Cover change of understory *R. rosifolius* among plots with decreased vs. no change in *M. faya* canopy cover between 2014 and 2017 from Palikea MU vegetation monitoring. Positive numbers indicate increased cover, while negative numbers indicate decreased cover.

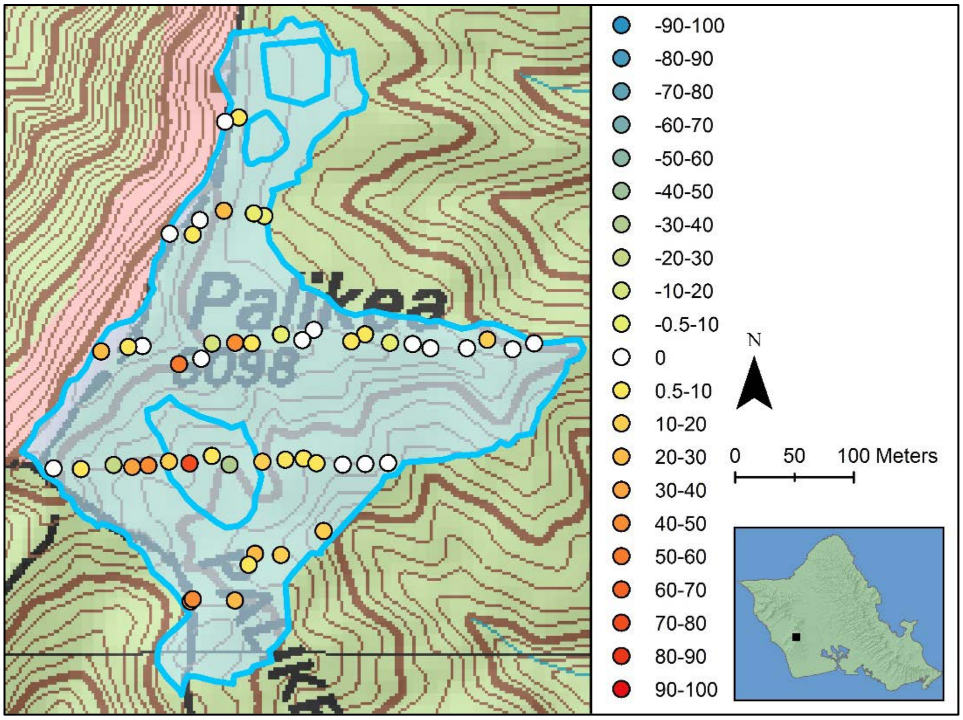



**Figure 15.** Locations of change in understory *R. rosifolius* percent cover in monitored plots in Palikea MU between 2014 and 2017. Positive numbers indicate increased cover, while negative numbers indicate decreased cover. Cover change of 0 indicates there was no change in percent cover.

## Native ecosystem restoration efforts

Native ecosystem restoration efforts, including outplanting, seed sowing, and transplanting of primarily common native taxa, began at Palikea in 2012, initially focused on improving habitat in the *A. mustelina* enclosure during the 2011 to 2014 vegetation monitoring interval (412 outplants), and continually expanded since that time throughout the MU during the 2014 to 2017 monitoring interval (1042 outplants) for stabilization of *A. mustelina* and *Drosophila*, as well as general MU restoration (Figure 16). Restoration efforts crossed through two plots during the 2014 to 2017 monitoring interval. Sample sizes were insufficient for statistical comparison of cover change in plots for restored vs. unrestored areas to discern the impacts of restoration on the native and non-native understory and canopy.

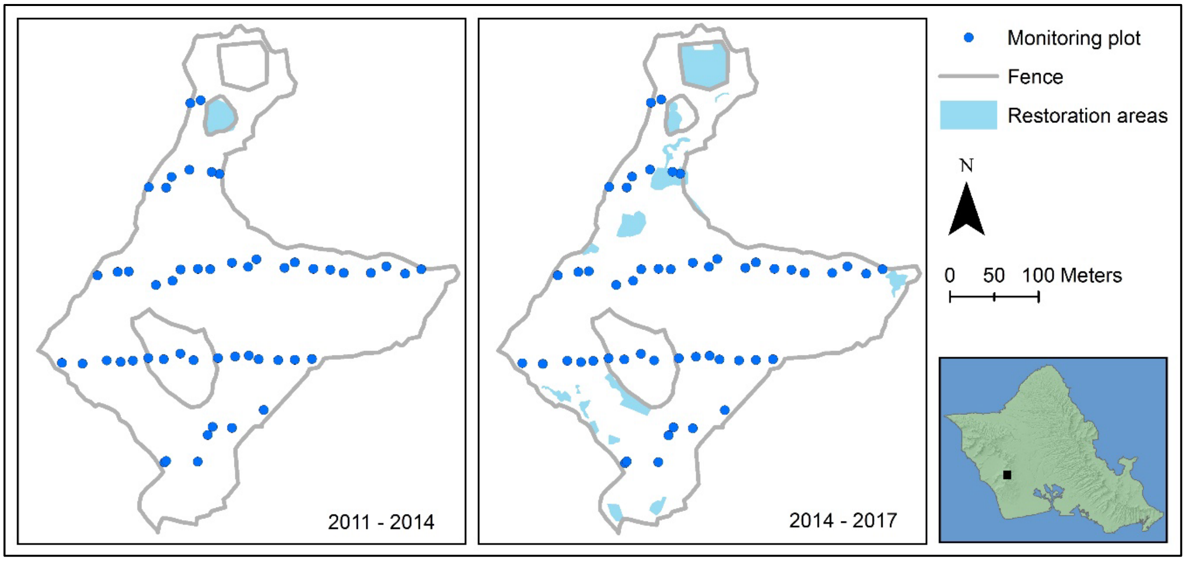



**Figure 16.** Locations of vegetation monitoring plots in relation to native ecosystem restoration actions between monitoring intervals at Palikea MU.

## SUMMARY AND DISCUSSION

Management objectives continue to be met for percent cover of non-native understory and, for the first time since monitoring began in 2008, are now met for the non-native canopy for Palikea MU. Objectives are still not met for native understory and canopy cover, though there was progress towards the objective for native canopy cover. There were a number of significant differences in the 2017 data as compared with prior years, many of which were relatively small. The most noteworthy changes (and the date ranges in which change primarily occurred) included:

- **Categorical cover**
    - Increased
        - Native canopy (from 2011 to 2017)
    - Decreased
        - Non-native canopy (from 2014 to 2017)
        - Total canopy
- **Frequency**
    - Increased
        - Native understory
            - *D. sandwichianum* (from 2008 to 2017)
            - *M. strigosa* (from 2008 to 2017)
            - *P. albidus* (from 2008 to 2017)
        - Native canopy
            - *C. chamissoi* (from 2008 to 2017)
        - Non-native understory
            - *C. parasiticus* (from 2011 to 2017)
            - *D. petersenii* (from 2011 to 2017)
            - *E. stipoides* (from 2008 to 2017)
        - Non-native canopy
            - *P. suberosa* (from 2008 to 2017)
    - Decreased
        - Non-native understory

        - *M. faya* (from 2014 to 2017)
        - *S. terebinthifolius* (from 2008 to 2017)
      - Non-native canopy
        - *M. faya* (from 2014 to 217)
- **Species cover**
  - Increased:
    - Non-native understory
      - *C. hirta* (from 2008 to 2017)
      - *R. rosifolius* (from 2008 to 2017)
  - Decreased:
    - Non-native understory
      - *M. minutiflora* (from 2008 to 2017)
      - *M. faya* (from 2008 to 2017)
    - Non-native canopy
      - *M. faya* (from 20011 to 2017)
- **Weed control**
  - Decrease in non-native canopy cover was influenced by decrease in *M. faya* canopy cover
  - Increase in *R. rosifolius* cover not was not influenced by decrease in *M. faya* canopy cover

The most notable changes between 2014 and 2017 were the decrease in non-native canopy as well as canopy *M. faya* both in frequency and percent cover, and the increase in *R. rosifolius* understory cover. The increase in native canopy cover and fern taxa frequencies, along with a lack of decline in cover or frequency for any native taxa, indicates the native components of Palikea are either stable or improving. However, the increase in either frequency or cover for a number of widespread target weed taxa, particularly in the understory, suggests challenges remain for weed control, despite extensive and increased levels of weed control effort in the MU.

## RECOMMENDATIONS

Based on the results of vegetation monitoring, a number of recommendations were made with the goal of making progress towards meeting management objectives:

- Continued efforts for general ecosystem weeding
- Continued efforts for ICA control, including determining if there is an effective herbicide treatment for *C.* x *crocosmiifolia*
- Continued native ecosystem restoration efforts
- Postpone further IPA treatment of *M. faya* until further assessment of understory response to canopy removal can be made in association with continued monitoring of IPA treatment every three years
- Target *D. cordata* var. *pacifica* along trails, fencelines, LZs, staging areas, and anywhere else found
- Targeted sweeps for *A. evecta* and *N. brownii* in WCAs-04, -05, and -06
- Target *S. cooperi*, *P. suberosa*, *C. parasiticus* and *D. petersenii* during regular weed sweeps
- Control grasses in rare taxa and restoration areas
- Continue to control grasses on trails to reduce spread of *E. stipoides* in particular
- Target *G. robusta* in the canopy within the fence using IPA
- Continue discussions of possible *C. japonica* canopy removal
- Conduct understory weed control in WCA-05 (TNC fence)

- Consider future restoration efforts at WCA-04, one of the weediest WCAs

**REFERENCES**

Oahu Army Natural Resource Program. 2008. Appendix 2.0 MIP/OIP Belt Plot Sampling Monitoring Protocol *in* 2008 Status Report for the Makua Implementation Plan. http://manoa.hawaii.edu/hpicesu/DPW/2008_YER/008.pdf.

Oahu Army Natural Resource Program. 2009. MU Vegetation Monitoring *in* Chapter 1.4.8 Palikea Ecosystem Restoration Management Plan *in* 2009 Status Report for the Makua and Oahu Implementation Plans. http://manoa.hawaii.edu/hpicesu/DPW/ERMUP/2009_Palikea.pdf.

Oahu Army Natural Resource Program. 2011. Appendix 1-3 Vegetation Monitoring Trend Analysis for the Palikea MU *in* 2011 Status Report for the Makua and Oahu Implementation Plans. http://manoa.hawaii.edu/hpicesu/DPW/2011_YER/017.pdf.

Oahu Army Natural Resource Program. 2014. Appendix 1-3-2 Vegetation Monitoring at Palikea Management Unit, 2014 *in* 2014 Status Report for the Makua and Oahu Implementation Plans. http://manoa.hawaii.edu/hpicesu/DPW/2014_YER/A6.pdf.

Oahu Army Natural Resource Program. 2017. Appendix 3-10 Monitoring of Understory Vegetation Change in Association with IPA Control of *Morella faya* One Year Post-Treatment at Palikea *in* 2017 Status Report for the Makua and Oahu Implementation Plans. https://pcsuhawaii.org/projects/oanrp/reports/2017/A3-10.pdf.

# Biological Control


What is Chromolaena?
Differences between AWA and SA chromolaena
Workshops
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Expertise
Other invasive alien plants within the Eupatorieae
Bibliography
Useful links

**Table 1.**

Insect species tested as potential biological control agents against *Chromolaena odorata* [ pdf]

**Figure 2.** Neotropical insect species established on *Chromolaena odorata* in the Old World, on a country record basis. Map generated by Jimaima Le Grand (Queensland Department of Primary Industries and Fisheries). A version of this map was published in Zachariades et al. (2009) and is used here with permission from Cambridge University Press [ pdf]

*(Table 1 and Figure 2 indicate which agents are established in which countries. )*

Established agents are as follows:

1. *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae)
2. *Cecidochares connexa* Macquart (Diptera: Tephritidae)
3. *Actinote thalia pyrrha* (Fabr.) and *Actinote anteas* (Doubleday & Hewitson) (Lepidoptera: Nymphalidae)
4. *Acalitus adoratus* Keifer (Acari: Eriophyidae)
5. *Calycomyza eupatorivora* Spencer (Diptera: Agromyzidae)
6. *Pareuchaetes insulata* (Walker)

## 1. Pareuchaetes pseudoinsulata Rego Barros (Lepidoptera: Arctiidae)

Adult *P. pseudoinsulata*.
Photo: Po-Yung Lai, NPUST

**Action:** Leaf feeder (defoliator)

**Distribution**:

- *Native:* Trinidad, eastern Venezuela (Cock & Holloway, 1982)
- *Origin of biocontrol agent culture:* Trinidad
- Introduced: This month is now widely established in the Old World (Table 1, Fig 2)

**Biology:**

Adults are nocturnal, living about a week. Females lay eggs in batches on the underside of leaves. The young larvae feed as a group, removing the surface of, and later skeletonising leaves. Older larvae are solitary, eating holes through the leaves, and the largest larvae can eat entire leaves, leaving only a mid-rib. Young larvae remain on the plants, feeding at night, whereas older larvae

Appendix 3-11

Mature *P. pseudoinsulata* larva.
Photo: Michael Day, QDPIF

Mature *P. pseudoinsulata* larvae,
one pupating, on a leaf with typical feeding damage.
Photo: Po-Yung Lai, NPUST

move down during the day, ultimately spending this time in the leaf litter below the plant. Heavy feeding on plants in the field results in the entire plant turning yellow. Pupation occurs in a flimsy cocoon within dead leaves lower on the plant or on the ground. The lifecycle takes about 6 weeks in the laboratory.

**Safety:** The moth shows a good degree of specificity, feeding only on chromolaena and, as a secondary host, the closely related *Ageratum conyzoides*, which is also an invasive alien species in the Old World.

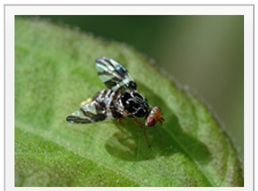
**Ease of rearing and release:** Although *P. pseudoinsulata* is easily mass-reared in containers with cut foliage in the laboratory, it is highly susceptible to disease in this environment, a factor which has resulted in the failure of several release programs. A sophisticated, hygienic laboratory situation under the supervision of an entomologist is necessary to increase the chances of success. In general, it seems that releases of large numbers of larvae (e.g. >100,000) over an extended period of time (e.g. 2-3 years) increases the probability of establishment. This means that release sites should be within driving distance of the mass-rearing station and that personnel are required to conduct releases on a regular basis over an extended period.

**Establishment and efficacy:** Results, both in establishing *P. pseudoinsulata* and in its subsequent effectiveness, have been very variable. In some countries, it was easily established from the release of a few thousand individuals (adults/larvae), while in others, despite concerted efforts and releases of hundreds of thousands of individuals, it has still not established. Although little research has been conducted on the species, the possible reasons for non-establishment (vary from case to case) include poor climate matching, poor site selection, insufficient numbers released over an insufficient period (leading to loss of the population through Allee effects and predation) and release of diseased individuals. The insect spreads reasonably quickly once it has established. Although defoliation of large areas of chromolaena has been reported, this generally happened within a few years of the agent's establishment, and longer-term efficacy has generally not been very high. The only places where a high degree of efficacy (i.e. long-term reduction of chromolaena populations) has been reported are some Pacific islands. Waterhouse (1994) and Zachariades *et al*. (2009) have reviewed the history and success of *P. pseudoinsulata* releases around the world.

**Recommendations:** This insect is quite difficult to establish, and generally is not very effective in reducing chromolaena populations. It is lower on the recommended list than *C. connexa* (for the Asian/West African chromolaena biotype). As it is a leaf feeder and does not seem to have a strong diapause, it will probably not establish in areas which have a long, severe dry season.

**Availability:** Several countries in South-East Asia, Oceania and Ghana. Contact the IOBC working group convenor at ZachariadesC@arc.agric.za for more information.

## 2. Cecidochares connexa Macquart (Diptera: Tephritidae)



Adult *C. connexa*.
Photo: Colin Wilson

Larvae and pupae in a gall.
Photo: Po-Yung Lai, NPUST

**Action:** Stem galler

**Distribution:**

- Native: Continental South and Central America, where C. odorata is present
- Origin of biocontrol agent culture: Colombia (Caribbean coast)
- Introduced: First released in Sumatra (Indonesia) in 1995. It has since been released and easily established from small founder cultures in several other countries (Table 1, Fig. 2).

**Biology:**

Adult flies lived for less than 2 weeks in the laboratory. Females insert their eggs into the plant tissue in the tip of the shoot. In the field usually 2 eggs are laid in each tip. After about 2 weeks a swelling in the node becomes visible. The mature gall becomes woody and is 2–3 cm long and 0.8–1.5 cm wide. In the field, 2-4 larvae usually develop in separate chambers in each gall, and before pupating an exit tunnel is chewed, leaving a thin layer of epidermis (a 'window'). The lifecycle takes an average of 60 days (McFadyen *et al*., 2003).

**Safety:**

This fly is highly specific, only developing on the Asian/West African biotype of *C. odorata.*

**Ease of rearing and release:**

This fly is easy to rear on potted plants in cages in the shadehouse or nursery. Galls with 'windows' indicating the presence of pupae can be placed into the field; adults emerge from the galls and establish easily. Once a population has been established in the field, galls can be collected from there for redistribution.

Mating *C. connexa*.
Photo: Warea Orapa, SPC

Ovipositing female *C. onnexa*.
Photo: Po-Yung Lai, NPUST

Young *C. connexa* galls.
Photo: Michael Day, QDPIF

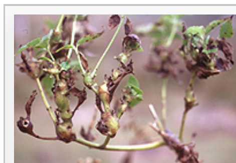
**Establishment and efficacy:**

The fly spreads and builds up the population size quickly. It locates isolated *C. odorata* plants efficiently, and is generally very damaging. Large numbers of galls are frequently found on individual plants, stressing and sometimes killing them. Significant reduction in the density of infestations has been recorded in several countries. The fly appears to be somewhat less effective in seasonally drier parts of the invasive range of chromolaena, where stems die back in the dry season and fires occur, and in cooler, higher altitude regions where fly development is slower. Some degree of parasitism and predation of larvae has been recorded in East Timor and Indonesia but does not significantly affect the impact of the agent. A number of papers on the establishment and efficacy of this fly in Indonesia and Papua New Guinea have been published in the proceedings of more recent chromolaena workshops, and reviewed in Zachariades *et al.* (2009).

**Recommendations:** *C. connexa* is the best biocontrol agent for chromolaena available at present, in terms of host range, efficacy and ease of establishment. Unfortunately, due to its narrow host range, it cannot develop on the SA biotype of chromolaena.

**Availability: India, and several countries in South-East Asia and Oceania. Contact the IOBC working group convenor at for more information.**

India, and several countries in South-East Asia and Oceania. Contact the IOBC working group convenor at ZachariadesC@arc.agric.za for more information.



Old *C. connexa* galls, some showing exit holes.
Photo: Colin Wilson

## 3. Actinote thalia pyrrha (Fabr.) and Actinote anteas (Doubleday & Hewitson) (Lepidoptera: Nymphalidae)

Adult male *A. thalia pyrrha*

Adult *A. anteas* (= *A. thalia thalia*)

**Action:** Leaf feeder (defoliator)
**Distribution:**

Native: Actinote anteas was recorded by Rachel Cruttwell in Trinidad, and appears to have a geographical range extending to Venezuela and Costa Rica. The taxonomy of Actinote spp. is rather complex and confused. http://www.funet.fi/pub/sci/bio/life/insecta/lepidoptera/ditrysia/papilionoidea/nymphalidae/heliconiinae/actinote/index.html#About%20maps lists *Actinote anteas* (=A. thalia anteas) as having a range Mexico, Costa Rica, Honduras, Guatemala, Panama, Venezuela and Colombia; and Actinote thalia pyrrha (=A. pyrrha pyrrha): Brazil (Espirito Santo, Minas Gerais, Paraná, Rio Grando do Sul, Rio de Janeiro, Santa Catarina, São Paulo) and Argentina (Entre Rios).

Origin of biocontrol agent cultures: A culture from Costa Rica was imported into quarantine in SA in the early 1990s and partially tested for host range, but the culture was lost (Caldwell & Kluge, 1993). It was imported into Indonesia (Sumatra) in 1996 from Colombia and tested for host specificity; however, the culture was again lost. At the same time Actinote thalia pyrrha was imported into SA from north-eastern Brazil and comprehensively tested. However, it was found to feed on the native Mikania capensis and M. natalensis as well as chromolaena. Actinote spp. are associated with Mikania species in the Americas and there are several other Mikania species native to the African continent. It was thus not released in South Africa (Zachariades et al., 2002), but a culture was sent to Indonesia, where Mikania micrantha is a major threat. A culture of a species from Venezuela, identified in SA as A. thalia thalia but which is probably A. anteas, was also sent to Indonesia. Both were released in Indonesia (Desmier de Chenon et al., 2002)

Introduced: A. thalia pyrrha spread quite quickly and is widespread through Sumatra. A. anteas proved less robust, and has not spread far from the release sites on Sumatra. A. thalia pyrrha has been forwarded to China as a biocontrol agent against M. micrantha, but did not establish due to low ambient temperatures (R. Desmier de Chenon, pers. comm.). cultures of both species were lost from quarantine in Fiji, while applications to import into PNG are pending (M. Day, pers. comm.).

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**Biology:**

The diurnally active butterfly adults lay eggs in large batches on the underside of leaves. The young larvae feed communally to skeletonize leaves, creating a characteristic silk webbing over the plant. Older larvae are solitary and consume entire leaves. Mature larvae pupate on stems and leaves, often on neighbouring plants, attached with a silk pad. The lifecycle takes about 2.5 to 3 months.

**Safety:**

The larvae of both these butterflies are oligophagous, feeding over more than one genus in the asteraceous tribe Eupatorieae (Chromolaena, Mikania, Austroeupatorium). Therefore in countries with native species of Eupatorieae, exhaustive host-range testing should be conducted on these species before release.

**Ease of rearing and release:**

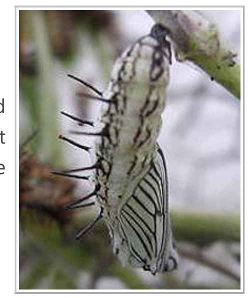
Initial problems with mating of adults in cages appear to have been overcome by keeping cages with potted plants in a warm sunny position. Eggs cannot be removed from leaves attached to the plant, and it is best to allow development of younger instars on potted plants. If space or potted plants are constraining, older larvae can be reared in containers. Release of younger, gregarious larvae in large numbers over several generations is recommended (Desmier de Chenon et al., 2002).

**Establishment and efficacy:**

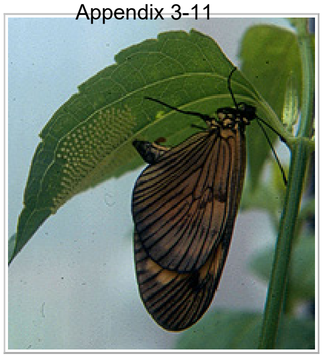
*A. thalia pyrrha* is very damaging not only to chromolaena and mikania, but also to the related neotropical invasive, Austroeupatorium inulifolium (R. Desmier de Chenon, A. Simamora and Nirwanto, Indonesian Oil Palm Research Institute, personal information, 2006).

**Recommendations:**

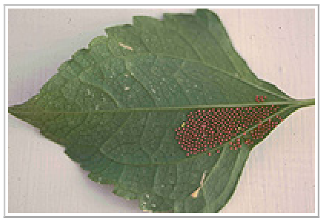
*A. thalia pyrrha* is effective where it has been released. Both species can probably be used against chromolaena, mikania and austroeupatorium. However, Actinote species are not recommended for release where native Mikania species or other, untested Eupatorieae are present.



**Availability:** Indonesia [Photo right: *Actinote* pupa. Photo: Warea Orapa, SPC]



Ovipositing *A. thalia pyrrha*



Mature egg batch of *A. thalia pyrrha* on underside of *C. odorata* leaf

Young *A. thalia pyrrha* larvae feeding on *A. inulifolium*. Photo: Roch Desmier de Chenon

Young *Actinote* larvae, probably *A. thalia thalia*, skeletonizing *C. odorata* leaves in Venezuela

First and last larval instars, *A. thalia pyrrha*

Yellowing of *C. odorata* leaves after feeding by *A. thalia pyrrha*. Photo: Roch Desmier de Chenon

Mature *A. anteas* (= *A. thalia thalia*) larva

## 4. Acalitus adoratus Keifer (Acari: Eriophyidae)

**Action:** Leaf feeder

**Distribution:**

- *Native*: Widespread through continental South America, where *C. odorata* is present. May also be present in the Caribbean and Central America.
- *Origin of biocontrol agent culture*: Probably Trinidad
- *Introduced*: It was introduced accidentally into SE Asia (probably Malaysia, from Trinidad) and has since spread widely (Table 1, Fig. 2) (McFadyen, 1995).

**Biology:**

Feeding by the mite causes the development of hairy patches on leaves, and in severe infestations these can coalesce to cause leaf deformity.

**Safety:**

This mite was shown to be host specific by Cruttwell (1977b), and recommended as an agent.

*C. odorata* leaves in Venezuela with erinia, probably caused by *A. adoratus*. Note also the *C. reticulatus* oviposition sites

*C. odorata* leaves in Jamaica showing deformity associated with eriopyhid mite feeding

**Ease of rearing and release:**

This mite has never been intentionally reared and released.

**Establishment and efficacy:**

This mite has established throughout Southeast Asia from unintentional releases at probably only one site. No research has been conducted on the efficacy of the mite, but it is thought to be low.

**Recommendations:**

There are better agents available and in the pipeline. Lower priority.

**Availability:**

Most countries in Southeast Asia have this agent, as does PNG.

## 5. Calycomyza eupatorivora Spencer (Diptera: Agromyzidae)

*C. odorata* seedling in Jamaica with heavy *C. eupatorivora* mining

Mid-instar *C. eupatorivora* larva

*C. eupatorivora* pupa

*C. eupatorivora* adult. Photo: Rob Osborne

**Action:** leaf feeder (blotch mine)

**Distribution:**

- Native: It is widely distributed in the neotropics (Martinez et al., 1993), but at the time of Cruttwell's PhD study was not recognized as a species separate from C. flavinotum, which has a broader host range. It was later described (Spencer & Stegmaier, 1973).
- Origin of biocontrol agent culture: Jamaica
- Introduced: The first releases were made in 2003 in South Africa. The fly has since established along the coast of KwaZulu-Natal province, and is becoming more common. It is also present in Mpumalanga province and some unsuccessful releases were made in Papua New Guinea.

**Biology:** Adult flies live less than two weeks in the laboratory. Females insert eggs singly on the underside of the leaf, and the larvae form blotch mines which cover about 50% of the leaf surface. Larvae exit the mine and drop to the ground to pupate. The lifecycle takes about 4-5 weeks in the laboratory.

**Safety:** Host range testing in South Africa showed that the fly was highly specific to C. odorata (Zachariades et al., 2002). It has also been recorded from Brazil on Alomia fastigiata (Asteraceae: Eupatorieae) (Spencer & Stegmaier, 1973).

**Ease of rearing and release:**: The insect is best reared in a large walk-in cage with a large number of potted chromolaena plants. Adults can be released in the cage and leaves harvested just before larvae exit them to pupate. Pupae are placed in an emergence box and adults collected from the attached vial. Pupae are the easiest developmental stage to release (at the initial site of establishment in South Africa, ~500 were put out over 4 months). In order to minimize predation on the pupae they should be placed in a container with exit holes, suspended from a tree by cord coated with antbar.

**Establishment and efficacy**: In South Africa, the insect established fairly easily at a site where chromolaena remained in good condition throughout the year. It spreads quite quickly, but until now does not seem highly damaging, except possibly to young plants in shadier conditions.

**Recommendations:** May do best in island ecosystems with fewer predators (can be very abundant in Jamaica). Will probably not do well in areas experiencing a prolonged, severe dry season because it is a leaf feeder. May prefer relatively cooler subtropical rather than tropical areas.

**Availability:** ARC-PPRI, South Africa (C. Zachariades)

Large mines with mature *C. eupatorivora* larvae

## 6. Pareuchaetes insulata (Walker)

*P. insulata* (upper) and *P. pseudoinsulata* (lower) adults are very similar

*P. insulata* egg batch on underside of *C. odorata* leaf

*P. insulata* eggs about to hatch. Larval head capsules and setae visible

Young *P. insulata* larva

Mature *P. insulata* larva

**Action:**

Leaf feeder (defoliator)

**Distribution:**

Native: From western Venezuela through Central America and the Caribbean to Florida (Cock & Holloway, 1982).

**Origin of biocontrol agent cultures:** USA (Florida), Jamaica, Cuba.

Introduced: Released in KwaZulu-Natal province, South Africa from 2001 until present. Out of the 18 sites at which the culture from Florida was released, only one has established (where the largest number of larvae, 380,000, were released over 21 months), with confirmation of establishment in late 2004. Populations from Jamaica and Cuba were also imported and released at four sites each but have probably not established. The Florida culture is spreading along the KZN South Coast (Zachariades & Strathie, 2006; Zachariades et al., 2009).

**Biology:** As for *P. pseudoinsulata*.

**Safety:** As for *P. pseudoinsulata*.

**Ease of rearing and release:** As for *P. pseudoinsulata*.

**Establishment and efficacy:**

Probably similar to *P. pseudoinsulata*. An outbreak during the 2005/6 summer in the vicinity of the established site in KZN, South Africa caused widespread defoliation and death of *C. odorata* plants, but has not been repeated as yet. By April 2008 the insect had spread about 100km along the coast and 10km inland.

**Recommendations:**

It proved very difficult and expensive to establish this agent in South Africa, and will probably not establish in areas with a prolonged and severe dry season. Possibly better adapted to cooler, less tropical conditions than *P. pseudoinsulata*.

**Availability:** ARC-PPRI, South Africa (C. Zachariades)

## HISTORY

Research on the biocontrol of chromolaena was initiated in the 1960s, when a survey of the phytophagous arthropods on chromolaena was undertaken, mainly in Trinidad, by Rachel Cruttwell (McFadyen). Of the 225 species found feeding on chromolaena in the neotropics (Cruttwell, 1974), several were considered suitable for further study due to the damage they caused and their likely narrow host range. Host range tests were carried out on five species, of which four were found to be safe for release.

During the 1970s, two of these, the moth *Pareuchaetes pseudoinsulata* (Lepidoptera: Arctiidae) and the weevil *Apion brunneonigrum* (Coleoptera: Curculionidae) were released in various Old World countries, with an emphasis on *P. pseudoinsulata*. The moth, which has caterpillars which feed on the leaves of chromolaena, has been released in 15 countries, and established in 10. In most countries in which it established, the moth acted as an outbreak species, initially building up to high numbers and causing widespread defoliation of the weed. However,

*P. insulata* pupa

Damage to *C. odorata* leaves in Florida caused by *P. insulata* larvae. Mid-instar larvae typically remove a triangular are between the larger veins on the leaf during one night's feeding. Larvae feed from underneath the leaf

Damage to *C. odorata* leaves in Florida caused by older *P. insulata* larvae, which typically leave only the mid-vein after a night's feeding

A *C. odorata* bush in South Africa largely defoliated by *P. insulata* larvae. The leaves have turned yellow in response to heavy feeding

*C. odorata* plants are visible as grey patches

except for on some Pacific islands, it subsequently fell to low densities and has not been a satisfactory agent in the long term. *A. brunneonigrum*, whose larvae feed in the flowers, did not establish in any of the six countries in which it was released.

A third neotropical arthropod, the leaf-galling mite *Acalitus adoratus* (Acari: Eriophyidae), became accidentally established in South East Asia, probably through infected plant material used in field releases of *A. brunneonigrum* in the 1980s. However, its impact has not been evaluated and is unlikely to be very high.

In the 1990s, a project in South East Asia funded by the Australian Centre for International Agricultural Research (ACIAR) imported the stem-galling tephritid, *Cecidochares connexa*, into Sumatra for host-range testing. The first releases were made in 1995, and since then, the fly has been widely redistributed throughout South-East Asia and also spread by itself. It has proved a great success, consistently damaging plants over time, resulting in die-back and thinning of plants. It has subsequently been released in 10 countries, establishing in all but one of these.

In South Africa, which has a different chromolaena biotype ('SA biotype') to that of South-East Asia ('AWA biotype'), the biocontrol programme started in the late 1980s. Problems were initially encountered because the origin of the SA biotype could not be ascertained, and some of the insects (including *C. connexa*), and all the pathogens, imported into quarantine in South Africa, did not develop on this form. Furthermore, field releases of two *Pareuchaetes* species did not result in establishment. However, recent studies suggest that the probable origin of the SA biotype is Jamaica, Cuba or another island in the northern Caribbean. In addition, *Pareuchaetes insulata* and the leaf-mining fly *Calycomyza eupatorivora* (Diptera: Agromyzidae) are now established.

*Funding:*
Several sources of funding have contributed towards research on the biocontrol of *C. odorata* over the years (McFadyen, 1996). Funding for the initial surveys in the 1960s was provided by the Nigerian Institute for Oil Palm Research. Sustained funding from national governments in Ghana (in the 1990s), South Africa and Micronesia allowed biocontrol programmes to be undertaken in those countries. International funding from ACIAR was provided for projects in Indonesia, the Philippines, Papua New Guinea (PNG) and East Timor during the 1990s and 2000s. The International Organization for Biological Control of Noxious Animals and Plants (IOBC) provided seeding money and institutional support for several international workshops and publications. However, not all international interventions have proved successful. A project funded by the European Economic Community from 1990-1992 produced limited results due to its short duration, and a UN Food and Agriculture Organization project in West Africa was blocked due to the controversy surrounding the usefulness of *C. odorata* as a fallow crop. Chromolaena remains a major weed in numerous countries so backing from national and international sources for control programmes is still necessary

## Current research and other projects

Currently this is the only project world-wide that is investigating the host range and efficacy of new biocontrol agents. The project is conducted from Cedara, KZN (insects) and Stellenbosch, Western Cape (pathogens). The project concentrates on insects which will be compatible with the SA biotype of chromolaena and those which will tolerate prolonged dry periods and fire. All attack different parts of the stem. [read more]

## Other Insects

Other insects have been considered over the years, and some of these were released but did not establish. [read more]

## References

KEY REFERENCES AND HOST RANGE STUDIES (not all cited in text):

Barreto, R.W. and Evans, H.C. (1994) The mycobiota of the weed *Chromolaena odorata* in southern Brazil with particular reference to fungal pathogens for biological control. *Mycological Research* 98: 1107-1116.

Bennett, F. D. and Cruttwell, R. E. (1973) Insects attacking *Eupatorium odoratum* in the neotropics. 1. Ammalo insulata (Walk.) (Lep., Arctiidae), a potential biotic agent for the control of Eupatorium odoratum L. (Compositae). *Technical Bulletin of the Commonwealth Institute of Biological Control* 16: 105-115.

Brown, J.W. and Zachariades, C. (2007) A new species of *Dichrorampha* (Lepidoptera: Tortricidae: Grapholitini) from Jamaica: a potential biocontrol agent against *Chromolaena odorata (Asteraceae). Proceedings of the Entomological Society of Washington* 109: 938-947.

Caldwell, P. M. and Kluge, R. L. (1993) Failure of the introduction of *Actinote anteas* (Lep.: Acraeidae) from Costa Rica as a biological control candidate for *Chromolaena odorata* (Asteraceae) in South Africa. *Entomophaga* 38: 475 478.

Cock, M. J. W. (1984) Possibilities for biological control of *Chromolaena odorata. Tropical Pest Management* 30: 7-13.

Cock, M. J. W. and Holloway, J. D. (1982) The history of, and prospects for, the biological control of *Chromolaena odorata* (Compositae) by *Pareuchaetes pseudoinsulata* Rego Barros and allies (Lepidoptera: Arctiidae). *Bulletin of Entomological Research*, 72, 193-205.

Cruttwell, R. E. (1973a) Insects attacking *Eupatorium odoratum* in the neotropics. 3. *Dichomeris* sp. nov. (=Trichotaphe sp. nr eupatoriella) (Lep.: Gelechiidae), a leaf-roller on *Eupatorium odoratum* L. (Compositae). *Technical Bulletin of the Commonwealth Institute of Biological Control* 16: 125-134.

Cruttwell, R. E. (1973b) Insects attacking *Eupatorium odoratum* in the neotropics. 2. Studies of the seed weevil *Apion brunneonigrum* B.B., and its potential use to control *E. odoratum* L.. *Technical Bulletin of the Commonwealth Institute of Biological Control* 16: 117-124.

Cruttwell, R. E. (1974). Insects and mites attacking *Eupatorium odoratum* in the neotropics. 4. An annotated list of the insects and mites recorded from *Eupatorium odoratum* L., with a key to the types of damage found in Trinidad. *Technical Bulletin of the Commonwealth Institute of Biological Control*, 17, 87-125.

Cruttwell, R. E. (1977a) Insects attacking *Eupatorium odoratum* L. in the Neotropics. 5. *Mescinia* sp. nr. *parvula* (Zeller). *Technical Bulletin of the Commonwealth Institute of Biological Control* 18: 49-58.

Cruttwell, R. E. (1977b) Insects and mites attacking *Eupatorium odoratum* L. in the Neotropics. 6. Two eriophyid mites, *Acalitus adoratus* Keifer and *Phyllocoptes cruttwellae* Keifer. *Technical Bulletin of the Commonwealth Institute of Biological Control* 18: 59-63.

Day, M. and Bofeng, I. (2007). The status of biocontrol of *Chromolaena odorata* in Papua New Guinea. In *Proceedings of the Seventh International Workshop on Biological Control and Management of Chromolaena and Mikania*, ed. P.-Y. Lai, G.V.P. Reddy and R. Muniappan. Taiwan: National Pingtung University, pp. 53–67.

Desmier de Chenon, R., Sipayung, A. and Sudharto, A. (2002) A new biological agent, *Actinote anteas*, introduced into Indonesia from South America for the control of *Chromolaena odorata*. In *Proceedings of the Fifth International Workshop on Biological Control and Management of Chromolaena odorata*, ed. C. Zachariades, R. Muniappan and L.W. Strathie. Pretoria, South Africa: ARC-PPRI, pp. 170-176.

Eichlin, T.D., Delgado, O.S., Strathie, L.W., Zachariades, C. and Clavijo, J. (2009) *Carmenta* chromolaena Eichlin, a new species (Lepidoptera: Sesiidae) for the biological control of Chromolaena odorata (L.) King & Robinson (Asteraceae).

Elango, D.E., Holden, A.N.G. and Prior, C. (1993) The potential of plant pathogens collected in Trinidad for biological control of *Chromolaena odorata* (L.) King & Robinson. *International Journal of Pest Management* 39: 393-396.

Julien, M. H. and Griffiths, M. W. (1998) *Biological Control of Weeds: a World Catalogue of Agents and their Target Weeds*, 4th edn. Wallingford, UK: CAB International Publishing.

Kluge, R. L. (1990) Prospects for the biological control of triffid weed, *Chromolaena odorata*, in Southern Africa. *South African Journal of Science* 86: 229 230.

Kluge, R. L. and Caldwell, P. M. (1993a) Host specificity of *Pareuchaetes insulata* (Lep.: Arctiidae), a biological control agent for *Chromolaena odorata* (Compositae). *Entomophaga* 38: 451 457.

Kluge, R. L. and Caldwell, P. M. (1993b) The biology and host specificity of *Pareuchaetes aurata aurata* (Lepidoptera: Arctiidae), a “new association” biological *control agent for Chromolaena odorata (Compositae).* Bulletin of Entomological Research 83: 87-94.

Kluge, R.L. and Caldwell, P.M. (1994) *Dysschema sacrifica* Hubner (Lep: Arctiidae) from Brazil: a biological control candidate for *Chromolaena odorata* (L.) R.M. King & H. Robinson (Asteraceae) in South Africa. *Chromolaena odorata Newsletter* 8: 1-2.

Kluge, R.L. and Zachariades, C. (2006) Assessing the damage potential of the stem-boring weevil *Lixus aemulus* for the biological control of *Chromolaena odorata. BioControl* 51: 547-552.

McFadyen, R.E.C. (1988) Phytophagous insects recorded from *C. odorata. Chromolaena odorata Newsletter* 2: 5-23.

McFadyen, R.E.C. (1995) The accidental introduction of the *Chromolaena* mite, *Acalitus adoratus*, into South-East Asia. In *Proceedings of the Eighth International Symposium on Biological Control of Weeds*, ed. E.S. Delfosse and R.R. Scott. Melbourne: DSIR/CSIRO, pp. 649-652.

McFadyen, R. C. (1996). Biocontrol of *Chromolaena odorata*: divided we fail. In *Proceedings of the Ninth International Symposium on Biological Control of Weeds*, ed. V.C. Moran and J.H. Hoffmann. Cape Town: University of Cape Town Press, pp. 455-459.

McFadyen, R. E. C., Desmier de Chenon, R. and Sipayung, A. (2003) Biology and host specificity of the chromolaena stem gall fly, *Cecidochares connexa* (Macquart) (Diptera: Tephritidae). *Australian Journal of Entomology* 42: 294-297.

Martinez, M., Etienne, J., Abud-Antun, A. and Reyes, M. (1993) Les Agromyzidae de la Republique Dominicaine (Diptera). *Bulletin de la Societe entomologique de France*, 98, 165-179.

Muniappan, R., Reddy, G.V.P. and Lai, P.Y. (2005) Distribution and Biological Control of *Chromolaena odorata*. In *Invasive Plants: Ecological and Agricultural Aspects*, ed. Inderjit. Basel, Switzerland: Birkhauser Verlag, pp. 223-233.

Seibert, T. F. (1989) Biological *control of the weed, Chromolaena odorata (Asteraceae), by* Pareuchaetes pseudoinsulata (Lepidoptera: Arctiidae) on Guam and the Northern Mariana Islands. *Entomophaga* 35: 531-539.

Solis, M.A., Metz, M.A., & Zachariades, C. (2008) Identity and generic placement of *Phestinia* costella Hampson (Lepidoptera: Pyralidae: Phycitinae) reared on the invasive plant Chromolaena odorata (L.) R.M. King & H. Rob. (Asteraceae). *Proceedings of the Entomological Society of Washington*. 110: 292-301.

Spencer, K.A. & Stegmaier, C.E. (1973) Agromyzidae of Florida, with a supplement on species from the Caribbean. *Arthropods of Florida and neighbouring land areas, Vol. 7. Contribution No. 171, Bureau of Entomology, Florida Department of Agriculture & Consumer Services.*

Waterhouse, D. F. (1994b) *Biological Control of Weeds: Southeast Asian Prospects. ACIAR Monograph* 26: 1-302.

Zachariades C. and Strathie L. W. (2006) Biocontrol of chromolaena in South Africa: recent activities in research and implementation. *Biocontrol News and Information*, 27, 10N-15N.

Zachariades, C., Strathie, L. W. and Kluge, R. L. (2002) Biology, host specificity and effectiveness of insects for the biocontrol of *Chromolaena odorata* in South Africa. In *Proceedings of the Fifth International Workshop on Biological Control and Management of Chromolaena odorata*, ed. C. Zachariades, R. Muniappan and L. W. Strathie. Pretoria, South Africa: ARC-PPRI, pp. 160-166.

Zachariades, C., Strathie, L., Delgado, O. and Retief, E. (2007). Pre-release research on biocontrol agents for chromolaena in South Africa. In *Proceedings of the Seventh International Workshop on Biological Control and Management of Chromolaena and Mikania*, ed. P.-Y. Lai, G.V.P. Reddy and R. Muniappan, National Pingtung University, Taiwan, pp. 68-80.

Zachariades, C., Day, M., Muniappan, R. and Reddy, G.V.P. (2009) *Chromolaena odorata* (L.) King and Robinson (Asteraceae). Chapter 8 in: *Biological Control of Tropical Weeds using Arthropods. Muniappan*, R., Reddy, G.V.P. and Raman, A. (eds). Cambridge University Press. pp. 130-162.

Appendix 3-12

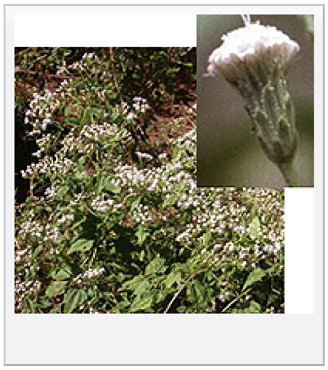
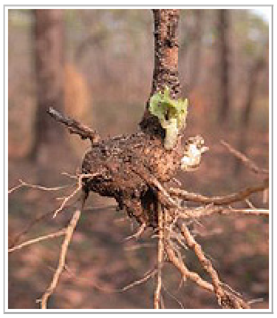


# Differences between AWA and SA Chromolaena


What is Chromolaena?
Biological Control
Workshops
Newsletters
Expertise
Other invasive alien plants within the Eupatorieae
Bibliography
Useful links

| Character | AWA | SA |
|---|---|---|
| **Leaves** |  Fine hairs giving a soft texture, particularly to younger leaves<br>Grey-green to dark green<br>Young leaves often purple, especially when growing in sun<br>Leaves often larger, more prominently ribbed |  Largely smooth<br>Yellow-green when growing in sun, dark green in semi-shade<br>Young leaves often red, especially when growing in sun<br>Leaves generally smaller |
| **Stems** | Hairy, grey-green to dark green | Largely smooth, yellow-green |
| **Flowers** | Pale lilac<br>Broader individual flowers<br>Bracts with sharp tips, lax around flower-head | White<br>Narrower individual flowers<br>Bracts with rounded tips, tight around flower-head |

Appendix 3-12

| | | |
|---|---|---|
| |  |  |
| **Crown** | Larger plants have underground 'corm' structure  | 'Corm' less prominent |
| **Growth form** | Branches more lax | More upright growth form, especially young growth in dense stands |
| **Ecology** | May be more fire resistant, resprouting from crown<br>May be more adapted to tropical conditions | May be more susceptible to fire. Burning frequently kills large plants<br>May be more cool tolerant (Kriticos et al., 2005) |

## Photographic acknowledgements

All AWA chromolaena biotype photos courtesy of Colin Wilson, except for photo of corm from Joshi (2006). All SA chromolaena biotype photos courtesy of ARC-PPRI.

## References

Kriticos, D. J., Yonow, T. and McFadyen, R. E. (2005) The potential distribution of *Chromolaena odorata* (Siam weed) in relation to climate. Weed Research 45: 246-254.

Joshi, C. (2006) Mapping cryptic invaders and invasibility of tropical forest ecosystems: *Chromolaena odorata* in Nepal. Dissertation, International Institute for Geo-information Science & Earth Observation, Enschede, the Netherlands.

Zachariades, C., Day, M.D., Muniappan, R. and Reddy, G.V.P. (2009) *Chromolaena odorata* (Asteraceae) and its biological control. In: Muniappan, R., Reddy, G.V.P., Raman, A. (Eds.), Biological Control of Tropical Weeds using Arthropods. Cambridge University Press, Cambridge. pp. 130-162.

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Alectryon macrococcus var. macrococcus

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Keawapilau** | Manage for stability | 2 | 6 | 0 | 1 | 1 | 0 | **0** | **1** | **0** | 0 | 0 | 0 | 0 | 1 | 0 | 2017-02-08 | Monitoring showed a decline |
| **Makua** | Manage for stability | 15 | 0 | 0 | 4 | 0 | 0 | **4** | **0** | **0** | 4 | 0 | 0 | 0 | 0 | 0 | 2017-02-14 | No changes observed in the last year |
| **South Mohiakea** | Genetic Storage | 16 | 1 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2017-01-24 | No changes observed in the last year |
| **West Makaleha** | Genetic Storage | 40 | 4 | 0 | 13 | 0 | 0 | **3** | **0** | **0** | 3 | 0 | 0 | 0 | 0 | 0 | 2018-06-06 | A thorough census has shown a substantial decline |
| | **In Total:** | 73 | 11 | 0 | 20 | 1 | 0 | **9** | **1** | **0** | 9 | 0 | 0 | 0 | 1 | 0 | | |

## Action Area: Out

### TaxonName: Alectryon macrococcus var. macrococcus

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Central Kaluaa to Central Waieli** | Manage for stability | 50 | 3 | 0 | 3 | 1 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2018-03-15 | Monitoring in the last year showed a decline |
| **Makaha** | Manage for stability | 75 | 0 | 2 | 29 | 0 | 0 | **11** | **0** | **0** | 11 | 0 | 0 | 0 | 0 | 0 | 2018-05-01 | A thorough census has shown a substantial decline |
| **Waianae Kai** | Genetic Storage | 16 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2016-06-13 | No monitoring in the last year |
| | **Out Total:** | 141 | 3 | 2 | 32 | 1 | 0 | **13** | **0** | **0** | 13 | 0 | 0 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 214 | 14 | 2 | 52 | 2 | 0 | **22** | **1** | **0** | 22 | 0 | 0 | 0 | 1 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

## TaxonName: Abutilon sandwicense

Target # of Matures: 50 # MFS PU Met Goal: 3 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kaawa to Puulu** | Manage for stability | 36 | 88 | 6 | 27 | 176 | 1 | **27** | **187** | **0** | 27 | 187 | 0 | 0 | 0 | 0 | 2018-04-26 | A thorough census has shown an increase in the immature age class |
| **Kahanahaiki** | Manage reintroduction for stability | 0 | 0 | 0 | 69 | 5 | 0 | **69** | **5** | **0** | 0 | 0 | 0 | 69 | 5 | 0 | 2017-02-07 | No changes observed in the last year |
| **Kaluakauila** | Manage reintroduction for storage | 0 | 4 | 0 | 0 | 3 | 0 | **0** | **3** | **0** | 0 | 0 | 0 | 0 | 3 | 0 | 2016-08-16 | No changes observed in the last year |
| **Keaau** | Genetic Storage | 1 | 0 | 10 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2016-09-07 | No changes observed in the last year |
| | **In Total:** | 37 | 92 | 16 | 96 | 184 | 1 | **96** | **195** | **0** | 27 | 187 | 0 | 69 | 8 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: Out

## TaxonName: Abutilon sandwicense

Target # of Matures: 50 # MFS PU Met Goal: 3 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **East Makaleha** | Genetic Storage | 2 | 2 | 40 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2013-09-10 | No monitoring in the last year |
| **Ekahanui and Huliwai** | Manage for stability | 14 | 30 | 0 | 57 | 118 | 0 | **54** | **99** | **30** | 2 | 26 | 30 | 52 | 73 | 0 | 2018-02-13 | A thorough census has shown a small decline in the immature age class but an increase in number of seedlings |
| **Halona** | Genetic Storage | 0 | 0 | 0 | 10 | 5 | 0 | **10** | **5** | **0** | 10 | 5 | 0 | 0 | 0 | 0 | 2016-08-15 | No changes observed in the last year |
| **Makaha Makai** | Manage for stability | 73 | 27 | 6 | 92 | 133 | 0 | **92** | **133** | **0** | 92 | 133 | 0 | 0 | 0 | 0 | 2015-07-08 | A new census was initiated but not yet completed |
| **Makaha Mauka** | Genetic Storage | 5 | 58 | 4 | 13 | 1 | 0 | **29** | **16** | **0** | 29 | 16 | 0 | 0 | 0 | 0 | 2017-08-16 | A thorough census led to more plants being discovered |
| **Nanakuli** | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **North Mikilua** | Genetic Storage | 2 | 39 | 0 | 9 | 11 | 0 | **9** | **11** | **0** | 9 | 11 | 0 | 0 | 0 | 0 | 2012-07-19 | No monitoring in the last year |
| **South Mikilua** | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Waianae Kai** | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2015-07-09 | No monitoring in the last year |
| **West Makaleha** | Genetic Storage | 0 | 2 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2012-09-17 | No monitoring in the last year |
| | **Out Total:** | 98 | 158 | 50 | 181 | 268 | 0 | **194** | **264** | **30** | 142 | 191 | 30 | 52 | 73 | 0 | | |
| | **Total for Taxon:** | 135 | 250 | 66 | 277 | 452 | 1 | **290** | **459** | **30** | 169 | 378 | 30 | 121 | 81 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

### TaxonName: Cyanea acuminata

Target # of Matures: 50 — # MFS PU Met Goal: 3 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Helemano-Punaluu Summit Ridge to North Kaukonahua** | Manage for stability | 59 | 13 | 7 | 96 | 109 | 9 | **81** | **77** | **0** | 81 | 77 | 0 | 0 | 0 | 0 | 2018-03-05 | Thorough monitoring in the last year showed a decline |
| **Kahana and South Kaukonahua** | Genetic Storage | 2 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 1993-01-01 | No monitoring in the last year |
| **Kawaiiki** | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Makaleha to Mohiakea** | Manage for stability | 85 | 33 | 0 | 195 | 89 | 0 | **195** | **89** | **0** | 195 | 89 | 0 | 0 | 0 | 0 | 2016-12-29 | No monitoring in the last year |
| | **In Total:** | 147 | 46 | 7 | 293 | 198 | 9 | **278** | **166** | **0** | 278 | 166 | 0 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Cyanea acuminata

Target # of Matures: 50 — # MFS PU Met Goal: 3 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahana and Makaua** | Genetic Storage | 5 | 0 | 0 | 11 | 3 | 0 | **11** | **3** | **0** | 11 | 3 | 0 | 0 | 0 | 0 | 2008-11-06 | No monitoring in the last year |
| **Kaipapau and Koloa** | Genetic Storage | 0 | 0 | 0 | 70 | 30 | 0 | **70** | **30** | **0** | 70 | 30 | 0 | 0 | 0 | 0 | 2013-12-16 | No monitoring in the last year |
| **Kaluanui and Maakua** | Manage for stability | 0 | 0 | 0 | 123 | 126 | 50 | **123** | **126** | **50** | 123 | 126 | 50 | 0 | 0 | 0 | 2015-01-14 | No monitoring in the last year |
| **Konahuanui** | Genetic Storage | 30 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Pia** | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Puukeahiakahoe** | Genetic Storage | 3 | 0 | 0 | 3 | 0 | 0 | **3** | **0** | **0** | 3 | 0 | 0 | 0 | 0 | 0 | 1997-02-04 | No monitoring in the last year |
| **Puuokona** | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| | **Out Total:** | 39 | 0 | 0 | 207 | 159 | 50 | **207** | **159** | **50** | 207 | 159 | 50 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 186 | 46 | 7 | 500 | 357 | 59 | **485** | **325** | **50** | 485 | 325 | 50 | 0 | 0 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

## TaxonName: Cyanea koolauensis

Target # of Matures: 50 # MFS PU Met Goal: 1 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kaipapau, Koloa and Kawainui** | Manage for stability | 51 | 25 | 6 | 113 | 12 | 0 | **113** | **12** | **0** | 113 | 12 | 0 | 0 | 0 | 0 | 2017-05-10 | A new census was initiated but not yet completed |
| **Kamananui-Kawainui Ridge** | Genetic Storage | 6 | 2 | 0 | 6 | 2 | 0 | **6** | **2** | **0** | 6 | 2 | 0 | 0 | 0 | 0 | 2001-03-12 | No monitoring in the last year |
| **Kaukonahua** | Genetic Storage | 11 | 1 | 0 | 8 | 3 | 0 | **8** | **3** | **0** | 8 | 3 | 0 | 0 | 0 | 0 | 2015-07-01 | No monitoring in the last year |
| **Kawaiiki** | Genetic Storage | 3 | 4 | 0 | 4 | 4 | 0 | **4** | **4** | **0** | 4 | 4 | 0 | 0 | 0 | 0 | 2000-01-01 | No monitoring in the last year |
| **Lower Opaeula** | Genetic Storage | 3 | 1 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2011-07-12 | No monitoring in the last year |
| **Opaeula to Helemano** | Manage for stability | 10 | 3 | 0 | 21 | 7 | 0 | **21** | **7** | **0** | 21 | 7 | 0 | 0 | 0 | 0 | 2016-09-28 | No monitoring in the last year |
| **Poamoho** | Manage for stability | 12 | 0 | 0 | 20 | 19 | 0 | **20** | **19** | **0** | 20 | 19 | 0 | 0 | 0 | 0 | 2017-05-02 | No monitoring in the last year |
| | **In Total:** | 96 | 36 | 6 | 173 | 47 | 0 | **173** | **47** | **0** | 173 | 47 | 0 | 0 | 0 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: Out

## TaxonName: Cyanea koolauensis

Target # of Matures: 50 | # MFS PU Met Goal: 1 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Halawa** | Genetic Storage | 3 | 0 | 0 | 4 | 0 | 0 | **4** | **0** | **0** | 4 | 0 | 0 | 0 | 0 | 0 | 1990-09-16 | No monitoring in the last year |
| **Halawa-Kalauao Ridge** | Genetic Storage | 6 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Lulumahu** | Genetic Storage | 10 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Waialae Nui** | Genetic Storage | 2 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 1990-09-06 | No monitoring in the last year |
| **Waiawa to Waimano** | Genetic Storage | 1 | 0 | 0 | 11 | 2 | 0 | **11** | **2** | **0** | 11 | 2 | 0 | 0 | 0 | 0 | 2012-09-18 | No monitoring in the last year |
| **Wailupe** | Genetic Storage | 15 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2006-08-10 | No monitoring in the last year |
| **Waimalu** | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| | **Out Total:** | 39 | 0 | 0 | 18 | 2 | 0 | **18** | **2** | **0** | 18 | 2 | 0 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 135 | 36 | 6 | 191 | 49 | 0 | **191** | **49** | **0** | 191 | 49 | 0 | 0 | 0 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

### TaxonName: Eugenia koolauensis

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aimuu** | Genetic Storage | 0 | 0 | 0 | 8 | 10 | 0 | **8** | **10** | **0** | 8 | 10 | 0 | 0 | 0 | 0 | 2015-04-09 | No monitoring in the last year |
| **Kaiwikoele and Kamananui** | Genetic Storage | 16 | 16 | 15 | 21 | 26 | 1 | **17** | **26** | **1** | 17 | 26 | 1 | 0 | 0 | 0 | 2016-03-30 | Thorough monitoring in the last year showed a decline |
| **Kaleleiki** | Genetic Storage | 25 | 30 | 250 | 14 | 54 | 80 | **14** | **46** | **80** | 14 | 46 | 80 | 0 | 0 | 0 | 2015-05-06 | Thorough monitoring in the last year showed a decline |
| **Kaunala** | Manage for stability | 48 | 93 | 6 | 20 | 39 | 27 | **15** | **39** | **27** | 15 | 39 | 27 | 0 | 0 | 0 | 2017-04-04 | Thorough monitoring in the last year showed a decline |
| **Malaekahana** | Genetic Storage | | | | 0 | 4 | 0 | **0** | **4** | **0** | 0 | 4 | 0 | 0 | 0 | 0 | 2017-04-04 | |
| **Ohiaai and East Oio** | Genetic Storage | 5 | 8 | 10 | 1 | 1 | 0 | **1** | **1** | **0** | 1 | 1 | 0 | 0 | 0 | 0 | 2015-03-18 | No monitoring in the last year |
| **Oio** | Manage for stability | 18 | 56 | 0 | 6 | 2 | 0 | **6** | **2** | **0** | 6 | 2 | 0 | 0 | 0 | 0 | 2015-07-07 | No monitoring in the last year |
| **Pahipahialua** | Manage for stability | 57 | 234 | 1 | 22 | 6 | 141 | **18** | **6** | **124** | 18 | 6 | 124 | 0 | 0 | 0 | 2015-10-07 | Thorough monitoring in the last year showed a decline |
| | **In Total:** | 169 | 437 | 282 | 92 | 142 | 249 | **79** | **134** | **232** | 79 | 134 | 232 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Eugenia koolauensis

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hanaimoa** | Genetic Storage | 1 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2015-06-25 | No monitoring in the last year |
| **Palikea and Kaimuhole** | Genetic Storage | 3 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2014-05-28 | No monitoring in the last year |
| **Papali** | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| | **Out Total:** | 5 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 174 | 437 | 282 | 94 | 142 | 249 | **81** | **134** | **232** | 81 | 134 | 232 | 0 | 0 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

## TaxonName: Gardenia mannii

Target # of Matures: 50 # MFS PU Met Goal: 1 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Haleauau** | Manage for stability | 2 | 0 | 0 | 74 | 0 | 0 | **60** | **4** | **0** | 2 | 0 | 0 | 58 | 4 | 0 | 2018-02-21 | Thorough monitoring in the last year showed a decline |
| **Helemano and Poamoho** | Manage for stability | 18 | 0 | 0 | 22 | 1 | 0 | **23** | **0** | **0** | 23 | 0 | 0 | 0 | 0 | 0 | 2018-06-20 | Small changes were noted during monitoring in the last year |
| **Kaiwikoele, Kamananui, and Kawainui** | Genetic Storage | 20 | 0 | 0 | 13 | 0 | 0 | **13** | **0** | **0** | 13 | 0 | 0 | 0 | 0 | 0 | 2015-06-17 | No monitoring in the last year |
| **Lower Peahinaia** | Manage for stability | 45 | 1 | 0 | 10 | 12 | 0 | **9** | **30** | **0** | 9 | 0 | 0 | 0 | 30 | 0 | 2018-05-22 | More plants were added to the outplanting site |
| **South Kaukonahua** | Genetic Storage | 2 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2018-04-10 | No monitoring in the last year |
| **Upper Opaeula/Helemano** | Genetic Storage | 1 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2017-12-11 | No changes observed in the last year |
| | **In Total:** | 88 | 1 | 0 | 122 | 13 | 0 | **108** | **34** | **0** | 50 | 0 | 0 | 58 | 34 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: Out

## TaxonName: Gardenia mannii

Target # of Matures: 50 | # MFS PU Met Goal: 1 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ihiihi-Kawainui ridge** | Genetic Storage | 2 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 1993-01-01 | No data available as of 1993 |
| **Kahana and Makaua** | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Kaipapau to Punaluu** | Genetic Storage | 4 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Kalauao** | Genetic Storage | 4 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Kaluaa and Maunauna** | Genetic Storage | 1 | 0 | 0 | 2 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2017-05-11 | Thorough monitoring in the last year showed a decline |
| **Kamananui-Malaekahana Summit Ridge** | Genetic Storage | 13 | 0 | 0 | 3 | 0 | 0 | **3** | **0** | **0** | 3 | 0 | 0 | 0 | 0 | 0 | 2015-08-25 | No monitoring in the last year |
| **Kapakahi** | Genetic Storage | 4 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2016-06-25 | No changes observed in the last year |
| **Manana-Waimano Ridge** | Genetic Storage | 4 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No changes observed in the last year |
| **Pukele** | Genetic Storage | 1 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 1986-07-29 | No data available as of 1986 |
| **Waialae Nui** | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| | **Out Total:** | 36 | 0 | 0 | 10 | 0 | 0 | **9** | **0** | **0** | 9 | 0 | 0 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 124 | 1 | 0 | 132 | 13 | 0 | **117** | **34** | **0** | 59 | 0 | 0 | 58 | 34 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

### TaxonName: Hesperomannia swezeyi

Target # of Matures: 25 | # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kamananui to Kaluanui** | Manage for stability | 54 | 45 | 14 | 134 | 112 | 45 | **134** | **112** | **45** | 134 | 112 | 45 | 0 | 0 | 0 | 2017-05-10 | A new census was initiated but not yet completed |
| **Kaukonahua** | Manage for stability | 76 | 51 | 122 | 55 | 54 | 2 | **55** | **54** | **2** | 55 | 54 | 2 | 0 | 0 | 0 | 2015-07-29 | A new census was initiated but not yet completed |
| **Lower Opaeula** | Manage for stability | 9 | 15 | 0 | 11 | 15 | 6 | **11** | **15** | **6** | 11 | 15 | 6 | 0 | 0 | 0 | 2017-05-03 | A new census was initiated but not yet completed |
| **Ohiaai ridge** | Genetic Storage | 5 | 1 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Poamoho** | Genetic Storage | 38 | 16 | 3 | 13 | 1 | 4 | **13** | **1** | **4** | 13 | 1 | 4 | 0 | 0 | 0 | 2017-05-03 | No monitoring in the last year |
| | **In Total:** | 182 | 128 | 139 | 213 | 182 | 57 | **213** | **182** | **57** | 213 | 182 | 57 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Hesperomannia swezeyi

Target # of Matures: 25 | # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Halawa** | Genetic Storage | 3 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Kapakahi** | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| **Niu-Waimanalo Summit Ridge** | Genetic Storage | 4 | 0 | 0 | 1 | 4 | 1 | **1** | **4** | **1** | 1 | 4 | 1 | 0 | 0 | 0 | 2015-05-29 | No monitoring in the last year |
| **Waimano** | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| | **Out Total:** | 8 | 0 | 0 | 1 | 4 | 1 | **1** | **4** | **1** | 1 | 4 | 1 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 190 | 128 | 139 | 214 | 186 | 58 | **214** | **186** | **58** | 214 | 186 | 58 | 0 | 0 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

### TaxonName: Labordia cyrtandrae

Target # of Matures: 50 | # MFS PU Met Goal: 1 of 2

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **East Makaleha to North Mohiakea** | Manage for stability | 84 | 16 | 2 | 294 | 49 | 0 | **275** | **35** | **0** | 68 | 0 | 0 | 207 | 35 | 0 | 2018-03-05 | Thorough monitoring in the last year showed a decline |
| | **In Total:** | 84 | 16 | 2 | 294 | 49 | 0 | **275** | **35** | **0** | 68 | 0 | 0 | 207 | 35 | 0 | | |

## Action Area: Out

### TaxonName: Labordia cyrtandrae

Target # of Matures: 50 | # MFS PU Met Goal: 1 of 2

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Koloa** | Manage reintroduction for stability | | | | 9 | 22 | 0 | **3** | **19** | **0** | 0 | 0 | 0 | 3 | 19 | 0 | 2018-06-14 | Thorough monitoring in the last year showed a decline |
| | **Out Total:** | | | | 9 | 22 | 0 | **3** | **19** | **0** | 0 | 0 | 0 | 3 | 19 | 0 | | |
| | **Total for Taxon:** | 84 | 16 | 2 | 303 | 71 | 0 | **278** | **54** | **0** | 68 | 0 | 0 | 210 | 54 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

## TaxonName: Phyllostegia hirsuta

Target # of Matures: 100 | # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Haleauau to Mohiakea** | Manage for stability | 6 | 12 | 0 | 96 | 2 | 0 | **47** | **2** | **0** | 11 | 2 | 0 | 36 | 0 | 0 | 2018-04-16 | Thorough monitoring in the last year showed a decline |
| **Helemano and Opaeula** | Genetic Storage | 14 | 5 | 6 | 1 | 4 | 0 | **1** | **4** | **0** | 1 | 4 | 0 | 0 | 0 | 0 | 2013-11-20 | No monitoring in the last year |
| **Helemano and Poamoho** | Genetic Storage | 1 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2016-06-02 | No monitoring in the last year |
| **Kaipapau and Kawainui** | Genetic Storage | 7 | 0 | 0 | 4 | 0 | 0 | **4** | **0** | **0** | 4 | 0 | 0 | 0 | 0 | 0 | 2013-12-17 | No monitoring in the last year |
| **Kaukonahua** | Genetic Storage | 4 | 2 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2010-07-28 | No monitoring in the last year |
| **Kawaiiki** | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2008-10-09 | No monitoring in the last year |
| **Koloa** | Manage for stability | 0 | 0 | 0 | 111 | 38 | 1 | **26** | **6** | **1** | 9 | 2 | 1 | 17 | 4 | 0 | 2018-06-14 | Thorough monitoring in the last year showed a decline |
| | **In Total:** | 32 | 19 | 6 | 214 | 44 | 1 | **80** | **12** | **1** | 27 | 8 | 1 | 53 | 4 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: Out

## TaxonName: Phyllostegia hirsuta

Target # of Matures: 100 # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hapapa to Kaluaa** | Genetic Storage | 11 | 9 | 7 | 1 | 27 | 0 | **0** | **7** | **0** | 0 | 7 | 0 | 0 | 0 | 0 | 2018-02-13 | Thorough monitoring in the last year showed a decline |
| **Kaluanui and Punaluu** | Genetic Storage | 5 | 0 | 0 | 5 | 3 | 0 | **5** | **3** | **0** | 5 | 3 | 0 | 0 | 0 | 0 | 2011-05-17 | No monitoring in the last year |
| **Makaha-Waianae Kai Ridge** | Genetic Storage | 2 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2016-09-19 | No monitoring in the last year |
| **Palawai** | Genetic Storage | 0 | 1 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2009-03-03 | No monitoring in the last year |
| **Puu Palikea** | Manage reintroduction for stability | | | | 87 | 55 | 0 | **22** | **11** | **3** | 0 | 0 | 0 | 22 | 11 | 3 | 2018-04-16 | Thorough monitoring in the last year showed a decline |
| **Waiamano** | Genetic Storage | | | | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2006-01-01 | No monitoring in the last year |
| | **Out Total:** | 18 | 10 | 7 | 95 | 85 | 0 | **29** | **21** | **3** | 7 | 10 | 0 | 22 | 11 | 3 | | |
| | **Total for Taxon:** | 50 | 29 | 13 | 309 | 129 | 1 | **109** | **33** | **4** | 34 | 18 | 1 | 75 | 15 | 3 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

### TaxonName: Phyllostegia mollis

Target # of Matures: 100 | # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mohiakea** | Genetic Storage | 0 | 4 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2017-05-24 | No changes observed in the last year |
| | **In Total:** | 0 | 4 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Phyllostegia mollis

Target # of Matures: 100 | # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ekahanui** | Manage for stability | 35 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 0 | 0 | 0 | 1 | 0 | 0 | 2016-05-11 | No monitoring in the last year |
| **Kaluaa** | Manage for stability | 38 | 11 | 0 | 72 | 25 | 0 | **42** | **1** | **7** | 0 | 0 | 0 | 42 | 1 | 7 | 2018-06-06 | Thorough monitoring in the last year showed a decline |
| **Pualii** | Manage reintroduction for stability | 0 | 0 | 0 | 11 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2017-08-16 | The outplants died |
| **Waieli** | Genetic Storage | 0 | 0 | 0 | 1 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2018-04-12 | The plant has died |
| | **Out Total:** | 73 | 11 | 0 | 85 | 25 | 0 | **43** | **1** | **7** | 0 | 0 | 0 | 43 | 1 | 7 | | |
| | **Total for Taxon:** | 73 | 15 | 0 | 86 | 25 | 0 | **44** | **1** | **7** | 1 | 0 | 0 | 43 | 1 | 7 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

## TaxonName: Schiedea trinervis

Target # of Matures: 50 # MFS PU Met Goal: 1 of 1

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kalena to East Makaleha** | Manage for stability | 180 | 196 | 318 | 296 | 351 | 377 | **296** | **351** | **377** | 296 | 351 | 377 | 0 | 0 | 0 | 2015-08-04 | A new census was initiated but not yet completed |
| | **In Total:** | 180 | 196 | 318 | 296 | 351 | 377 | **296** | **351** | **377** | 296 | 351 | 377 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 180 | 196 | 318 | 296 | 351 | 377 | **296** | **351** | **377** | 296 | 351 | 377 | 0 | 0 | 0 | | |

# Population Unit Status - Oahu Implementation Plan

## Action Area: In

### TaxonName: Stenogyne kanehoana

Target # of Matures: 100 | # MFS PU Met Goal: 1 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Haleauau** | Manage reintroduction for stability | 1 | 0 | 0 | 230 | 0 | 0 | **136** | **0** | **0** | 0 | 0 | 0 | 136 | 0 | 0 | 2017-07-20 | Thorough monitoring in the last year showed a decline |
| | **In Total:** | 1 | 0 | 0 | 230 | 0 | 0 | **136** | **0** | **0** | 0 | 0 | 0 | 136 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Stenogyne kanehoana

Target # of Matures: 100 | # MFS PU Met Goal: 1 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kaluaa** | Manage reintroduction for stability | 0 | 79 | 0 | 26 | 178 | 0 | **5** | **21** | **0** | 0 | 0 | 0 | 5 | 21 | 0 | 2018-06-25 | Thorough monitoring in the last year showed a decline |
| **Makaha** | Manage reintroduction for stability | | | | 0 | 60 | 0 | **0** | **8** | **0** | 0 | 0 | 0 | 0 | 8 | 0 | 2018-03-27 | Thorough monitoring in the last year showed a decline |
| | **Out Total:** | 0 | 79 | 0 | 26 | 238 | 0 | **5** | **29** | **0** | 0 | 0 | 0 | 5 | 29 | 0 | | |
| | **Total for Taxon:** | 1 | 79 | 0 | 256 | 238 | 0 | **141** | **29** | **0** | 0 | 0 | 0 | 141 | 29 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Cenchrus agrimonioides var. agrimonioides

Target # of Matures: 50 | # MFS PU Met Goal: 3 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki and Pahole** | Manage for stability | 210 | 66 | 0 | 200 | 76 | 20 | **195** | **73** | **17** | 64 | 26 | 15 | 131 | 47 | 2 | 2018-06-04 | A small decline was noted during monitoring in the last year |
| **Kuaokala** | Genetic Storage | | | | 1 | 3 | 0 | **1** | **3** | **0** | 1 | 3 | 0 | 0 | 0 | 0 | 2014-04-30 | No monitoring in the last year |
| | **In Total:** | 210 | 66 | 0 | 201 | 79 | 20 | **196** | **76** | **17** | 65 | 29 | 15 | 131 | 47 | 2 | | |

## Action Area: Out

### TaxonName: Cenchrus agrimonioides var. agrimonioides

Target # of Matures: 50 | # MFS PU Met Goal: 3 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Central Ekahanui** | Manage for stability | 20 | 0 | 0 | 184 | 118 | 54 | **203** | **58** | **44** | 67 | 36 | 41 | 136 | 22 | 3 | 2017-09-27 | Thorough monitoring in the last year showed a decline in immatures but an increase in mature plants |
| **Makaha and Waianae Kai** | Manage for stability | 9 | 3 | 0 | 161 | 128 | 5 | **164** | **126** | **0** | 7 | 3 | 0 | 157 | 123 | 0 | 2017-08-22 | Small changes were noted during monitoring in the last year |
| **South Huliwai** | Genetic Storage | 27 | 0 | 0 | 17 | 17 | 2 | **22** | **12** | **1** | 22 | 12 | 1 | 0 | 0 | 0 | 2017-07-25 | A thorough census has shown immature plants transition into mature plants |
| | **Out Total:** | 56 | 3 | 0 | 362 | 263 | 61 | **389** | **196** | **45** | 96 | 51 | 42 | 293 | 145 | 3 | | |
| | **Total for Taxon:** | 266 | 69 | 0 | 563 | 342 | 81 | **585** | **272** | **62** | 161 | 80 | 57 | 424 | 192 | 5 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Cyanea grimesiana subsp. obatae

Target # of Matures: 100 # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pahole to West Makaleha** | Manage for stability | 22 | 24 | 0 | 70 | 36 | 0 | **61** | **42** | **0** | 4 | 17 | 0 | 57 | 25 | 0 | 2017-10-31 | Small changes were noted during monitoring in the last year |
| | **In Total:** | 22 | 24 | 0 | 70 | 36 | 0 | **61** | **42** | **0** | 4 | 17 | 0 | 57 | 25 | 0 | | |

## Action Area: Out

### TaxonName: Cyanea grimesiana subsp. obatae

Target # of Matures: 100 # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kaluaa** | Manage for stability | 0 | 0 | 0 | 124 | 17 | 0 | **97** | **12** | **0** | 2 | 1 | 0 | 95 | 11 | 0 | 2017-10-23 | Thorough monitoring in the last year showed a decline |
| **Makaha** | Genetic Storage | | | | 13 | 56 | 0 | **11** | **293** | **0** | 0 | 0 | 0 | 11 | 293 | 0 | 2018-03-19 | More plants were added to the outplanting site |
| **North branch of South Ekahanui** | Manage reintroduction for stability | 5 | 0 | 0 | 82 | 65 | 0 | **82** | **65** | **0** | 0 | 0 | 0 | 82 | 65 | 0 | 2016-05-11 | A new census was initiated but not yet completed |
| **Palikea (South Palawai)** | Manage for stability | 3 | 60 | 0 | 911 | 10 | 0 | **914** | **6** | **0** | 11 | 1 | 0 | 903 | 5 | 0 | 2017-10-30 | A thorough census has shown immature plants transition into mature plants |
| | **Out Total:** | 8 | 60 | 0 | 1130 | 148 | 0 | **1104** | **376** | **0** | 13 | 2 | 0 | 1091 | 374 | 0 | | |
| | **Total for Taxon:** | 30 | 84 | 0 | 1200 | 184 | 0 | **1165** | **418** | **0** | 17 | 19 | 0 | 1148 | 399 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Cyanea longiflora

Target # of Matures: 75 | # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kapuna to West Makaleha** | Manage for stability | 66 | 0 | 0 | 61 | 196 | 2 | **89** | **147** | **0** | 10 | 21 | 0 | 79 | 126 | 0 | 2018-04-09 | More outplants matured this year; but populations declined slightly overall |
| **Pahole** | Manage for stability | 114 | 0 | 0 | 59 | 15 | 2 | **58** | **161** | **70** | 56 | 149 | 70 | 2 | 12 | 0 | 2018-02-28 | A thorough census led to more plants being discovered and more plants were added to a new outplanitng site |
| | **In Total:** | 180 | 0 | 0 | 120 | 211 | 4 | **147** | **308** | **70** | 66 | 170 | 70 | 81 | 138 | 0 | | |

## Action Area: Out

### TaxonName: Cyanea longiflora

Target # of Matures: 75 | # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Makaha and Waianae Kai** | Manage for stability | 4 | 0 | 0 | 116 | 130 | 0 | **116** | **130** | **0** | 7 | 2 | 0 | 109 | 128 | 0 | 2017-05-23 | A new census was initiated but not yet completed |
| | **Out Total:** | 4 | 0 | 0 | 116 | 130 | 0 | **116** | **130** | **0** | 7 | 2 | 0 | 109 | 128 | 0 | | |
| | **Total for Taxon:** | 184 | 0 | 0 | 236 | 341 | 4 | **263** | **438** | **70** | 73 | 172 | 70 | 190 | 266 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Cyanea superba subsp. superba

Target # of Matures: 50 — # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Manage reintroduction for stability | 3 | 149 | 0 | 48 | 178 | 1 | **46** | **325** | **4** | 0 | 0 | 0 | 46 | 325 | 4 | 2018-04-03 | More plants were added to the outplanting site |
| **Pahole to Kapuna** | Manage reintroduction for stability | 31 | 139 | 0 | 95 | 71 | 4 | **95** | **71** | **4** | 0 | 0 | 0 | 95 | 71 | 4 | 2015-06-08 | No monitoring in the last year |
| | **In Total:** | 34 | 288 | 0 | 143 | 249 | 5 | **141** | **396** | **8** | 0 | 0 | 0 | 141 | 396 | 8 | | |

## Action Area: Out

### TaxonName: Cyanea superba subsp. superba

Target # of Matures: 50 — # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Makaha** | Manage reintroduction for stability | | | | 27 | 172 | 246 | **39** | **141** | **175** | 0 | 0 | 0 | 39 | 141 | 175 | 2018-01-24 | Thorough monitoring in the last year showed a decline |
| **Manuwai** | Manage reintroduction for stability | 0 | 0 | 0 | 0 | 79 | 0 | **0** | **83** | **0** | 0 | 0 | 0 | 0 | 83 | 0 | 2018-03-20 | A thorough census led to more plants being discovered |
| | **Out Total:** | 0 | 0 | 0 | 27 | 251 | 246 | **39** | **224** | **175** | 0 | 0 | 0 | 39 | 224 | 175 | | |
| | **Total for Taxon:** | 34 | 288 | 0 | 170 | 500 | 251 | **180** | **620** | **183** | 0 | 0 | 0 | 180 | 620 | 183 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Cyrtandra dentata

Target # of Matures: 50 # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Manage for stability | 52 | 45 | 0 | 33 | 142 | 9 | **25** | **53** | **18** | 25 | 53 | 18 | 0 | 0 | 0 | 2017-11-29 | A thorough census has shown a substantial decline in the immature age class |
| **Kawaiiki (Koolaus)** | Manage for stability | 50 | 0 | 0 | 2 | 19 | 1 | **2** | **19** | **1** | 2 | 19 | 1 | 0 | 0 | 0 | 2016-06-23 | No monitoring in the last year |
| **Opaeula (Koolaus)** | Manage for stability | 21 | 5 | 0 | 35 | 161 | 2 | **35** | **161** | **2** | 35 | 161 | 2 | 0 | 0 | 0 | 2016-04-27 | No monitoring in the last year |
| **Pahole to West Makaleha** | Manage for stability | 300 | 0 | 0 | 330 | 484 | 97 | **330** | **484** | **97** | 330 | 484 | 97 | 0 | 0 | 0 | 2016-09-22 | A new census was initiated but not yet completed |
| | **In Total:** | 423 | 50 | 0 | 400 | 806 | 109 | **392** | **717** | **118** | 392 | 717 | 118 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Cyrtandra dentata

Target # of Matures: 50 # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Central Makaleha** | Genetic Storage | | | | 3 | 0 | 0 | **3** | **0** | **0** | 3 | 0 | 0 | 0 | 0 | 0 | 2006-10-23 | No monitoring in the last year |
| | **Out Total:** | | | | 3 | 0 | 0 | **3** | **0** | **0** | 3 | 0 | 0 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 423 | 50 | 0 | 403 | 806 | 109 | **395** | **717** | **118** | 395 | 717 | 118 | 0 | 0 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Delissea waianaeensis

Target # of Matures: 100 | # MFS PU Met Goal: 4 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Keawapilau** | Manage for stability | 33 | 1 | 0 | 185 | 9 | 0 | **140** | **6** | **1** | 3 | 2 | 0 | 137 | 4 | 1 | 2018-06-25 | Thorough monitoring in the last year showed a decline |
| **Kaluakauila** | Manage reintroduction for storage | | | | 15 | 3 | 0 | **7** | **0** | **0** | 0 | 0 | 0 | 7 | 0 | 0 | 2017-08-01 | Thorough monitoring in the last year showed a decline |
| **Kapuna** | Manage reintroduction for storage | | | | 113 | 46 | 0 | **93** | **23** | **0** | 0 | 0 | 0 | 93 | 23 | 0 | 2017-07-20 | Thorough monitoring in the last year showed a decline |
| **Palikea Gulch** | Genetic Storage | 2 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2014-05-28 | No monitoring in the last year |
| **South Mohiakea** | Genetic Storage | 2 | 0 | 0 | 10 | 15 | 3 | **12** | **16** | **2** | 12 | 16 | 2 | 0 | 0 | 0 | 2018-06-18 | A thorough census led to more plants being discovered |
| | **In Total:** | 37 | 1 | 0 | 324 | 73 | 3 | **253** | **45** | **3** | 16 | 18 | 2 | 237 | 27 | 1 | | |

## Action Area: Out

### TaxonName: Delissea waianaeensis

Target # of Matures: 100 | # MFS PU Met Goal: 4 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ekahanui** | Manage for stability | 14 | 44 | 0 | 196 | 23 | 0 | **196** | **23** | **0** | 2 | 1 | 0 | 194 | 22 | 0 | 2015-05-28 | A new census was initiated but not yet completed |
| **Kaluaa** | Manage for stability | 44 | 0 | 0 | 499 | 39 | 0 | **425** | **16** | **0** | 5 | 0 | 0 | 420 | 16 | 0 | 2018-06-25 | Thorough monitoring in the last year showed a decline |
| **Kealia** | Genetic Storage | 0 | 7 | 0 | 4 | 13 | 0 | **4** | **13** | **0** | 4 | 13 | 0 | 0 | 0 | 0 | 2016-06-01 | No monitoring in the last year |
| **Manuwai** | Manage reintroduction for stability | | | | 132 | 36 | 0 | **132** | **36** | **0** | 0 | 0 | 0 | 132 | 36 | 0 | 2017-06-06 | A new census was initiated but not yet completed |
| **Palawai** | Genetic Storage | 1 | 0 | 0 | 24 | 30 | 0 | **24** | **30** | **0** | 24 | 30 | 0 | 0 | 0 | 0 | 2016-06-22 | A new census was initiated but not yet completed |
| | **Out Total:** | 59 | 51 | 0 | 855 | 141 | 0 | **781** | **118** | **0** | 35 | 44 | 0 | 746 | 74 | 0 | | |
| | **Total for Taxon:** | 96 | 52 | 0 | 1179 | 214 | 3 | **1034** | **163** | **3** | 51 | 62 | 2 | 983 | 101 | 1 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Dubautia herbstobatae

Target # of Matures: 50 | # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Keaau** | Genetic Storage | 70 | 0 | 0 | 70 | 0 | 0 | **70** | **0** | **0** | 70 | 0 | 0 | 0 | 0 | 0 | 2000-01-01 | No monitoring in the last year |
| **Makaha/Ohikilolo** | Genetic Storage | | | | 229 | 0 | 0 | **229** | **0** | **0** | 229 | 0 | 0 | 0 | 0 | 0 | 2016-06-21 | A new census was initiated but not yet completed |
| **Ohikilolo Makai** | Manage for stability | 700 | 0 | 0 | 133 | 4 | 0 | **133** | **4** | **0** | 133 | 4 | 0 | 0 | 0 | 0 | 2016-09-27 | A new census was initiated but not yet completed |
| **Ohikilolo Mauka** | Manage for stability | 1300 | 0 | 0 | 373 | 27 | 0 | **373** | **27** | **0** | 373 | 27 | 0 | 0 | 0 | 0 | 2017-08-02 | A new census was initiated but not yet completed |
| | **In Total:** | 2070 | 0 | 0 | 805 | 31 | 0 | **805** | **31** | **0** | 805 | 31 | 0 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Dubautia herbstobatae

Target # of Matures: 50 | # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kamaileunu** | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2001-01-01 | No monitoring in the last year |
| **Makaha** | Manage for stability | 0 | 0 | 0 | 52 | 2 | 0 | **41** | **2** | **0** | 23 | 2 | 0 | 18 | 0 | 0 | 2018-05-16 | Thorough monitoring in the last year showed a decline |
| **Waianae Kai** | Genetic Storage | 5 | 0 | 0 | 10 | 4 | 0 | **10** | **4** | **0** | 10 | 4 | 0 | 0 | 0 | 0 | 2018-03-22 | No changes observed in the last year |
| | **Out Total:** | 6 | 0 | 0 | 62 | 6 | 0 | **51** | **6** | **0** | 33 | 6 | 0 | 18 | 0 | 0 | | |
| | **Total for Taxon:** | 2076 | 0 | 0 | 867 | 37 | 0 | **856** | **37** | **0** | 838 | 37 | 0 | 18 | 0 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Euphorbia celastroides var. kaenana

Target # of Matures: 25 | # MFS PU Met Goal: 3 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **East Kahanahaiki** | Genetic Storage | 2 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2010-11-18 | No monitoring in the last year |
| **Kaluakauila** | Genetic Storage | 17 | 1 | 0 | 11 | 3 | 0 | **11** | **3** | **0** | 11 | 3 | 0 | 0 | 0 | 0 | 2010-06-24 | No monitoring in the last year |
| **Makua** | Manage for stability | 36 | 4 | 0 | 85 | 0 | 0 | **85** | **0** | **0** | 85 | 0 | 0 | 0 | 0 | 0 | 2014-12-09 | A new census was initiated but not yet completed |
| **North Kahanahaiki** | Genetic Storage | 218 | 0 | 0 | 115 | 36 | 0 | **115** | **36** | **0** | 115 | 36 | 0 | 0 | 0 | 0 | 2013-03-21 | No changes observed in the last year |
| **Puaakanoa** | Manage for stability | 147 | 10 | 0 | 135 | 15 | 0 | **140** | **2** | **0** | 140 | 2 | 0 | 0 | 0 | 0 | 2017-11-15 | Small changes were noted during monitoring in the last year |
| | **In Total:** | 420 | 15 | 0 | 348 | 54 | 0 | **353** | **41** | **0** | 353 | 41 | 0 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Euphorbia celastroides var. kaenana

Target # of Matures: 25 | # MFS PU Met Goal: 3 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **East of Alau** | Manage for stability | 21 | 5 | 0 | 20 | 2 | 66 | **20** | **2** | **66** | 20 | 2 | 66 | 0 | 0 | 0 | 2015-09-28 | No monitoring in the last year |
| **Kaena** | Manage for stability | 300 | 0 | 0 | 880 | 274 | 0 | **880** | **274** | **0** | 880 | 274 | 0 | 0 | 0 | 0 | 2015-09-15 | A new census was initiated but not yet completed |
| **Keawaula** | Genetic Storage | 69 | 6 | 0 | 43 | 1 | 2 | **42** | **3** | **0** | 42 | 3 | 0 | 0 | 0 | 0 | 2014-08-25 | Small changes were noted during monitoring in the last year |
| **Waianae Kai** | Genetic Storage | 48 | 0 | 0 | 34 | 0 | 0 | **34** | **0** | **0** | 34 | 0 | 0 | 0 | 0 | 0 | 2011-06-13 | No monitoring in the last year |
| | **Out Total:** | 438 | 11 | 0 | 977 | 277 | 68 | **976** | **279** | **66** | 976 | 279 | 66 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 858 | 26 | 0 | 1325 | 331 | 68 | **1329** | **320** | **66** | 1329 | 320 | 66 | 0 | 0 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Euphorbia herbstii

Target # of Matures: 25 | # MFS PU Met Goal: 1 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kapuna to Pahole** | Manage for stability | 170 | 0 | 0 | 54 | 43 | 1 | **33** | **45** | **0** | 7 | 6 | 0 | 26 | 39 | 0 | 2018-02-28 | A thorough census has shown a substantial decline and more plants were added to the outplanting site |
| **Manuwai** | Manage reintroduction for stability | | | | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | No monitoring in the last year |
| | **In Total:** | 170 | 0 | 0 | 54 | 43 | 1 | **33** | **45** | **0** | 7 | 6 | 0 | 26 | 39 | 0 | | |

## Action Area: Out

### TaxonName: Euphorbia herbstii

Target # of Matures: 25 | # MFS PU Met Goal: 1 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kaluaa** | Manage reintroduction for stability | | | | 0 | 20 | 0 | **2** | **88** | **0** | 0 | 0 | 0 | 2 | 88 | 0 | 2018-02-21 | More plants were added to the outplanting site |
| **Makaha** | Manage reintroduction for storage | | | | 2 | 7 | 0 | **2** | **7** | **0** | 0 | 0 | 0 | 2 | 7 | 0 | 2017-10-04 | No changes observed in the last year |
| | **Out Total:** | | | | 2 | 27 | 0 | **4** | **95** | **0** | 0 | 0 | 0 | 4 | 95 | 0 | | |
| | **Total for Taxon:** | 170 | 0 | 0 | 56 | 70 | 1 | **37** | **140** | **0** | 7 | 6 | 0 | 30 | 134 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Flueggea neowawraea

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Kapuna** | Manage for stability | 6 | 26 | 0 | 5 | 138 | 0 | **5** | **120** | **0** | 5 | 0 | 0 | 0 | 120 | 0 | 2018-04-18 | Thorough monitoring in the last year showed a decline |
| **Ohikilolo** | Manage for stability | 3 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2016-03-02 | No monitoring in the last year |
| **West Makaleha** | Genetic Storage | 3 | 0 | 0 | 6 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2010-11-18 | Thorough monitoring in the last year showed a decline |
| | **In Total:** | 12 | 26 | 0 | 12 | 138 | 0 | **8** | **120** | **0** | 8 | 0 | 0 | 0 | 120 | 0 | | |

## Action Area: Out

### TaxonName: Flueggea neowawraea

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Central and East Makaleha** | Genetic Storage | 6 | 0 | 0 | 4 | 0 | 0 | **4** | **0** | **0** | 4 | 0 | 0 | 0 | 0 | 0 | 2015-09-23 | No changes observed in the last year |
| **Halona** | Genetic Storage | 2 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2010-12-07 | No monitoring in the last year |
| **Kauhiuhi** | Genetic Storage | 1 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2006-11-22 | No monitoring in the last year |
| **Makaha** | Manage for stability | 4 | 0 | 0 | 9 | 55 | 0 | **7** | **37** | **0** | 7 | 0 | 0 | 0 | 37 | 0 | 2018-05-01 | Thorough monitoring in the last year showed a decline |
| **Manuwai** | Manage reintroduction for stability | 0 | 0 | 0 | 0 | 16 | 0 | **0** | **16** | **0** | 0 | 0 | 0 | 0 | 16 | 0 | 2017-04-12 | A new census was initiated but not yet completed |
| **Mt. Kaala NAR** | Genetic Storage | 4 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2018-04-26 | No changes observed in the last year |
| **Nanakuli, south branch** | Genetic Storage | 1 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2010-10-19 | No monitoring in the last year |
| **Waianae Kai** | Genetic Storage | 1 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2018-06-20 | No changes observed in the last year |
| | **Out Total:** | 19 | 0 | 0 | 19 | 71 | 0 | **17** | **53** | **0** | 17 | 0 | 0 | 0 | 53 | 0 | | |
| | **Total for Taxon:** | 31 | 26 | 0 | 31 | 209 | 0 | **25** | **173** | **0** | 25 | 0 | 0 | 0 | 173 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Gouania vitifolia

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Keaau** | Manage for stability | | | | 51 | 0 | 0 | **47** | **2** | **0** | 47 | 2 | 0 | 0 | 0 | 0 | 2018-05-15 | Small changes were noted during monitoring in the last year |
| | **In Total:** | | | | 51 | 0 | 0 | **47** | **2** | **0** | 47 | 2 | 0 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Gouania vitifolia

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Makaha (Future Introduction)** | Manage reintroduction for stability | | | | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | Introduction has not begun |
| **Manuwai (Future Introduction)** | Manage reintroduction for stability | | | | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | Introduction has not begun |
| **Waianae Kai** | Genetic Storage | | | | 3 | 0 | 0 | **1** | **1** | **0** | 1 | 1 | 0 | 0 | 0 | 0 | 2017-09-06 | Small changes were noted during monitoring in the last year |
| | **Out Total:** | | | | 3 | 0 | 0 | **1** | **1** | **0** | 1 | 1 | 0 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | | | | 54 | 0 | 0 | **48** | **3** | **0** | 48 | 3 | 0 | 0 | 0 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Hesperomannia oahuensis

Target # of Matures: 75 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Haleauau** | Manage for stability | | | | 1 | 4 | 0 | **1** | **4** | **0** | 1 | 0 | 0 | 0 | 4 | 0 | 2018-02-21 | No changes observed in the last year |
| **Pahole NAR** | Manage reintroduction for stability | 8 | 0 | 0 | 3 | 21 | 0 | **3** | **21** | **0** | 0 | 0 | 0 | 3 | 21 | 0 | 2017-04-03 | A new census was initiated but not yet completed |
| | **In Total:** | 8 | 0 | 0 | 4 | 25 | 0 | **4** | **25** | **0** | 1 | 0 | 0 | 3 | 25 | 0 | | |

## Action Area: Out

### TaxonName: Hesperomannia oahuensis

Target # of Matures: 75 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Makaha** | Manage for stability | 13 | 0 | 0 | 11 | 34 | 0 | **11** | **69** | **0** | 5 | 1 | 0 | 6 | 68 | 0 | 2018-05-01 | More plants were added to the outplanting site |
| **Pualii** | Manage reintroduction for stability | | | | 14 | 58 | 1 | **14** | **58** | **1** | 0 | 0 | 0 | 14 | 58 | 1 | 2017-04-04 | A new census was initiated but not yet completed |
| **Waianae Kai** | Genetic Storage | 9 | 0 | 1 | 0 | 1 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2018-04-16 | A thorough census showed the plant has died |
| | **Out Total:** | 22 | 0 | 1 | 25 | 93 | 1 | **25** | **127** | **1** | 5 | 1 | 0 | 20 | 126 | 1 | | |
| | **Total for Taxon:** | 30 | 0 | 1 | 29 | 118 | 1 | **29** | **152** | **1** | 6 | 1 | 0 | 23 | 151 | 1 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Hibiscus brackenridgei subsp. mokuleianus

Target # of Matures: 50    # MFS PU Met Goal: 4 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Keaau** | Manage for stability | | | | 82 | 4 | 0 | **82** | **4** | **0** | 0 | 3 | 0 | 82 | 1 | 0 | 2017-06-01 | A new census was initiated but not yet completed |
| **Makua** | Manage for stability | 4 | 3 | 0 | 124 | 20 | 0 | **95** | **0** | **0** | 8 | 0 | 0 | 87 | 0 | 0 | 2018-06-21 | Thorough monitoring in the last year showed a decline |
| | **In Total:** | 4 | 3 | 0 | 206 | 24 | 0 | **177** | **4** | **0** | 8 | 3 | 0 | 169 | 1 | 0 | | |

## Action Area: Out

### TaxonName: Hibiscus brackenridgei subsp. mokuleianus

Target # of Matures: 50    # MFS PU Met Goal: 4 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Haili to Kawaiu** | Manage for stability | 3 | 1 | 0 | 117 | 5 | 0 | **82** | **2** | **0** | 3 | 2 | 0 | 79 | 0 | 0 | 2018-03-21 | Thorough monitoring in the last year showed a decline |
| **Manuwai** | Manage reintroduction for stability | | | | 102 | 8 | 20 | **70** | **1** | **12** | 0 | 0 | 0 | 70 | 1 | 12 | 2018-06-07 | Thorough monitoring in the last year showed a decline |
| **Waialua** | Genetic Storage | 4 | 9 | 0 | 49 | 85 | 9 | **49** | **85** | **9** | 49 | 85 | 9 | 0 | 0 | 0 | 2013-04-02 | No monitoring in the last year |
| | **Out Total:** | 7 | 10 | 0 | 268 | 98 | 29 | **201** | **88** | **21** | 52 | 87 | 9 | 149 | 1 | 12 | | |
| | **Total for Taxon:** | 11 | 13 | 0 | 474 | 122 | 29 | **378** | **92** | **21** | 60 | 90 | 9 | 318 | 2 | 12 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Kadua degeneri subsp. degeneri

Target # of Matures: 50 # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Pahole** | Manage for stability | 161 | 0 | 0 | 102 | 100 | 150 | **102** | **100** | **150** | 102 | 100 | 150 | 0 | 0 | 0 | 2016-08-10 | A new census was initiated but not yet completed |
| | **In Total:** | 161 | 0 | 0 | 102 | 100 | 150 | **102** | **100** | **150** | 102 | 100 | 150 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Kadua degeneri subsp. degeneri

Target # of Matures: 50 # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alaiheihe and Manuwai** | Manage for stability | 60 | 0 | 0 | 77 | 84 | 4 | **75** | **72** | **0** | 17 | 9 | 0 | 58 | 63 | 0 | 2017-09-28 | Small changes were noted during monitoring in the last year |
| **Central Makaleha and West Branch of East Makaleha** | Manage for stability | 47 | 0 | 0 | 22 | 10 | 22 | **17** | **32** | **0** | 17 | 32 | 0 | 0 | 0 | 0 | 2017-09-11 | Small changes were noted during monitoring in the last year |
| **East branch of East Makaleha** | Genetic Storage | 10 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2010-09-22 | No monitoring in the last year |
| | **Out Total:** | 117 | 0 | 0 | 99 | 94 | 26 | **92** | **104** | **0** | 34 | 41 | 0 | 58 | 63 | 0 | | |
| | **Total for Taxon:** | 278 | 0 | 0 | 201 | 194 | 176 | **194** | **204** | **150** | 136 | 141 | 150 | 58 | 63 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Kadua parvula

Target # of Matures: 50 | # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ohikilolo** | Manage for stability | 66 | 0 | 0 | 129 | 101 | 0 | **90** | **149** | **20** | 40 | 145 | 20 | 50 | 4 | 0 | 2017-12-27 | A thorough census led to more plants being discovered |
| | **In Total:** | 66 | 0 | 0 | 129 | 101 | 0 | **90** | **149** | **20** | 40 | 145 | 20 | 50 | 4 | 0 | | |

## Action Area: Out

### TaxonName: Kadua parvula

Target # of Matures: 50 | # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ekahanui** | Manage reintroduction for stability | | | | 58 | 29 | 0 | **58** | **29** | **0** | 0 | 0 | 0 | 58 | 29 | 0 | 2017-03-28 | A new census was initiated but not yet completed |
| **Halona** | Manage for stability | 64 | 0 | 0 | 31 | 4 | 0 | **31** | **4** | **0** | 31 | 4 | 0 | 0 | 0 | 0 | 2016-06-29 | No monitoring in the last year |
| | **Out Total:** | 64 | 0 | 0 | 89 | 33 | 0 | **89** | **33** | **0** | 31 | 4 | 0 | 58 | 29 | 0 | | |
| | **Total for Taxon:** | 130 | 0 | 0 | 218 | 134 | 0 | **179** | **182** | **20** | 71 | 149 | 20 | 108 | 33 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Melanthera tenuifolia

Target # of Matures: 50 | # MFS PU Met Goal: 3 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Genetic Storage | 300 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2016-09-20 | No monitoring in the last year |
| **Kaluakauila** | Genetic Storage | 113 | 0 | 0 | 4 | 80 | 0 | **4** | **80** | **0** | 4 | 80 | 0 | 0 | 0 | 0 | 2011-03-07 | No monitoring in the last year |
| **Keawaula** | Genetic Storage | 20 | 20 | 0 | 200 | 50 | 0 | **200** | **50** | **0** | 200 | 50 | 0 | 0 | 0 | 0 | 2016-03-30 | No monitoring in the last year |
| **Ohikilolo** | Manage for stability | 2008 | 1 | 0 | 571 | 11 | 0 | **570** | **11** | **0** | 570 | 11 | 0 | 0 | 0 | 0 | 2018-01-30 | No monitoring in the last year |
| | **In Total:** | 2441 | 21 | 0 | 776 | 141 | 0 | **775** | **141** | **0** | 775 | 141 | 0 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Melanthera tenuifolia

Target # of Matures: 50 | # MFS PU Met Goal: 3 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kamaileunu and Waianae Kai** | Manage for stability | 880 | 0 | 0 | 815 | 246 | 274 | **815** | **246** | **274** | 815 | 246 | 274 | 0 | 0 | 0 | 2010-04-28 | No monitoring in the last year |
| **Mt. Kaala NAR** | Manage for stability | 250 | 0 | 0 | 131 | 24 | 0 | **131** | **24** | **0** | 131 | 24 | 0 | 0 | 0 | 0 | 2015-09-22 | No monitoring in the last year |
| | **Out Total:** | 1130 | 0 | 0 | 946 | 270 | 274 | **946** | **270** | **274** | 946 | 270 | 274 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 3571 | 21 | 0 | 1722 | 411 | 274 | **1721** | **411** | **274** | 1721 | 411 | 274 | 0 | 0 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Neraudia angulata

Target # of Matures: 100 | # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kaluakauila** | Manage reintroduction for stability | | | | 100 | 24 | 1 | **258** | **0** | **0** | 0 | 0 | 0 | 258 | 0 | 0 | 2017-08-01 | More plants were added to the outplanting site |
| **Kapuna** | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2016-05-16 | No monitoring in the last year |
| **Makua** | Manage for stability | 29 | 0 | 22 | 67 | 11 | 0 | **45** | **4** | **0** | 20 | 4 | 0 | 25 | 0 | 0 | 2017-08-08 | Thorough monitoring in the last year showed a decline |
| **Punapohaku** | Genetic Storage | | | | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2016-05-23 | No monitoring in the last year |
| | **In Total:** | 30 | 0 | 22 | 169 | 35 | 1 | **305** | **4** | **0** | 22 | 4 | 0 | 283 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Neraudia angulata

Target # of Matures: 100 | # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Halona** | Genetic Storage | 15 | 0 | 0 | 4 | 10 | 1 | **4** | **10** | **1** | 4 | 10 | 1 | 0 | 0 | 0 | 2016-08-15 | No monitoring in the last year |
| **Leeward Puu Kaua** | Genetic Storage | 3 | 0 | 0 | 9 | 0 | 0 | **9** | **0** | **0** | 9 | 0 | 0 | 0 | 0 | 0 | 2006-11-21 | No monitoring in the last year |
| **Makaha** | Manage for stability (backup site) | 56 | 14 | 0 | 131 | 8 | 0 | **82** | **19** | **0** | 3 | 8 | 0 | 79 | 11 | 0 | 2018-03-15 | Thorough monitoring in the last year showed a decline |
| **Manuwai** | Manage for stability | 12 | 0 | 0 | 97 | 64 | 10 | **97** | **63** | **10** | 0 | 3 | 0 | 97 | 60 | 10 | 2018-06-07 | Small changes were noted during monitoring in the last year |
| **Waianae Kai Makai** | Genetic Storage | 4 | 0 | 0 | 13 | 0 | 0 | **13** | **0** | **0** | 13 | 0 | 0 | 0 | 0 | 0 | 2013-11-25 | No monitoring in the last year |
| **Waianae Kai Mauka** | Manage for stability | 21 | 25 | 0 | 11 | 2 | 0 | **11** | **2** | **0** | 7 | 2 | 0 | 4 | 0 | 0 | 2016-03-15 | No monitoring in the last year |
| | **Out Total:** | 111 | 39 | 0 | 265 | 84 | 11 | **216** | **94** | **11** | 36 | 23 | 1 | 180 | 71 | 10 | | |
| | **Total for Taxon:** | 141 | 39 | 22 | 434 | 119 | 12 | **521** | **98** | **11** | 58 | 27 | 1 | 463 | 71 | 10 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

## TaxonName: Nototrichium humile

Target # of Matures: 25 # MFS PU Met Goal: 4 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Genetic Storage | 140 | 0 | 0 | 79 | 5 | 0 | **28** | **1** | **0** | 28 | 1 | 0 | 0 | 0 | 0 | 2017-05-31 | Thorough monitoring in the last year showed a decline |
| **Kaluakauila** | Manage for stability | 200 | 0 | 0 | 140 | 48 | 0 | **133** | **45** | **0** | 133 | 45 | 0 | 0 | 0 | 0 | 2017-08-02 | Thorough monitoring in the last year showed a decline |
| **Keaau** | Genetic Storage | 21 | 31 | 0 | 20 | 31 | 0 | **20** | **31** | **0** | 20 | 31 | 0 | 0 | 0 | 0 | 2016-09-07 | No monitoring in the last year |
| **Keawaula** | Genetic Storage | 200 | 30 | 0 | 70 | 70 | 10 | **109** | **22** | **0** | 109 | 22 | 0 | 0 | 0 | 0 | 2017-08-03 | A thorough census has shown immature plants transition into mature plants |
| **Makua (East rim)** | Genetic Storage | 1 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 1997-01-01 | No monitoring in the last year |
| **Makua (south side)** | Manage for stability | 120 | 18 | 0 | 50 | 3 | 0 | **50** | **3** | **0** | 43 | 3 | 0 | 7 | 0 | 0 | 2013-07-11 | No monitoring in the last year |
| **Punapohaku** | Genetic Storage | 152 | 14 | 0 | 178 | 77 | 0 | **178** | **77** | **0** | 178 | 77 | 0 | 0 | 0 | 0 | 2013-10-08 | No monitoring in the last year |
| | **In Total:** | 834 | 93 | 0 | 538 | 234 | 10 | **519** | **179** | **0** | 512 | 179 | 0 | 7 | 0 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: Out

## TaxonName: Nototrichium humile

Target # of Matures: 25 # MFS PU Met Goal: 4 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kaimuhole and Palikea Gulch** | Genetic Storage | 48 | 6 | 0 | 29 | 1 | 0 | **29** | **1** | **0** | 29 | 1 | 0 | 0 | 0 | 0 | 2013-09-26 | No monitoring in the last year |
| **Keawapilau** | Genetic Storage | 9 | 1 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2013-04-17 | No monitoring in the last year |
| **Kolekole** | Genetic Storage | 13 | 0 | 0 | 12 | 0 | 0 | **12** | **0** | **0** | 12 | 0 | 0 | 0 | 0 | 0 | 2005-01-01 | No monitoring in the last year |
| **Makaha** | Genetic Storage | 159 | 0 | 0 | 22 | 5 | 0 | **22** | **5** | **0** | 22 | 5 | 0 | 0 | 0 | 0 | 2010-03-02 | No monitoring in the last year |
| **Manuwai** | Manage reintroduction for stability | | | | 111 | 0 | 0 | **111** | **0** | **0** | 0 | 0 | 0 | 111 | 0 | 0 | 2017-04-11 | A new census was initiated but not yet completed |
| **Nanakuli** | Genetic Storage | 5 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2016-03-29 | No monitoring in the last year |
| **Puu Kaua (Leeward side)** | Genetic Storage | 12 | 0 | 0 | 2 | 0 | 0 | **2** | **0** | **0** | 2 | 0 | 0 | 0 | 0 | 0 | 2006-11-21 | No monitoring in the last year |
| **Waianae Kai** | Manage for stability | 200 | 0 | 0 | 204 | 101 | 0 | **134** | **130** | **0** | 134 | 130 | 0 | 0 | 0 | 0 | 2017-06-29 | Thorough monitoring in the last year showed a decline |
| | **Out Total:** | 446 | 7 | 0 | 381 | 107 | 0 | **311** | **136** | **0** | 200 | 136 | 0 | 111 | 0 | 0 | | |
| | **Total for Taxon:** | 1280 | 100 | 0 | 919 | 341 | 10 | **830** | **315** | **0** | 712 | 315 | 0 | 118 | 0 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Phyllostegia kaalaensis

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Keawapilau to Kapuna** | Manage reintroduction for stability | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2010-08-02 | No monitoring in the last year |
| **Pahole** | Manage reintroduction for stability | 10 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2010-08-10 | No monitoring in the last year |
| **Palikea Gulch** | Genetic Storage | 10 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2004-09-01 | No monitoring in the last year |
| | **In Total:** | 20 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Phyllostegia kaalaensis

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Makaha** | Manage reintroduction for stability | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2015-01-01 | No monitoring in the last year |
| **Manuwai** | Manage reintroduction for stability | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2015-03-18 | No monitoring in the last year |
| **Waianae Kai** | Genetic Storage | 6 | 2 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2004-01-01 | No monitoring in the last year |
| | **Out Total:** | 6 | 2 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 26 | 2 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Plantago princeps var. princeps

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **North Mohiakea** | Manage for stability | 20 | 10 | 0 | 39 | 12 | 0 | **28** | **43** | **0** | 28 | 43 | 0 | 0 | 0 | 0 | 2018-06-19 | A decrease in matures was observed but more immature plants were discovered |
| **Ohikilolo** | Manage for stability | 14 | 0 | 0 | 28 | 22 | 0 | **24** | **0** | **0** | 0 | 0 | 0 | 24 | 0 | 0 | 2017-12-27 | Thorough monitoring in the last year showed a decline |
| **Pahole** | Genetic Storage | 12 | 0 | 0 | 4 | 5 | 0 | **4** | **5** | **0** | 4 | 5 | 0 | 0 | 0 | 0 | 2016-05-25 | No monitoring in the last year |
| | **In Total:** | 46 | 10 | 0 | 71 | 39 | 0 | **56** | **48** | **0** | 32 | 48 | 0 | 24 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Plantago princeps var. princeps

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ekahanui** | Manage for stability | 16 | 17 | 0 | 5 | 52 | 0 | **5** | **51** | **0** | 5 | 50 | 0 | 0 | 1 | 0 | 2017-08-08 | Small changes were noted during monitoring in the last year |
| **Halona** | Manage for stability | 50 | 0 | 0 | 6 | 9 | 0 | **6** | **9** | **0** | 6 | 9 | 0 | 0 | 0 | 0 | 2016-06-30 | No monitoring in the last year |
| **North Palawai** | Genetic Storage | 32 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2018-02-08 | No changes observed in the last year |
| **Waieli** | Manage reintroduction for storage | | | | 12 | 30 | 0 | **5** | **9** | **0** | 0 | 0 | 0 | 5 | 9 | 0 | 2018-04-12 | Thorough monitoring in the last year showed a decline |
| | **Out Total:** | 98 | 17 | 0 | 24 | 91 | 0 | **17** | **69** | **0** | 12 | 59 | 0 | 5 | 10 | 0 | | |
| | **Total for Taxon:** | 144 | 27 | 0 | 95 | 130 | 0 | **73** | **117** | **0** | 44 | 107 | 0 | 29 | 10 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Pritchardia kaalae

Target # of Matures: 25 — # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ohikilolo** | Manage for stability | 65 | 408 | 0 | 85 | 1590 | 0 | **131** | **1556** | **3** | 72 | 1178 | 0 | 59 | 378 | 3 | 2017-08-02 | A thorough census has shown immature plants transition into mature plants |
| **Ohikilolo East and West Makaleha** | Manage reintroduction for stability | 0 | 75 | 0 | 6 | 328 | 0 | **11** | **284** | **0** | 0 | 0 | 0 | 11 | 284 | 0 | 2017-08-10 | Thorough monitoring in the last year showed a decline |
| | **In Total:** | 65 | 483 | 0 | 91 | 1918 | 0 | **142** | **1840** | **3** | 72 | 1178 | 0 | 70 | 662 | 3 | | |

## Action Area: Out

### TaxonName: Pritchardia kaalae

Target # of Matures: 25 — # MFS PU Met Goal: 2 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Makaha** | Genetic Storage | 1 | 0 | 0 | 1 | 0 | 0 | **1** | **0** | **0** | 1 | 0 | 0 | 0 | 0 | 0 | 2014-09-17 | No monitoring in the last year |
| **Makaleha to Manuwai** | Manage for stability | 138 | 3 | 0 | 123 | 11 | 0 | **123** | **11** | **0** | 123 | 11 | 0 | 0 | 0 | 0 | 2016-07-12 | A new census was initiated but not yet completed |
| **Waianae Kai** | Genetic Storage | 7 | 2 | 0 | 4 | 5 | 0 | **4** | **5** | **0** | 4 | 5 | 0 | 0 | 0 | 0 | 2002-06-12 | No monitoring in the last year |
| | **Out Total:** | 146 | 5 | 0 | 128 | 16 | 0 | **128** | **16** | **0** | 128 | 16 | 0 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 211 | 488 | 0 | 219 | 1934 | 0 | **270** | **1856** | **3** | 200 | 1194 | 0 | 70 | 662 | 3 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Sanicula mariversa

Target # of Matures: 100 — # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Keaau** | Manage for stability | 16 | 125 | 0 | 0 | 28 | 34 | **0** | **43** | **2** | 0 | 43 | 2 | 0 | 0 | 0 | 2018-05-10 | Thorough monitoring in the last year showed seedlings transition into immatures |
| **Ohikilolo** | Manage for stability | 34 | 128 | 0 | 0 | 229 | 0 | **0** | **229** | **0** | 0 | 97 | 0 | 0 | 132 | 0 | 2017-03-22 | A new census was initiated but not yet completed |
| | **In Total:** | 50 | 253 | 0 | 0 | 257 | 34 | **0** | **272** | **2** | 0 | 140 | 2 | 0 | 132 | 0 | | |

## Action Area: Out

### TaxonName: Sanicula mariversa

Target # of Matures: 100 — # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kamaileunu** | Manage for stability | 26 | 0 | 0 | 31 | 182 | 1 | **31** | **182** | **1** | 31 | 182 | 1 | 0 | 0 | 0 | 2017-03-21 | A new census was initiated but not yet completed |
| **Puu Kawiwi** | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2016-03-15 | No monitoring in the last year |
| | **Out Total:** | 28 | 0 | 0 | 31 | 182 | 1 | **31** | **182** | **1** | 31 | 182 | 1 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 78 | 253 | 0 | 31 | 439 | 35 | **31** | **454** | **3** | 31 | 322 | 3 | 0 | 132 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

## TaxonName: Schiedea kaalae

Target # of Matures: 50 | # MFS PU Met Goal: 2 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pahole** | Manage for stability | 3 | 0 | 0 | 45 | 39 | 3 | **40** | **39** | **3** | 1 | 0 | 0 | 39 | 39 | 3 | 2018-02-28 | Thorough monitoring in the last year showed a decline |
| | **In Total:** | 3 | 0 | 0 | 45 | 39 | 3 | **40** | **39** | **3** | 1 | 0 | 0 | 39 | 39 | 3 | | |

## Action Area: Out

## TaxonName: Schiedea kaalae

Target # of Matures: 50 | # MFS PU Met Goal: 2 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahana** | Genetic Storage | 0 | 0 | 0 | 8 | 0 | 2 | **8** | **0** | **2** | 5 | 0 | 1 | 3 | 0 | 1 | 2012-08-09 | No monitoring in the last year |
| **Kaluaa and Waieli** | Manage for stability | 2 | 53 | 0 | 164 | 4 | 0 | **141** | **2** | **0** | 0 | 0 | 0 | 141 | 2 | 0 | 2018-06-19 | Thorough monitoring in the last year showed a decline |
| **Maakua (Koolaus)** | Manage for stability | 4 | 0 | 0 | 10 | 0 | 0 | **10** | **0** | **0** | 10 | 0 | 0 | 0 | 0 | 0 | 2008-07-02 | No monitoring in the last year |
| **Makaua (Koolaus)** | Genetic Storage | 2 | 0 | 0 | 85 | 0 | 0 | **85** | **0** | **0** | 1 | 0 | 0 | 84 | 0 | 0 | 2012-02-29 | No monitoring in the last year |
| **North Palawai** | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2011-04-18 | No monitoring in the last year |
| **South Ekahanui** | Manage for stability | 10 | 75 | 0 | 172 | 96 | 1 | **170** | **95** | **21** | 7 | 1 | 20 | 163 | 94 | 1 | 2018-04-25 | Thorough monitoring in the last year showed an increase in seedlings<br><br>Thorough monitoring in the last year showed an increase in seedlings |
| | **Out Total:** | 19 | 128 | 0 | 439 | 100 | 3 | **414** | **97** | **23** | 23 | 1 | 21 | 391 | 96 | 2 | | |
| | **Total for Taxon:** | 22 | 128 | 0 | 484 | 139 | 6 | **454** | **136** | **26** | 24 | 1 | 21 | 430 | 135 | 5 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Schiedea nuttallii

Target # of Matures: 50 | # MFS PU Met Goal: 3 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Pahole** | Manage for stability | 48 | 17 | 0 | 88 | 35 | 317 | **141** | **104** | **168** | 9 | 0 | 1 | 132 | 104 | 167 | 2018-04-26 | A thorough census showed seedlings transition into immatures and in increse in mature plants |
| **Kapuna-Keawapilau Ridge** | Manage for stability | 3 | 1 | 0 | 55 | 2 | 0 | **75** | **25** | **45** | 0 | 0 | 0 | 75 | 25 | 45 | 2018-04-04 | More plants were added to the outplanting site |
| | **In Total:** | 51 | 18 | 0 | 143 | 37 | 317 | **216** | **129** | **213** | 9 | 0 | 1 | 207 | 129 | 212 | | |

## Action Area: Out

### TaxonName: Schiedea nuttallii

Target # of Matures: 50 | # MFS PU Met Goal: 3 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | **Total Mature Current** | **Total Immature Current** | **Total Seedling Current** | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Makaha** | Manage reintroduction for stability | 0 | 0 | 0 | 91 | 5 | 0 | **121** | **6** | **0** | 0 | 0 | 0 | 121 | 6 | 0 | 2018-04-16 | More plants were added to the outplanting site |
| | **Out Total:** | 0 | 0 | 0 | 91 | 5 | 0 | **121** | **6** | **0** | 0 | 0 | 0 | 121 | 6 | 0 | | |
| | **Total for Taxon:** | 51 | 18 | 0 | 234 | 42 | 317 | **337** | **135** | **213** | 9 | 0 | 1 | 328 | 135 | 212 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Schiedea obovata

Target # of Matures: 100 # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Pahole** | Manage for stability | 65 | 25 | 0 | 229 | 122 | 23 | **91** | **167** | **200** | 0 | 0 | 0 | 91 | 167 | 200 | 2018-05-23 | Thorough monitoring in the last year showed a decline, but more seedlings discovered |
| **Keawapilau to West Makaleha** | Manage for stability | 24 | 12 | 0 | 42 | 363 | 16 | **25** | **409** | **5** | 12 | 408 | 5 | 13 | 1 | 0 | 2018-05-31 | A decrease in matures, but increase in immatures was observed |
| | **In Total:** | 89 | 37 | 0 | 271 | 485 | 39 | **116** | **576** | **205** | 12 | 408 | 5 | 104 | 168 | 200 | | |

## Action Area: Out

### TaxonName: Schiedea obovata

Target # of Matures: 100 # MFS PU Met Goal: 0 of 3

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Makaha** | Manage reintroduction for stability | 0 | 0 | 0 | 76 | 14 | 0 | **20** | **0** | **0** | 0 | 0 | 0 | 20 | 0 | 0 | 2018-04-24 | Thorough monitoring in the last year showed a decline |
| | **Out Total:** | 0 | 0 | 0 | 76 | 14 | 0 | **20** | **0** | **0** | 0 | 0 | 0 | 20 | 0 | 0 | | |
| | **Total for Taxon:** | 89 | 37 | 0 | 347 | 499 | 39 | **136** | **576** | **205** | 12 | 408 | 5 | 124 | 168 | 200 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Tetramolopium filiforme

Target # of Matures: 50 # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Genetic Storage | 50 | 0 | 0 | 40 | 0 | 0 | **40** | **0** | **0** | 40 | 0 | 0 | 0 | 0 | 0 | 2006-10-04 | No monitoring in the last year |
| **Kalena** | Manage for stability | | | | 24 | 93 | 0 | **26** | **16** | **0** | 26 | 16 | 0 | 0 | 0 | 0 | 2018-06-19 | Thorough monitoring in the last year showed a decline |
| **Keaau** | Genetic Storage | 25 | 0 | 0 | 30 | 41 | 17 | **30** | **41** | **17** | 30 | 41 | 17 | 0 | 0 | 0 | 2005-11-07 | No monitoring in the last year |
| **Makaha/Ohikilolo Ridge** | Genetic Storage | | | | 350 | 200 | 0 | **350** | **200** | **0** | 350 | 200 | 0 | 0 | 0 | 0 | 2016-06-21 | A new census was initiated but not yet completed |
| **Ohikilolo** | Manage for stability | 2500 | 0 | 0 | 1903 | 1464 | 20 | **1740** | **1042** | **20** | 1740 | 1042 | 20 | 0 | 0 | 0 | 2016-09-27 | Thorough monitoring in the last year showed a decline |
| **Puhawai** | Manage for stability | 6 | 6 | 0 | 3 | 3 | 1 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2017-09-20 | Monitoring showed the plants have died |
| | **In Total:** | 2581 | 6 | 0 | 2350 | 1801 | 38 | **2186** | **1299** | **37** | 2186 | 1299 | 37 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Tetramolopium filiforme

Target # of Matures: 50 # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Waianae Kai** | Manage for stability | 20 | 2 | 0 | 20 | 0 | 0 | **20** | **0** | **0** | 20 | 0 | 0 | 0 | 0 | 0 | 2016-07-11 | No monitoring in the last year |
| | **Out Total:** | 20 | 2 | 0 | 20 | 0 | 0 | **20** | **0** | **0** | 20 | 0 | 0 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 2601 | 8 | 0 | 2370 | 1801 | 38 | **2206** | **1299** | **37** | 2206 | 1299 | 37 | 0 | 0 | 0 | | |

# Population Unit Status - Makua Implementation Plan

## Action Area: In

### TaxonName: Viola chamissoniana subsp. chamissoniana

Target # of Matures: 50 — # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Keaau** | Genetic Storage | 40 | 10 | 0 | 40 | 10 | 0 | **40** | **10** | **0** | 40 | 10 | 0 | 0 | 0 | 0 | 2002-06-04 | No monitoring in the last year |
| **Makaha/Ohikilolo Ridge** | Genetic Storage | 250 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 2016-06-21 | No monitoring in the last year |
| **Ohikilolo** | Manage for stability | | | | 191 | 52 | 0 | **107** | **233** | **0** | 107 | 233 | 0 | 0 | 0 | 0 | 2018-05-09 | A decrease in matures, but increase in immatures was observed |
| **Puu Kumakalii** | Manage for stability | 19 | 1 | 0 | 44 | 0 | 0 | **44** | **0** | **0** | 44 | 0 | 0 | 0 | 0 | 0 | 2004-10-21 | No monitoring in the last year |
| | **In Total:** | 309 | 11 | 0 | 275 | 62 | 0 | **191** | **243** | **0** | 191 | 243 | 0 | 0 | 0 | 0 | | |

## Action Area: Out

### TaxonName: Viola chamissoniana subsp. chamissoniana

Target # of Matures: 50 — # MFS PU Met Goal: 1 of 4

| Population Unit Name | Management Designation | Total Mature Original IP | Total Imm Original IP | Total Seedling Original IP | Total Mature 2017 | Total Immature 2017 | Total Seedling 2017 | Total Mature Current | Total Immature Current | Total Seedling Current | Wild Mature Current | Wild Immature Current | Wild Seedling Current | Outplanted Mature Current | Outplanted Immature Current | Outplanted Seedling Current | PU LastObs Date | Population Trend Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Halona** | Manage for stability | 3 | 0 | 0 | 16 | 5 | 0 | **16** | **5** | **0** | 16 | 5 | 0 | 0 | 0 | 0 | 2016-06-29 | No monitoring in the last year |
| **Kamaileunu** | Genetic Storage | 38 | 0 | 0 | 35 | 0 | 0 | **35** | **0** | **0** | 35 | 0 | 0 | 0 | 0 | 0 | 2000-05-23 | No monitoring in the last year |
| **Makaha** | Manage for stability | 50 | 0 | 0 | 68 | 11 | 0 | **29** | **24** | **0** | 29 | 24 | 0 | 0 | 0 | 0 | 2018-05-16 | No monitoring in the last year |
| **Makaleha** | Genetic Storage | | | | 19 | 9 | 1 | **19** | **9** | **1** | 19 | 9 | 1 | 0 | 0 | 0 | 2015-06-03 | No monitoring in the last year |
| **Puu Hapapa** | Genetic Storage | 10 | 3 | 0 | 6 | 1 | 0 | **6** | **1** | **0** | 6 | 1 | 0 | 0 | 0 | 0 | 2016-05-11 | No monitoring in the last year |
| | **Out Total:** | 101 | 3 | 0 | 144 | 26 | 1 | **105** | **39** | **1** | 105 | 39 | 1 | 0 | 0 | 0 | | |
| | **Total for Taxon:** | 410 | 14 | 0 | 419 | 88 | 1 | **296** | **282** | **1** | 296 | 282 | 1 | 0 | 0 | 0 | | |

# *Schiedea nuttallii*

**Scientific name:** *Schiedea nuttallii* Hooker.
**Hawaiian name:** None known
**Family:** Caryophyllaceae (Pink family)
**Federal status:** Listed endangered October 10, 1996
**Requirements for Makua Implementation Plan Stability**

- 3 Population Units (PUs)
- 50 reproducing individuals
- Stable population structure
- Threats controlled
- Complete genetic representation of all PUs in storage

## Description and biology

**Habit-** Erect to strongly ascending subshrubs 10-15 (-19)dm tall; stems many-branched, glabrous throughout, except bracts and sepals, internodes purple-tinged.

**Leaves-** Leaves opposite; blades 5-13 cm long, 1.4-3.5 cm wide, narrowly ovate or lanceolate to narrowly or broadly elliptic, dull green, sometimes purple-tinged, slightly thickened and rubbery, chartaceous when dry, with only the midvein evident, the midvein ± slightly excentric, margin entire, slightly thickened becoming revolute toward the base, apex acute to acuminate; petioles 0.3-1 cm long, weakly ± grooved.

**Flowers-** Inflorescence terminal, with 50-240 flowers, 20-25 (-32) cm long, diffuse, erect, the tertiary and higher level internodes or pedicels usually ascending or appressed, but pedicels usually spreading at anthesis, sometimes with a few hairs toward the base of the internodes; bracts subulate, the lowermost of central axis elliptic, green and purple-tinged or purple, margins ciliate, the lower ones 2-60 mm long, those of branches and flowers 1.5-2 mm long; pedicels 6-12 mm long at anthesis, elongating to 10-20 mm long in fruit, conspicuously asymmetrically flattened and weakly quadrangular, sometimes with a few hairs toward the base on the angles. Flowers hermaphroditic. Sepals 3.5-4.5 mm long, lanceolate, green, sometimes purple-tinged or nearly purple throughout, opaque, strongly reflexed and convex in the proximal 1/4, producing a small transverse bulge, the distal part concave or shallowly navicular, oriented at 5° to 30° angle to the pedicel, abaxial side glabrous, margins conspicuously scarious, ciliate, apex attenuate, often slightly twisted. Nectary base 0.7-1 mm long, yellow, the nectary shaft 2.8-3.7 mm long, gently recurved, at 90 ° angle to the axis, apex deeply bifid to ca. 1/2 their length. Stamens 10; filaments dimorphic, the antisepalous whorl 5.8-7.1 mm long, the alternate whorl 4.8-5.5 mm long; anthers 0.7-1.1 mm long, subequal, pale yellow. Styles 3. (Modified from Wagner *et a*l. 2005)

**Fruit-**Capsules 2.5-3.5 mm long. Narrowly ovoid.

**Seeds-** Seeds 0.9-1 mm long, orbicular-reniform, compressed, the surface rugose.

**Distribution-** Oahu, formerly nearly throughout the Waianae Mountains and Nuuanu pali, Manoa and Niu Valleys in the Southern Koolau Mountains on Oahu, now restricted to the north end of the Waianae Mountains on Oahu; rare and scattered on ridges and slopes in diverse mesic forest; 400-730 m. Extirpated from Molokai and West Maui.

**Pollination and dispersal:** Passerine birds have been suspected pollinators due to nectar concentration and amount (Weller et al. 1998), but no birds have been observed visiting this species (Weisenberger

2012). *S. nuttallii* plants were determined not to be wind-pollinated after using wind tunnels experiments to quantify pollen dispersal (Weller et al. 1998), and are presumed to be pollinated by insect or bird. Syrphid flies were the only visitors observed floral visitors were observed in 30 hours of monitoring plants in the largest reintroduction site in 2010. Pyralid moths (seen on *S. kaalae* and *S. lydgatei* flowers) are proposed as potential native pollinators (Norman et al. 1997, Weisenberger 2012).

**Taxonomic background:** There are 34 endemic species in the endemic genus *Schiedea*. All species have been shown to have arrived from one single colonization. Subspecies *S. nuttallii* subsp. *intermedia* and *molokaienis* previously were lumped with *S. nuttallii* from Oahu, however, fragmented historical collections appear to belong under *S. pubescens*. *S. pubescens* is closely related to *S. nuttallii* but differs in its nearly always puberulent inflorescences and vining habit. In addition plants on Kauai that were formerly considered *S. nuttallii* have been split off into a separate species with the distinct characteristic of sparsely to moderately puberulent inflorescences with whitish hairs. (Weller et al. 1998)

**Table 1.** Historic Collections of *Schiedea nuttallii* on Oahu

| Area | Year | Collector | Pop. Reference Code |
|---|---|---|---|
| Nuuanu | 1834 | Nuttall | |
| Pauoa | 1864 | Brigham | |
| Niu | 1867 | Hillebrand & Lydgate | |
| Makaleha | 1870 | Lydgate | |
| Kaala | 1908 | Forbes | |
| Nuuanu | 1909 | Faurie | |
| Waianae | 1909 | Faurie | |
| Makaleha | 1918 | Rock | |
| Ekahanui | 1922 | Degener | |
| Kaala | 1922 | Degener | |
| Kahanahaiki | 1922 | Degener | |
| Ohikilolo | 1922 | Degener | |
| Puu Kumakalii | 1922 | Degener | |
| Kanehoa | 1932 | Webster | |
| Huliwai | 1933 | Russ | |
| Kaala | 1933 | Swezey | |
| Haleauau | 1934 | Bryan | |
| Puu Kumakalii | 1937 | Fosberg | |
| Kalena | 1938 | Selling | |
| Puu Kanehoa | 1940 | Degener | |

**Table 1** (continued).

| Area | Year | Collector | Pop. Reference Code |
|---|---|---|---|
| Ekahanui | 1946 | St. John | |
| Makaleha | 1947 | Sakimura | |
| Puu Kanehoa | 1948 | Cowan | |
| Pahole | 1962 | Degener | |
| Pahole | 1973 | Herbst | |
| Ekahanui | 1978 | Obata | |
| Kahanahaiki | 1982 | Lau | MMR-B |
| Pahole | 1982 | Obata | PAH-A |
| Pahole | 1987 | Perlman & Obata | PAH-A |
| Keawapilau | 1991 | Welton Haus | PIL-A |
| Pahole | 1991 | Welton | PAH-A |

**Table 2**. Reproductive Biology

| | Observed Phenology | | | Reproductive Biology | | Seeds | |
|---|---|---|---|---|---|---|---|
| **Population Unit** | **Flower** | **Immature Fruit** | **Mature Fruit** | **Breeding System** | **Suspected Pollinator** | **Average # Per Fruit (viable)** | **Dormancy** |
| ALL | Jan-Aug | Mar-Aug | Mar-Sep | Hermaphroditic | Insect-pollinated | 4 ± 1 | None |

**Breeding system:** This species can easily self-fertilize when isolated. *S. nuttallii* may currently have high levels of selfing in all remaining sites.

**Fruit collection:** Peak collection time is in the spring (April-May). The first check for mature fruit should be early April.

# Plant morphology and habitat

**Figure 1.** Recruitment of seedlings and immature plants

**Figure 2.** Fruit capsules and seeds

**Figure 3.** Open flower

**Figure 4.** Seedling

**Figure 5.** Outplanting of mature plant

**Figure 6.** Mature plant filling out understory

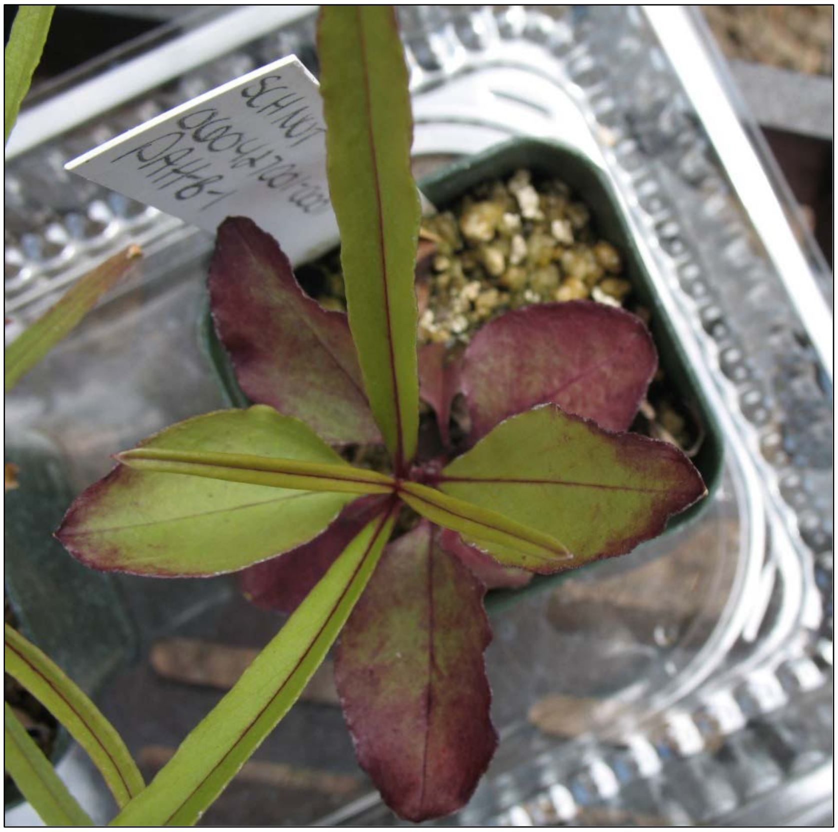


**Figure 7.** Seedlings growing in the greenhouse

**Figure 8.** *In situ* plant with new leaves

**Table 3.** Habitat Characteristics

| PU | Population reference code | Elev. (feet) | Slope | Topography | Aspect | Annual Ave. Max. Temp. (F)* | Average Annual Rainfall (mm)*/** |
|---|---|---|---|---|---|---|---|
| Kahanahaiki to Pahole | MMR-B *in situ* | 2000 | Moderate | Upper slope | N | 75.2 | 1561/ 1334 |
| Kahanahaiki to Pahole | PAH-A *in situ* | 2360 | Steep & Moderate | Upper slope | NE | 75.2 | 1766/ 1505 |
| Kahanahaiki to Pahole | PAH-B *in situ* | 1680 | Moderate | Lower slope | NE | 77.0 | 1588/ 1345 |
| Kahanahaiki to Pahole | PAH-D Reintro | 2120 | Moderate | Upper slope | N | 75.2 | 1619/ 1412 |
| Kahanahaiki to Pahole | PAH-E Reintro | 2160 | Moderate | Upper slope | N | 75.2 | 1619/ 1412 |
| Kapuna-Keawapilau Ridge | PIL-A *in situ* | 2160 | Moderate | Upper slope | N | 75.2 | 1781/ 1556 |
| Kapuna-Keawapilau Ridge | PIL-B Reintro | 2146 | Moderate | Upper slope | N | 75.2 | 1781/ 1556 |
| Makaha | MAK-A Reintro | 2600 | Steep | Crest | W | 73.4 | 1946/ 1638 |

Information was compiled from Army Natural Resource Program – Oahu (OANRP) observation forms, GIS data, PRISM Climate Group. *PRISM. 2018. Prism Climate Group. Oregon State University. http://prism.oregonstate.edu. **Giambelluca TW, Chen Q, Frazier AG, Price JP, Chen Y-L, Chu P-S, Eischeid J., and Delparte, D. 2011. The Rainfall Atlas of Hawai‘i. http://rainfall.geography.hawaii.edu.

**Table 4.** Associated species table, species are listed in order of abundance as observed by the Army natural resource program on Oahu (OANRP). Six digit codes used for species names.

| PU | Population reference code | Canopy | Understory |
|---|---|---|---|
| Kahanahaiki to Pahole | MMR-B *in situ* | PsiCat, SchTer, AcaKoa, GreRob, AntPla | AlyOli, PsiCat, AspKau, PanRep, CarWah, MicStr, MetPol |
| Kahanahaiki to Pahole | PAH-A *in situ* | AcaKoa, MetTre, MetPol, GreRob, PsiCat, MelPed | DryGla, NepExa, SphChi, AspHor, BidTor, DicLin, CarWah, MelMin, PasCon, AspKau, EriVal |
| Kahanahaiki to Pahole | PAH-B *in situ* | AleMol, SchTer, PsiGua, PsiCat, PsyOdo, HibArn, DioSan, DioHil, MorTri, PipAlb, PisUmb | BleApp, RubRos, ThePar, MicStr, OplHir, HedTer, HedAcu |
| Kahanahaiki to Pahole | PAH-D reintro | SchTer, MetPol, PsyOdo, NesSan, LepTam | BleApp, ChaMul, BidTor, CarWah, DooKun, ConBon, CorFru, PlePar |
| Kahanahaiki to Pahole | PAH-E reintro | SchTer, MetPol NesSan, PsyOdo, PsyMar, DioSan, PsiGua | BidTor, AlyOli, CopFol, CliHir, MelMin, DooKun, MepExa, DodVis |
| Kapuna-Keawapilau Ridge | PIL-A *in situ* | MetPol, HedTer, SchTer, GreRob, PitGla, AntPla, MelPed | BidTor, CarWah, AlyOli, BleApp, DiaSan, MelMin, CliHir, ChaMul |
| Kapuna-Keawapilau Ridge | PIL-B reintro | MetPol, SchTer, GreRob, HedTer, PitGla, AntPla, MelPed | BidTor, Schter, Bleapp, CarWah, AlyOli, DiaSan, MelMin, CliHir, ChaMul |
| Makaha | MAK-A reintro | DioHil, DodVis, HibArn, MetPol, SanFre, SchTer, GreRob, PsyMar | BidTor, DioSan, DodVis, EraVar, PanNep, ConBon, BleApp, AgeAde, RubArg, CarWah, ChaMul |

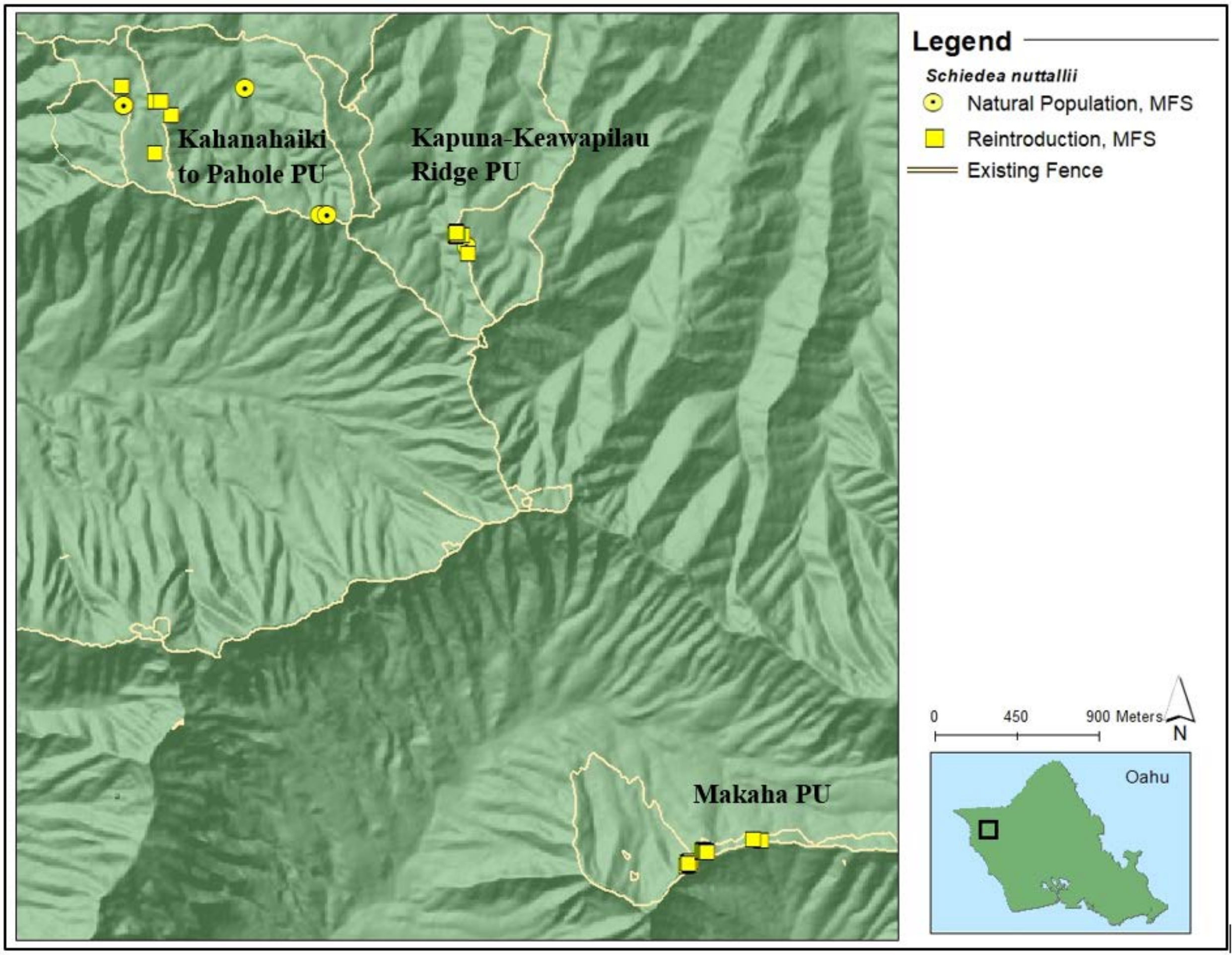



**Figure 9.** Map of current *Schiedea nuttallii* locations

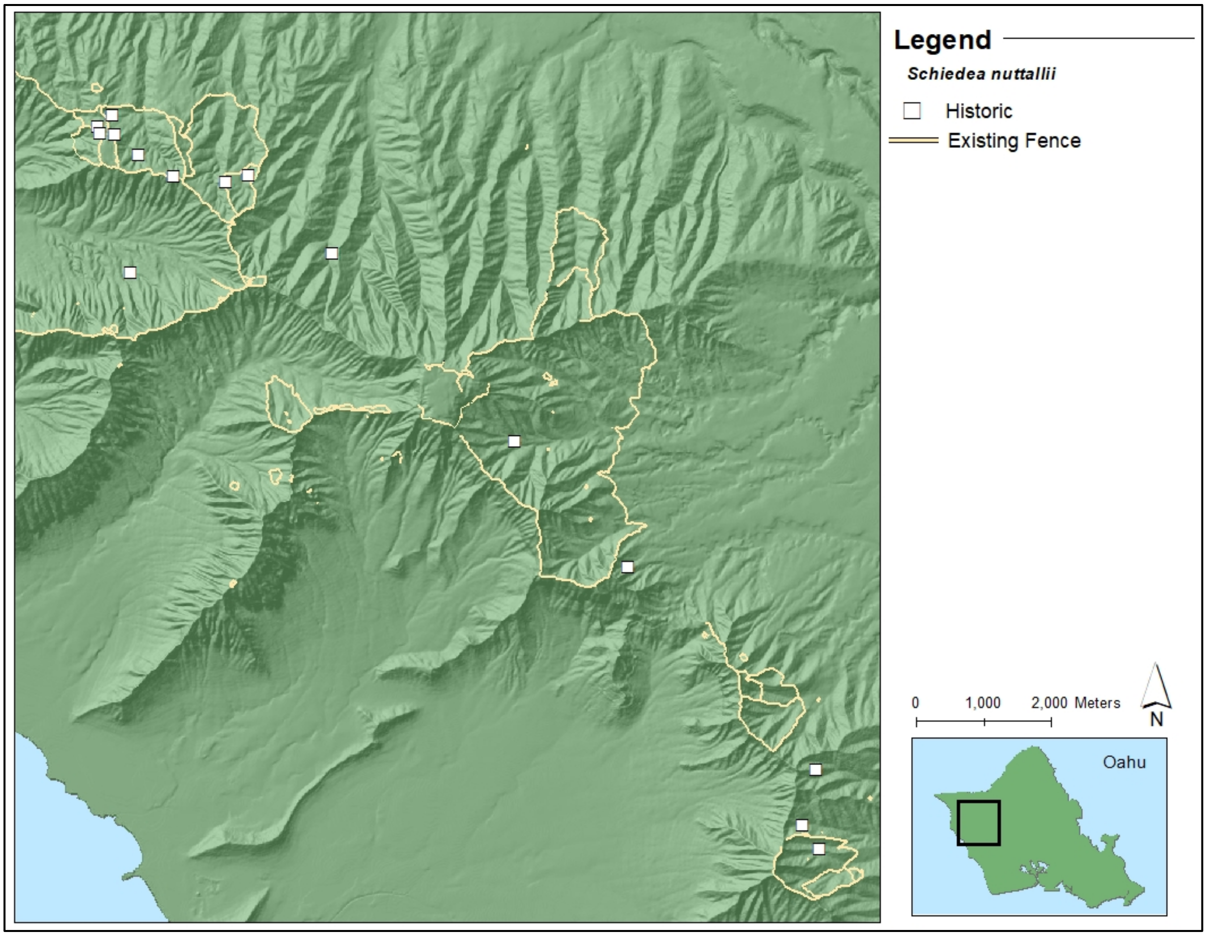



**Figure 10**. Historic locations, Waianae Mountains

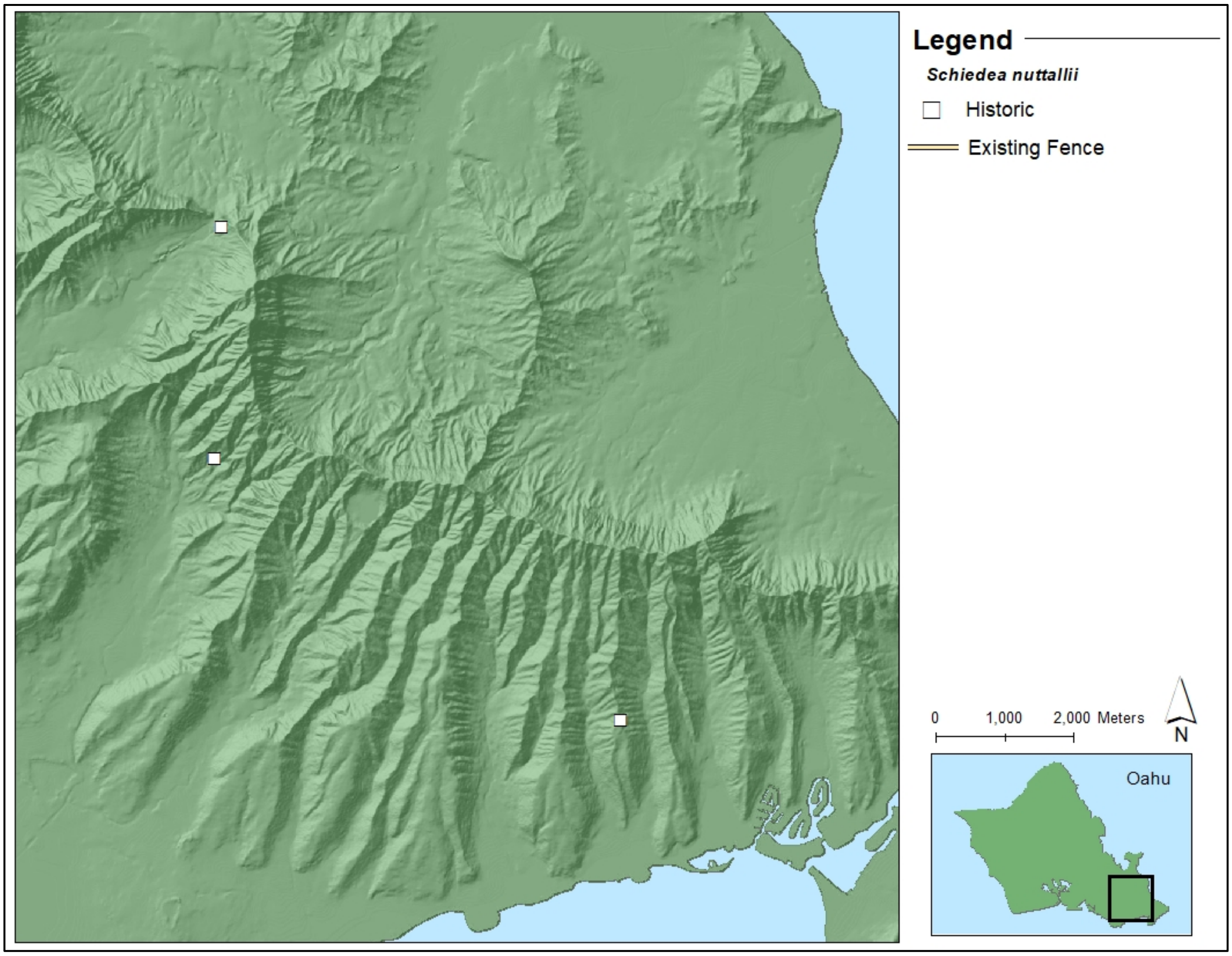



**Figure 11.** Historic locations, Koolau Mountains

## Current Status:

The known population units of *S. nuttallii* in the Waianae Mountains total 685 plants, consisting of mature and immature plants, and seedlings. This is an approximately 13% increase in the total plants from 2017, due to additional outplants added to reintroduction sites. Over 98% of this total are from reintroduced populations, and the only *in situ* plants are located in Pahole. Currently, all three manage of stability PUs have more than 50 reproducing individuals. However, the Kapuna-Keawapilau Ridge PU has historically had very low outplanting survival, less than 25% after five years, and meets the minimum number of individuals only because of recent the outplanting in 2018. On the other hand, two reintroduction sites in the Pahole PU (PAH-D and PAH-E) have had much better outplanting survival (over 60%) and recruitment. The PAH-E site, along with MAK-A, currently have the highest number of mature plants since outplanting began, with 100 or more mature individuals at each site. Overall, the Pahole PU has been most stable in regards to population structure, even with very little additional outplanting in the past five years. Although the Pahole and Makaha PU have the largest population size, they are also the most threatened by fire. Future outplantings may be needed to maintain stabilization goals for the number of reproducing individuals.

**Table 5.** Current population size and structure for all populations of *S. nuttallii*

| PU | Population Reference Code | Mature Plants | Immature Plants | Seedlings |
|---|---|---|---|---|
| Kahanahaiki to Pahole | MMR-C reintro | 2 | 0 | 0 |
| Kahanahaiki to Pahole | PAH-A *in situ* | 8 | 0 | 1 |
| Kahanahaiki to Pahole | PAH-B *in situ* | 1 | 0 | 0 |
| Kahanahaiki to Pahole | PAH-D reintro | 30 | 30 | 43 |
| Kahanahaiki to Pahole | PAH-E reintro | 100 | 74 | 124 |
| Kapuna-Keawapilau Ridge | PIL-B reintro | 75 | 25 | 45 |
| Makaha | MAK-A | 121 | 6 | 0 |
| Total for all populations | | 337 | 135 | 213 |

**Population Units:** Three Manage for Stability Population Units (MFS PU) are required for this taxon as it is found in the Makua Action Area. All PUs are MFS, as there are no Genetic Storage Population Units.

**Table 6.** Stabilization Goal Status, Yes/No/Partial refers to whether threat is mitigated

| | **PU Stability Target** | **MU Threat Control** | | | | | **Genetic Storage** |
|---|---|---|---|---|---|---|---|
| **Population Unit** | **50 reproducing plants** | **Ungulate** | **Slugs** | **Rodent** | **Fire** | **Weeds** | **% Completed** |
| Kahanahaiki to Pahole | Yes | Yes | Yes | Partial | No | Yes | 82% |
| Keawapilau to West Makaleha | Yes | Yes | Yes | Partial | No | Yes | 100% |
| Makaha | Yes | Yes | No | Yes | No | Yes | N/A |

## Population Unit Kahanahaiki to Pahole

Since observations of the *in situ* sites began in the 1980's, there have been no instances where >50 mature *in situ* plants were observed.  Therefore, it is difficult to predict with certainty the number of individuals needed to maintain a stable population.  In the past 15 years, only one *in situ* site, PAH-A, (in the Kahanahaiki to Pahole PU) has been observed to have more than 10 mature plants, with the most mature plants observed at one time being 12 (Fig. 12). Only two seedlings were observed to transition from immature plants to seed-bearing plants. Additionally, the number of plants have been in decline since 2009, and little recruitment has been documented since. This Pahole site PAH-A has been monitored by the Army natural resource program on Oahu (OANRP) since 1996.

Reintroductions have been ongoing since 1999.  Since 2013, all population units have exceeded the minimum number of reproducing individuals (50), but population structure is variable amongst the different PU.

OANRP began to outplant *S. nuttallii* into the Kahanahaiki to Pahole PU using seedlings and clones from the remaining *in situ* plants. The population structure that resulted from these outplants has been monitored annually and the number of plants in each age class in known. Since the remaining *in situ* sites of *S. nuttallii* are unable to serve as examples of stable or increasing populations with the population structure to support >50 mature plants, recruitment in the reintroductions are used to guide outplanting numbers. However, it is important to note the longevity of the seed bank at *in situ* sites, as a seedling was observed at an in situ site almost eight years after the last plant was observed in the population. Recruitment has been observed at some outplanting sites following the completion of outplanting. Depending on how recruitment rates change as the mature outplants die, continued outplanting may be necessary in the future to establish population structure in these PU.  This will also be determined by the success of threat control.

The reintroduction site at PAH-D (common name is Switchbacks site) has been outplanted seven times since 2004 and monitored at least annually. The recruitment resulting from outplants is monitored annually and the number of outplants remaining in each age class recorded. The survivorship for all outplants at PAH-D is 54% after five years, and most plants may live 5-10 years after planting. Recruitment of new seedlings and juvenile plants have been observed within a year of planting, and many have developed into mature plants. From 2013-present, over 50 seedlings and immature plants have been observed at one time; this is likely due the effectiveness of slug control in the area (Fig. 13). Many of these immatures have developed into mature plants in the past five years, and this site has had stable population structure over the same time period.

The reintroduction site at PAH-E (common name 2210 site) has been outplanted six times since 2007. The survivorship for outplants at PAH-E has been the highest of all outplanting sites, with over 67% of individuals surviving for at least five years.  Recruitment of new seedlings and juvenile plants was observed within one year of planting, and exceeded 300 individuals in the past five years (Fig 14). There was a large peak in recruitment in 2013 and 2016, with many plants surviving to maturity. Similarly to the PAH-D outplanting site, this site has also appeared to benefit from monthly slug control.

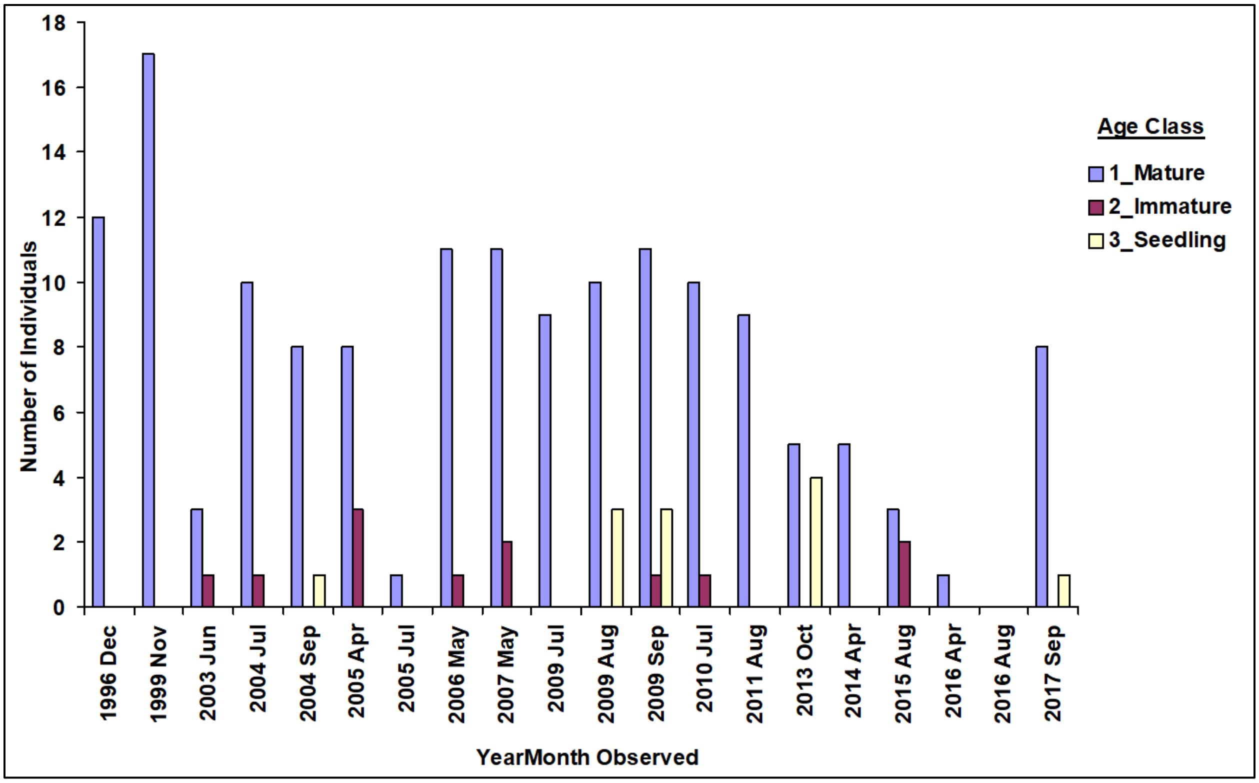



**Figure 12.** Schnut PAH-A *in situ* population structure for seedlings, immature, and mature plants

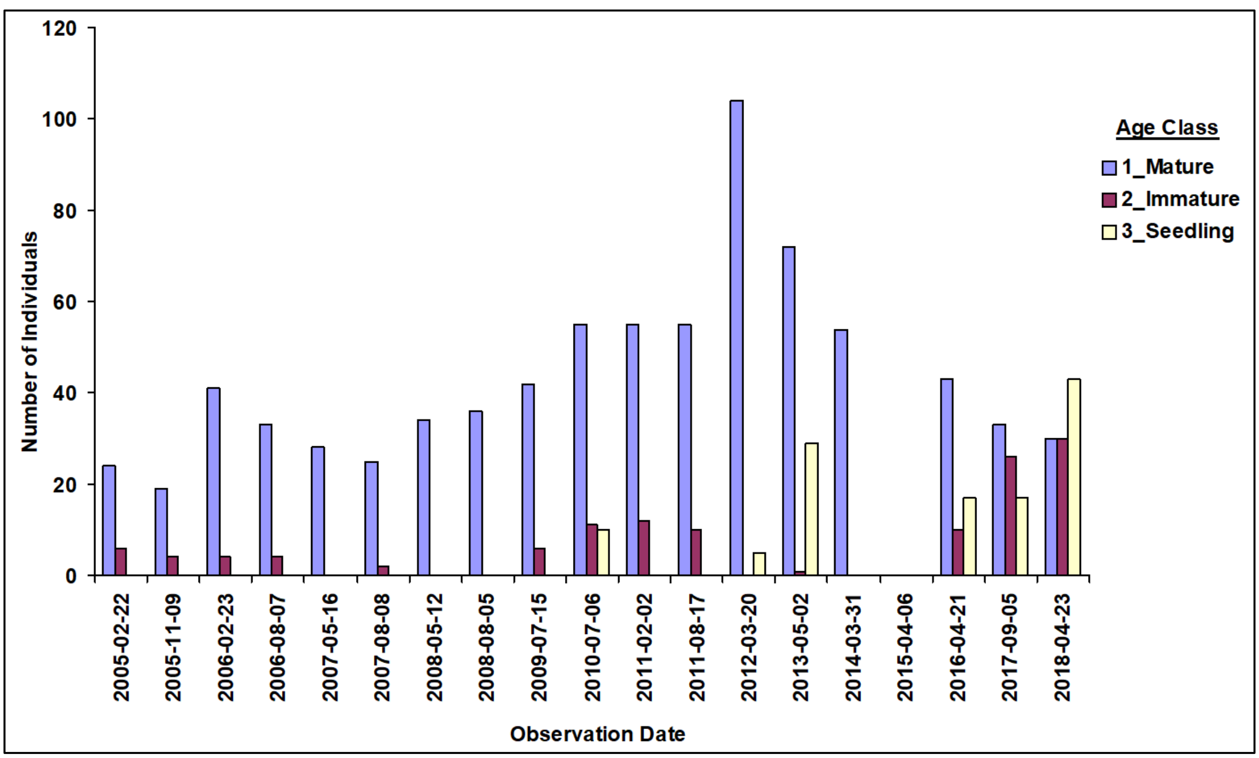



**Figure 13.** Schnut PAH-D reintroduction population structure for seedlings, immature, and mature plants

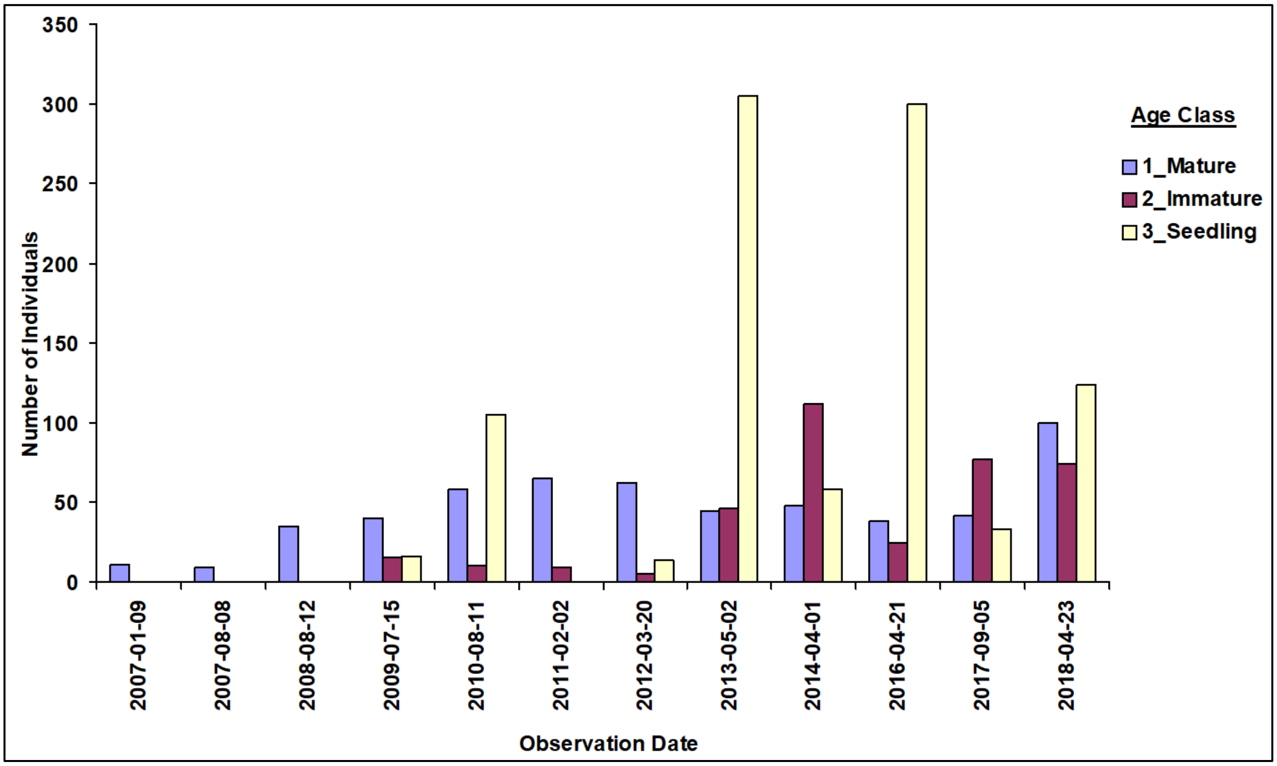



**Figure 14.** Schnut PAH-E reintroduction population structure for seedlings, immature, and mature plants

# Population Unit Kapuna-Keawapilau Ridge

The PIL-B reintroduction site has been outplanted twice since 2013 (Fig. 15). Individuals mature within one year of outplanting, but overall survival has been the lowest of all outplanting sites with less than 25% survival after five years. During the recent outplanting in 2017, the outplanting site was expanded following intensive weed control to include habitat in the upper slope of the outplanting zone. It is hoped that this new zone will provide better habitat for recruitment and outplanting survival. The Kapuna-Keawapilau Ridge PU contains only one population, PIL-B. It is also the only PU to fall below the required 50 reproducing individuals in the past 5 years.

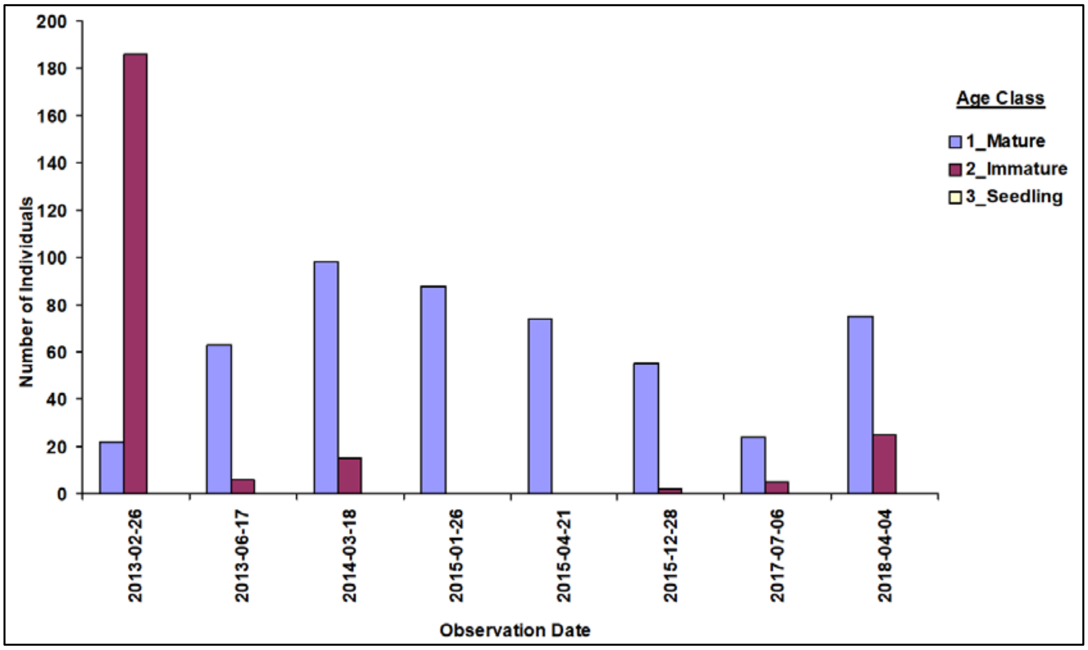



**Figure 15.** Schnut PIL-B reintroduction population structure for seedlings, immature, and mature plants

## Population Unit Makaha

The Makaha PU (MAK-A) was initially started in 2007 and recruitment has been observed only starting in 2015 after being outplanted eight times. Over 350 plants have been introduced there so far, and this PU contains the largest number of mature individuals from outplants, but currently recruitment is limited to less than ten seedlings and immature plants (Fig. 16). This site could benefit from molluscicide application following surveys to ensure there are no rare snails near the population.

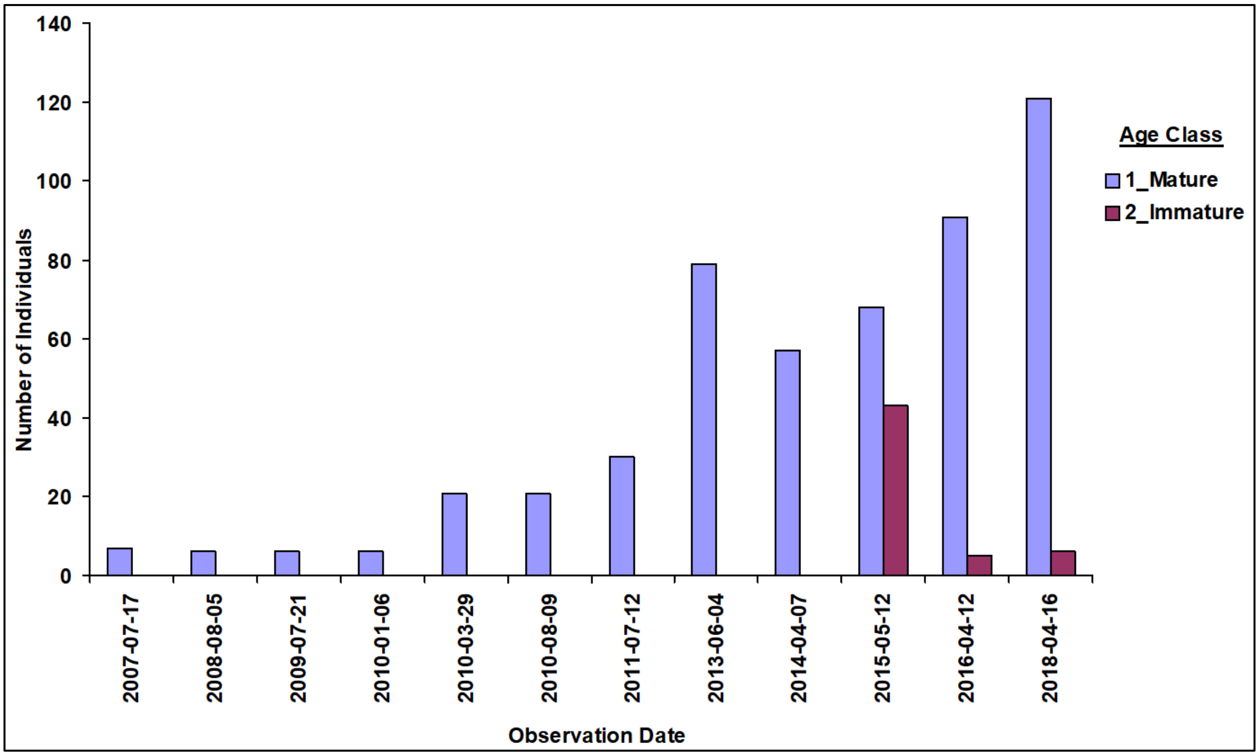



**Figure 16**. Schnut MAK-A reintroduction population structure for seedlings, immature, and mature plants

**Outplanting considerations from 2003 MIP:** Considerations for outplanting are as follows, "In the Waianae Mountains, *S. nuttallii* is often located in the same drainages as its close relatives *S. kaalae* and *S. pentandra*, and the more distantly related *Alsinidendron obovatum* (currently known as *S. obovata*). Hybridization between *Schiedea* species has been documented in the wild, and *Schiedea* species grown together in cultivation occasionally hybridize (Weller pers. comm. 2000). In order to avoid inadvertently causing unnatural hybridization, *S. nuttallii* should not be outplanted near any related species with which it does not naturally occur."

**Current Outplanting considerations and plan**: A study (Weisenberger 2012) was undertaken to determine the fitness of outplants grown from seed produced by outcrossing and selfing the MMR-B and PAH-A founders of *S. nuttallii*. Results and management recommendations from this study are being used to guide the founder mix at each outplanting. Results from the study are summarized below:

The Kahanahaiki (MMR-B) stock does not show inbreeding depression, outbreeding depression, or heterosis and is relatively less fit than stock from Pahole (PAH-A). The recommended reintroduction strategy for the Kahanahaiki stock is to complete the planting of all Kahanahaiki stock into the PAH-D site. Also, the Kahanahaiki stock should be included in multi-source reintroductions of the Pahole, Kahanahaiki, and Keawapilau stock into the Kapuna-Keawapilau Ridge and Makaha PUs. If these outplantings do not achieve stability goals for each PU within five years of establishment, more plants should be planted and the addition of plants grown from controlled breeding of all available founders should begin.

Pahole plants (PAH-A) do not suffer from inbreeding depression and do not express heterosis upon outcrossing with Kahanahaiki (MMR-B). Pahole outplants should be reintroduced into Pahole and not mixed with stock from other populations. The recommended reintroduction strategy for the Pahole stock is to complete the planting of all Pahole stock into the PAH-E site. Also, the Pahole stock should be included in a multi-source reintroduction of the Pahole, Kahanahaiki, and Keawapilau stock that will be used for outplantings in the Kapuna-Keawapilau Ridge and Makaha PUs. If these outplantings do not achieve stability goals for each PU within five years of establishment, more plants should be planted and the addition of plants grown from controlled breeding of all available founders should be considered.

The PAH-B site consists of one plant further down gulch from the PAH-A site. It is in a slightly different habitat and has a slightly different habit (longer leaves, more vine-like, longer internodes along stem and inflorescences). When the plant is cloned or seedlings propagated, the resulting plants are much more similar to other populations, suggesting phenotypic plasticity as opposed to genetic variation as the source for morphological differences.

Stock from the extirpated *in situ* site at Keawapilau (PIL-A) had been maintained in cultivation at UC Irvine by Drs. Stephen Weller and Ann Sakai. Propagules from these plants were used in the outplantings in the Kapuna-Keawapilau Ridge and Makaha PUs.

Very little pollinator activity was observed at the PAH-D site in 2010 and it is possible the current populations are too small and fragmented to attract effective pollinators (Groom 1998, Weisenberger, unpubl. data), or are located in areas where pollinators are not present.  Also, outplants are short-lived (average 5-10 years); and produce seeds for a few years yielding only a few cohorts. The density and total number of outplants may need to be increased to attract pollinators and produce a large quantity of seeds within the first few years of planting.

## Reintroduction Plan

Priority for reintroductions will be to establish population structure at the existing site in Makaha, as well as monitor the PIL-B site for improved outplanting survival and recruitment.  The expansion of the PIL-B site to the upper slope, as well as the addition of common native outplanting at the site should help to improve outplanting survival, compared to previous outplanting attempts.  As this site has historically had the lowest outplanting survival of all sites, continued outplantings will be needed to maintain the minimum number of reproducing plants unless seedling establishment increases. We plan to outplant additional plants in the coming year to build structure into the newly expanded area towards the upper slope of this population.

A majority of the plants encompassing the Kahanahaiki to Pahole PU are from two reintroduction sites, PAH-D and PAH-E.  This PU meets the goal for reproducing individuals, and there are also robust numbers of immature plants and seedlings.  The PAH-E site is difficult to monitor due to the dense mats of seedlings and immature plants present in the center of the population, but this site has had stable numbers of plants over the past four years and has the most total plants of any site.  The PAH-D site has also had recruitment over the past few years, after starting slug control.  This population has mature plants that will soon reach the end of their lifecycle and we will plan to expand the outplanting site downslope to add more individuals to this site and build population structure. These populations will be monitored to see if individuals develop into mature plants over the next year, and if needed, begin outplanting into the PAH-D site. The current number of mature plants observed at the outplanting sites in the Pahole PU are the highest since outplanting began.

The Makaha PU is similar to the Kapuna-Keawapilau Ridge PU in that all the individuals are found in just one population, MAK-A. While this population has over 100 mature plants, all are original outplants and not the result of recruitment. There is a lack of population structure with less than 10 total immature plants and seedlings present. The number of mature plants in this population has increased over the years, but this is due to the addition of new outplants over time. This site will be monitored for any major changes in the number of immature plants, as well as the number of individuals developing into mature plants. Augmentation to this site will likely be needed in the future, and will be determined following the next monitoring.

**Table 7.** Current and proposed outplantings of *S. nuttallii* to maintain stabilization goal of 25 reproducing individuals per PU.

| **Manage for Stability Population Units** | **Reintroduction Site(s)** | **Total Plants to be planted** | **Propagule Type** | **Propagule Population(s) Source** | **Plant Size** | **Year 2018-2019 # of plants** | **Year 2019-2020 # of plants** | **Year 2020 2021 # of plants** |
|---|---|---|---|---|---|---|---|---|
| Kahanahaiki to Pahole | PAH-D | 200 | Plants from cuttings | MMR-B | >10cm | 35 | 75 | 90 |
| Kahanahaiki to Pahole | PAH-E | 50 | Plants from cuttings | PAH-A/B | >10cm | 0 | 25 | 25 |
| Kapuna-Keawapilau Ridge | PIL-B | 150 | Plants from cuttings | MMR-B, PAH-A & B, PIL-A | >10cm | 50 | 50 | 50 |
| Makaha | MAK-A | 150 | Immature plants | MMR-B, PAH-A & B, PIL-A | >10cm | 50 | 50 | 50 |

The propagule type for each planting will be immature plants grown from seeds collected from wild or outplanted plants. An asterisk (*) indicates outplantings that have not yet been initiated.

The number to be planted at each site is currently determined by factoring in the survivorship of previous plantings at Pahole, Keawapilau, and Makaha and the number of mature recruits produced by the surviving outplants at each site. The data from survivorship at all sites and data from monitoring the recruitment at reintroduction sites will be used to guide future outplantings.

## Monitoring plan

The *in situ* site (PAH-A) will be monitored annually using the HRPRG Rare Plant Monitoring Form (RPMF) to record population structure and the age class, reproductive status and vigor of all known plants. The site will be searched for new seedlings and all new juvenile plants will be tagged. If there is any threat to the health and safety of plants, adjustments to the number of tagged individuals will be made. This monitoring data will serve to document the populations at the remaining sites to guide *in situ* threat management and genetic storage needs as these sites decline.

The reintroduction sites in all PUs will be monitored annually in the winter (January-March) using the RPMF to record population structure, age class, reproductive status and vigor. All outplants will be accounted for along with a total population census. This data will be used to guide future outplanting. The total number of mature recruits per total number of plants outplanted will be used to guide the number of outplants needed to establish 50 mature recruits.

All new juvenile F1 plants at PAH-D, PAH-E, PIL-B, and MAK-A will be tagged until a total of 50 have been tagged at each of these three sites. The annual survivorship (vigor) of these tagged plants will be recorded annually along with the rest of the plants using the RPMF. If the number of mature recruits have reached 50, this data will be used to document life-history data and transitions rates from each age class to the next in conjunction with current population structure data to predict population structure for future years. This projection will allow us to determine if 50 reproducing plants will be maintained, or if the population is projected to increase or decrease. These results may be used to adjust the number of outplants planned and to augment or replace underperforming sites if a decline is anticipated.

**Threats:** The primary threat to *S. nuttallii* at the time the Makua Implementation Plan was finalized (2003) was feral pigs. All populations are currently in ungulate-free fenced areas, which are monitored for damage from treefall and potential ungulate ingress under fences due to erosion. Predation of plants and seedlings by rodents and slugs has been documented, and have had a negative effect on seedling survival and plant development. Most populations are partially protected from rodents, but smaller grids around populations will be implemented as the outplanting sites expand. In addition, game birds have been observed to damage native plants in areas surrounding outplanting sites. Slug control has been initiated in many populations where native snails are absent, and most of these sites have shown excellent recruitment, likely attributed to threat control. Various alien plant species threaten *S. nuttallii* by altering its habitat and competing with it for sunlight, moisture, nutrients, and growing space. However, recruitment and survival in the Pahole reintroduction sites have been great despite the presence of invasive overstory canopy trees. Care should be taken not to open large light gaps that could be detrimental to continued success of these sites. Understory weed control is essential to maintain reproducing populations and continued recruitment of immature plants. Fungal pathogens are not currently an issue with this species but should be monitored for any potential impacts. We will continue to assess how these threats are impacting population stability as we monitor the populations, and adjust our management strategies accordingly.

## Genetic Storage Plan

The re-collection interval to replace *S. nuttallii* seeds in storage is currently 20 years and will be extended until a decline in viability is detected. Testing will cease once this decline in viability is observed. Seed will be collected for storage from PAH-D and PAH-E, as this PU is the only one that does not have complete genetic storage (currently 82%). Genetic storage for the Kahanahaiki to Pahole PU consists of a mix of seed collections and living collection plants. Priority for this PU will be to try to get all founders stored as seed collection. Collections are ongoing and re-collections are necessary following decline in viability determined by the seed storage interval. Once the new reintroductions are established, seeds will be stored from those mixed-founder reintroductions as well.

**Table 8.** Action plan for how to maintain genetic storage representation, and provide propagules for reintroduction.

| Propagule type used for meeting genetic storage goal? | Source for propagules? | Genetic Storage Method used to meet the goal? | Proposed re-collection interval for seed storage? | Seed storage testing ongoing? | Plan for maintaining genetic storage. |
|---|---|---|---|---|---|
| Seeds | Reintroductions | Seed Storage: -18C / 20% RH | ≥20 years† | Yes | Single-source and Mixed Reintroductions |
| †Seeds in storage of this species have not shown a decline in viability. The viability tests are conducted every five years. Re-collection intervals will continually be extended until a decline in viability is detected. | | | | | |

## Future Management Considerations

All three PUs currently meet the MIP goals for minimum number of reproducing individuals. While at least one site in each PU has over 50 immature plants, consideration should be given for additional outplantings within these PU. The effects of extreme weather events, fires, and long drought periods make individual sites susceptible to be being wiped out, while having plants spread across multiple sites within a PU gives the species a better chance for long term survival. Additionally, little recruitment is observed in some PUs, so continued outplantings may be needed as mature plants die, unless threat management strategies result in increased recruitment and survival of F1 generation plants.

In past years, recruitment following initial outplanting had been inconsistent, especially in the Kapuna-Keawapilau Ridge and Mahaka PUs. However, the Kahanahaiki to Pahole PU has had excellent recruitment and plants continue to develop into mature plants and replenish the seed bank. This has led to increases in both the mature and immature plant totals within this PU. The approach to threat control at these sites should be implemented in the other PUs, including increased weed control and habitat improvement. The primary strategy for this taxon for the next five years will be to focus on improving habitat through weed control, common outplantings, and threat control of rats and slugs. If recruitment and seedling survival continues to be limited, continued outplantings are the only current viable option to maintain stable population numbers, and new sites may need to be established. As there are only two *in situ* sites remaining, and one site contains only a single individual, successful establishment of reintroduction sites will be essential or the survival of this species.

The Kapuna-Keawapilau Ridge PU currently meets the genetic storage requirement 100%, while the Kahanahaiki to Pahole PU has 82% genetic storage completion. Collecting fruit from the remaining founders in this PU will be prioritized, and additional collections will only be required as seed storage intervals determine expiring seed collections.

Management efforts will also include monitoring as well as the feasibility of adding Sluggo to populations that do not show improved recruitment. In order to establish reintroduction sites that become stable, the following should be considered to improve plant survival and reproduction:

**Habitat site selection** (large scale and micro-site locations): OANRP plans to expand the PAH-D outplanting site downslope and increase the habitat area. Habitat and micro-site conditions that promote recruitment and stage class transitions to immature and mature plants, such as open native understory, will be prioritized. New outplanting sites should take into account the effects of climate change and drought, as well as weed control strategies, slug control, and habitat restoration for long-term survival and reproduction.

**Habitat improvement:** Outplantings of common native species have begun at some populations to provide shade for outplants following intensive weeding efforts. Continued habitat improvement before and after reintroductions should continue with common native species, in addition to monitoring for rare plant recruitment around these areas.

**Threat Control**: OANRP will review ongoing threat control methods for rodents and slugs to determine if increased efforts or alternative methods could have a positive effect on recruitment. A24 automatic rat traps have been an improvement in some areas as they require far less labor than previously used snap traps. All outplantings are contained in fences to control ungulates, have weed and rat control, and most receive slug control if rare native snails are not present. Increased frequency and time spent on control methods may be necessary in the future if natural recruitment and goals for population structure are not met.

## References


Ellshoff, Z. E., J. M. Yoshioka, J. E. Canfield, and D. R. Herbst. 1991. Endangered and threatened wildlife and plants; determination of endangered status for 26 plants from the Waianae Mountains, Island of Oahu, Hawaii. Federal Register **56**:55770-55786.

Groom, M. J. 1998. Allee Effects Limit Population Viability of an Annual Plant. The American Naturalist **151**:487-496.

Giambelluca, T.W., Q. Chen, A. Frazier, J.Price, Y.L. Chen, P.S. Chen, J. Eischeid, and D. Delparte. 2011. The Rainfall Atlas of Hawaii. http://rainfall.geography.hawaii.edu. University of Hawaii, Honolulu.

Makua Implementation Team (MIT). 2003. Final Makua Implementation Plan. Prepared for the U.S. Army Garrison, Schofield Barracks, HI.

Norman, J. K., A. K. Sakai, S. G. Weller, and T. E. Dawson. 1995. Inbreeding Depression in Morphological and Physiological Traits of *Schiedea lydgatei* (Caryophyllaceae) in Two Environments. Evolution; international journal of organic evolution **49**:297-306.

PRISM. 2018. Prism Climate Group. Oregon State University. http//prism.oregonstate.edu.

Wagner, W. L., S. G. Weller, and A. K. Sakai. 2005. Monograph of Schiedea (Caryophyllaceae – Alsinoideae. Systematic Botany Monographs **72**:1-169.

Weller, S. G., A. K. Sakai, A. E. Rankin, A. Golonka, B. Kutcher, and K. E. Ashby. 1998. Dioecy and the evolution of pollination systems in *Schiedea* and *Alsinidendron* (Caryophyllaceae: Alsinoideae) in the Hawaiian Islands. American journal of botany **85**:1377-1388.

Weisenberger, L. A. 2012. Inbreeding depression, outbreeding depression and heterosis in rare species in the genus Schiedea (Caryophyllaceae) on O`ahu. University of Hawai'i at Manoa, Honolulu.

# *Schiedea obovata*

**Scientific name:** *Schiedea obovata* Sherff
**Hawaiian name:** None
**Family:** Caryophyllaceae
**Federal status:** Listed Endangered October 29, 1991
**Requirements for MIP Stability**

- 3 Population Units (PU)
- 100 reproducing individuals in each PU
- Stable population structure
- Threats controlled
- Complete genetic representation of all PUs in storage

## Description and biology

**Habit-** Suberect or ascending, branched shrubs 3-10 dm tall, glabrous throughout except for the leaf margins.

**Leaves**- Leaves opposite; blades 4-11 cm long, (1.5-6.8) cm wide, thick and somewhat fleshy, light green becoming yellowish white toward the base and at the apex (youngest yellowish white, sometimes purple tinged), elliptic to broadly elliptic, sometimes obovate or oblanceolate, with 3 principal veins, sometimes also with an inconspicuous looping pair of veins near the margins, margins serrulate, the teeth with antrorsely hooked hairs ca. 0.1-0.2 mm long, apex mucronate; petioles 1-3 (-3.8) cm long, yellowish white.

**Flowers**- Inflorescence pseudoaxillary, with 22-33 flowers, somewhat congested; bracts much smaller than uppermost leaves, usually curled and twisted, lowest pair to 1.4 cm long; peduncles (2-) 5-25 mm long, not elongating much in fruit, the internodes of the lateral inflorescence branches 2-10 mm long; pedicels thinner, 15-30 mm long, elongating mostly just prior to anthesis. Flowers apparently adapted for bird pollination, pendent. Sepals (4-6), often variable on the same plant, 7-8.4 mm long, 5.5-6 mm wide, enlarging to 9-12 mm long and 8-9 mm wide in fruit, white adaxially, the outer ones oblong-elliptic, pale green abaxially, inner ones elliptic to obovate, greenish white with a green midrib, the apex broadly obtuse and usually retuse, the outer ones sometimes with a subapical minute mucro, becoming dark purple and fleshy as fruit matures. Stamens (8-12); filaments 4.4-5 mm long, subequal; anthers 1.9-2.65 mm long, pale reddish purple at anthesis, changing to a darker reddish purple, the pollen gray. Nectary ring bright green, the flap-like extensions weakly connate at the base, thin, translucent, 2.2-2.5 mm long, irregularly 2-toothed to subentire. Styles (4-8), often variable in number on the same plant (Modified from Wagner *et al.* 2005).

**Fruit-** Capsules 9-12 mm long, ovoid to subglobose.

**Seeds-** Seeds 1.2-1.5 mm long.

**Distribution-** Oahu, formerly nearly throughout the Waianae Mountains, now restricted to the north end of the Waianae Mountains; rare and scattered on ridges and slopes in diverse mesic forest; 550-800 m.

**Pollination and dispersal-** Passerine birds have been suspected pollinators due to nectar concentration and amount (Weller et al. 1998), but no birds have been observed visiting this species (Weisenberger 2012). The fleshy dark purple sepals surrounding the mature capsules of the two species (*S. obovata* and

*S. trinervis*) are unique in the Caryophyllaceae and may have attracted birds as dispersal agents. As the fruit matures, the calyx lobes persist and become purple and fleshy. This ‘false berry’ is very likely to attract fruit-eating birds that may disperse the species' seeds (Carlquist 1970).

**Taxonomic background:** There are 34 endemic species in the endemic genus *Schiedea.* All species have been shown to have arrived from one single colonization. The name *Schiedea obovata* was changed from *Alsinidendron obovatum* after molecular and morphological data from Wagner *et al*. (2005), concluded that *Alsinidendron* formed a monophyletic group within *Schiedea*. *Alsinidendron* has since been subsumed into the Hawaiian endemic genus *Schiedea*. *Schiedea obovata* is differentiated from the closely related *S. trinervis* by its more congested inflorescence, flowers that open fully during anthesis and have greater nectar production, and thicker leaves, the young ones whitish green. It grows in mesic forests at lower elevations than *S. trinervis*. The congestion in the inflorescence of *S. obovata* appears to be primarily due to the reduction of the internodes of the lateral inflorescence branches and to the delayed elongation of the pedicels until just prior to anthesis.

**Table 1.** Historic Collections of *Schiedea obovata* on Oahu

| Area | Year | Collector | Pop. Reference Code |
|---|---|---|---|
| Palehua | 1911 | Forbes | |
| Palehua | 1927 | Degener Horner | |
| Palehua | 1929 | Russ | |
| Palehua | 1929 | St John | |
| Palehua | 1931 | Degener Park | |
| Pahole | 1932 | Degener | PAH-A |
| Palehua | 1933 | Judd | |
| Palehua | 1933 | Russ | |
| Palehua | 1934 | Wilder | |
| Pahole | 1934 | Onouye | PAH-A |
| Pahole | 1934 | St John | |
| Palehua | 1937 | Fosberg | |
| Palehua | 1938 | Skottsberg | |
| Palehua | 1946 | Kerr | |
| Palehua | 1950 | Hatheway et al 87 | |
| Pahole | 1973 | Nagata & Obata | PAH-C |
| Pahole | 1975 | Herbst & Obata | |
| Makaleha | 1978 | Gagne & Gagne | LEH-B |
| Pahole | 1987 | Perlman & Obata | PAH-A |
| Pahole | 1987 | Perlman | PAH-A |
| Mokuleia | 1908-1920 | Forbes | |
| Kaluaa | 1978 | Takeuchi | |
| Keawapilau | 1980s | Welton | PIL-A |

**Table 2.** Reproductive Biology of *S. obovata*

| | **Observed Phenology** | | | **Reproductive Biology** | | **Seeds** | |
|---|---|---|---|---|---|---|---|
| **Population Unit** | **Flower** | **Immature Fruit** | **Mature Fruit** | **Breeding System** | **Suspected Pollinator** | **Average # Per Fruit (viable)** | **Dormancy** |
| Kahanahaiki to Pahole | Jan-Sept | Jan-Oct | Jan-Dec | Hermaphroditic | Bird or None | ~100 ± 15[¥] | None* |
| Keawapilau to West Makaleha | Jan-Dec | March-Dec | Jan-Dec | Hermaphroditic | Bird or None | 80±10 | None* |
| Makaha | Jan-June | April-June | April-Dec | Hermaphroditic | Bird or None | 48± 3 | None* |

*Some collections have delayed initial germination for approximately six months. A physiological mechanism to prevent germination until cooler, wetter winter months may be present. This delay has been documented occasionally across all populations and collections. There is substantial variation among length of time until initial germination between individual plants within the same collection and between different collections of the same plant. Delayed germination may be mechanism for preventing germination during the hottest months immediately following dispersal.

¥ Some collections of mature fruit have lower numbers of seeds per fruit; likely because fruit are picked after most seeds have dispersed.

**Breeding System:** Hermaphroditic (facultative autogamy) (Weller et al. 1998) with high selfing rates and very little pollinator visitation (Weisenberger 2012).

**Fruit collection:** Peak collection time is spring (April-May).

# Plant morphology and habitat

**Figure 1.** Outplanting of immature plants

**Figure 2.** Immature and Mature fruit

**Figure 3.** Mature plant variation in leaf morphology

**Figure 4.** Immature and mature fruit on plant with typical leaf morphology

**Figure 5.** Mature fruit and seed

**Figure 6.** Open flower with perianth removed

**Figure 7.** Seedling recruitment in a dense mat

**Figure 8.** Immature and mature fruit

**Figure 9.** Flower development

**Figure 10.** Flower with purple pollen

**Table 3.** Habitat characteristics

| PU | Population Reference Code | Elevation (feet) | Slope | Topography | Aspect | Annual Ave. Max. Temp. (F)* | Average Annual Rainfall (mm)*/** |
|---|---|---|---|---|---|---|---|
| Kahanahaiki to Pahole | MMR-A *in situ* | 1880 | Vertical | Upper Slope | N | 77 | 1561/ 1334 |
| Kahanahaiki to Pahole | MMR-G reintro | 2000 | Moderate | Upper Slope | N | 77 | 1531/ 1320 |
| Kahanahaiki to Pahole | PAH-A *in situ* | 2297 | Steep | Upper Slope | N | 75.2 | 1766/ 1505 |
| Kahanahaiki to Pahole | PAH-C *in situ* | 2100 | Steep | Upper Slope | N | 75.2 | 1667/ 1425 |
| Kahanahaiki to Pahole | PAH-D reintro | 2250 | Moderate | Upper Slope | N | 75.2 | 1667/ 1425 |
| Keawapilau to West Makaleha | PIL-A *in situ* | 2149 | Moderate | Upper Slope | N | 75.2 | 1781/ 1556 |
| Keawapilau to West Makaleha | PIL-B *in situ* | 2240 | Moderate | Upper Slope | NE | 75.2 | 1880/ 1612 |
| Keawapilau to West Makaleha | PIL-C reintro | 2500 | Moderate & Steep | Upper Slope & Crest | N | 75.2 | 1880/ 1612 |
| Keawapilau to West Makaleha | LEH-A *in situ* | 2598 | Steep & Vertical | Upper Slope | N | 73.4 | 2022/ 1765 |
| Keawapilau to West Makaleha | LEH-B *in situ* | 2500 | Moderate & Steep | Upper Slope | E | 75.2 | 1962/ 1651 |
| Keawapilau to West Makaleha | LEH-C reintro | 2760 | Steep | Upper Slope & Crest | NE | 73.4 | 2023/ 1766 |
| Makaha | MAK-A reintro | 2600 | Moderate & Steep | Upper Slope | N | 75.2 | 1921/ 1638 |

Information was compiled from Army Natural Resource Program - Oahu (OANRP) observation forms, GIS data, PRISM Climate Group. *PRISM. 2018. Prism Climate Group. Oregon State University. http://prism.oregonstate.edu. **Giambelluca TW, Chen Q, Frazier AG, Price JP, Chen Y-L, Chu P-S, Eischeid J., and Delparte, D. 2011. The Rainfall Atlas of Hawai‘i. http://rainfall.geography.hawaii.edu.

**Table 4.** Associated species table, species are listed in order of abundance as observed by the Army natural resource program on Oahu (OANRP). Six digit codes used for species names.

| PU | Population Reference Code | Canopy | Understory |
|---|---|---|---|
| Kahanahaiki to Pahole | MMR-G reintro | AcaKoa, PsyOdo, MetPol, SchTer, PsiCat, SanFre, AntPla, DioHil | AlyOli, MicStr, MepExa, DiaSan, CarWah, VioCha, OplHir, DooKun, HedTer, ConBon, MelMin, AspKau, PhlAur, AspNid, CocTri, RauSan, ChaMul, ReySan, DieFal, LanCam, PepTet, AspHor, BleApp |
| Kahanahaiki to Pahole | PAH-D reintro | AcaKoa, MetPol, PsyOdo, ChaTom, Schter, PsyMar, AntPla, Psicat | FreArb, Psicat, Alyste, DooKun, CibCha, Coplon, PsyOdo, Clihir, AntPla, Oplhir, Bleapp, Rubros |
| Kahanahaiki to Pahole | PAH-E reintro | SchTer, MetPol, LepTem, PsiCat, DodVis, PsyOdo | DiaSan, CliHir, MelMin, LanCam, MicStr, AlyOli, CocTri |
| Keawapilau to West Makaleha | PIL-A *in situ* | MetPol, MelPed, GreRob, AntPla, WikOah, PsyMar, PsiCat | NepExa, AlyOli, PasCon, OplHir, DiaSan, BidTor, DryGla, BleApp, HedTer, AspHor, PleAur, CliHir, SchNut, CyaLon |
| Keawapilau to West Makaleha | PIL-B *in situ* | MetPol, AcaKoa, AntPla, SchTer, GreRob, PsiCat | CarWah, MicStr, RubRos, CliHir, BleApp, DooKun |
| Keawapilau to West Makaleha | PIL-C reintro | MetPol, AcaKoa, PsiCat, SchTer, PsyOdo, NesSan, SyzCum, GreRob | DodVis, BleApp, DooKun, MelMin, LepTam, DicLin, StaDic, MicStr, RubRos, CarWah, BidTor, AlyOli, CopFol, NepCor, NepExaHaw, OxaCor, PsiCat, ElaPal, PsiNud, CreCre, PanNep, CliHir, CocTri, HedTer, WikOah, LanCam, ConBon |
| Keawapilau to West Makaleha | LEH-A *in situ* | AntPla, PsiCat, MetPol, GreRob | DipPin, AlyOli, CliHir, OdoChi, RubRos, DooKun |
| Keawapilau to West Makaleha | LEH-B *in situ* | MetPol, PsiCat, AcaKoa, SchTer | MelMin, BidTor, AlyOli, AgeAde, DodVis, PanNep, CarWah |
| Keawapilau to West Makaleha | LEH-C reintro | PsiCat, MetPol, CopFol, MelClu, ScaGau, AntPla, DodVis | RubArg, BleApp, MelMin, StaDic, RubRos, CliHir, ChrPar, MetPol, PriKaa, PitGla, DicLin, PsiCat, NepMul, MelClu, AntPla, DipSan, PepMem, WikOah, FreArb |

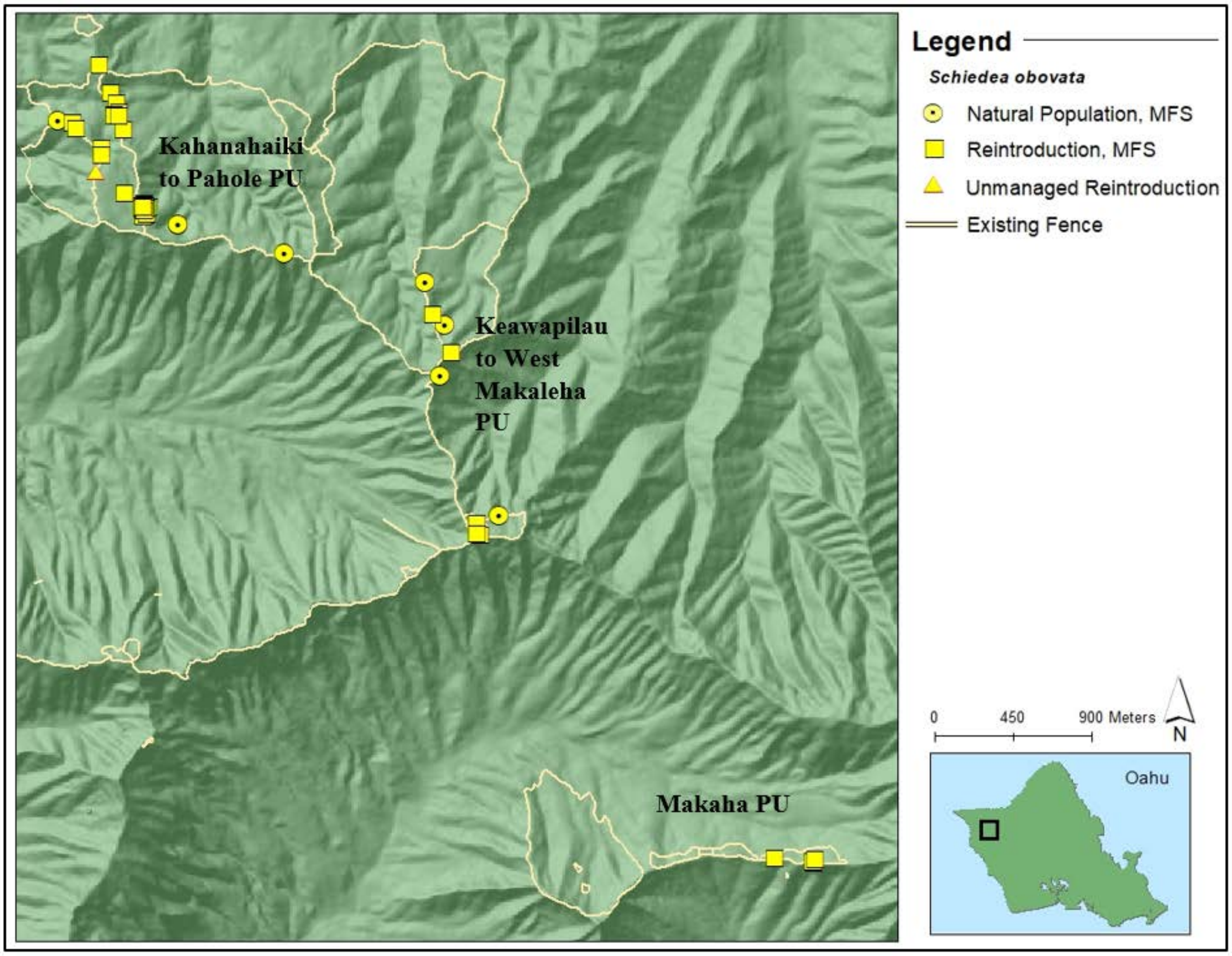



**Figure 11.** Map of current *Schiedea obovata* locations

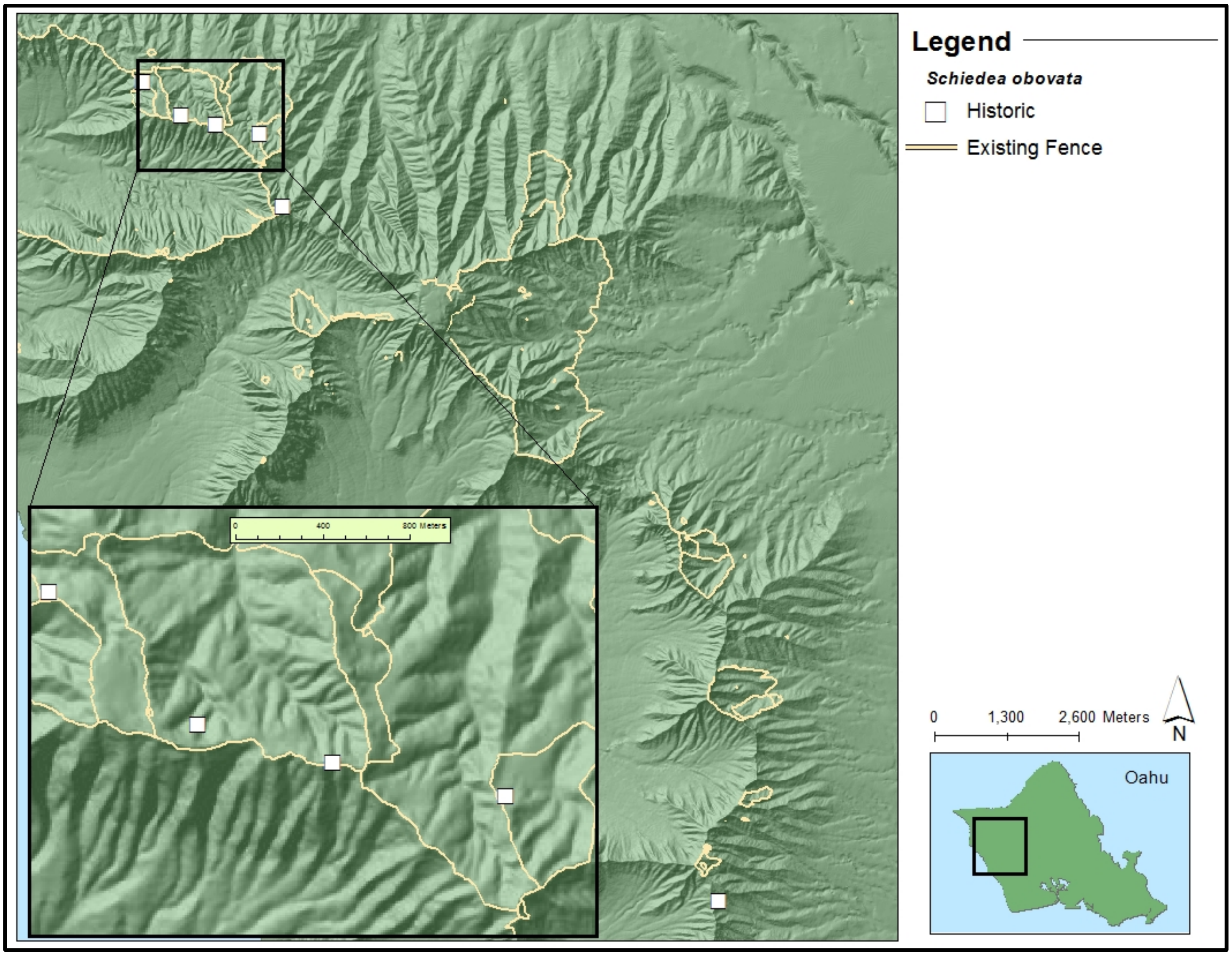



**Figure 12.** Map of historic *Schiedea obovata* locations

## Current status:

The known population units of *S. obovata* in the Waianae Mountains totals 917 plants, consisting of mature and immature plants, and seedlings (Table 5). This is an approximately 3% increase in the total plants from 2017. About 60% of this total is represented by *in situ* plants, and the remaining 40% from reintroduced populations. Currently, no PU has more than 100 reproducing individuals required to meet stabilization goals. While the total number of mature plants in the Keawapilau to West Makaleha PU and the Kahanahaiki to Pahole had previously been over 100 individuals, more recent declines, a lack of seedling development, and a reduction in immature plant survival has led to a decrease in overall plant numbers in these PU. The threat of fire is highest for the Makaha and Pahole PUs. Future outplantings will be needed to meet the stabilization goals for the number of reproducing individuals, as currently there are no PUs that meet the minimum number of reproducing individuals, despite slug control at two populations in the Keawapilau to West Makaleha PU, and at the lone population in the Makaha PU.

**Table 5.** Current population size and structure for all populations of *S. obovata*.

| PU | Population Reference Code | Mature Plants | Immature Plants | Seedlings |
|---|---|---|---|---|
| Kahanahaiki to Pahole | MMR-G reintro | 84 | 167 | 200 |
| Kahanahaiki to Pahole | PAH-D Reintro | 3 | 0 | 0 |
| Kahanahaiki to Pahole | PAH-E reintro | 4 | 0 | 0 |
| Keawapilau to West Makaleha | PIL-A *in situ* | 1 | 0 | 0 |
| Keawapilau to West Makaleha | PIL-B *in situ* | 3 | 306 | 2 |
| Keawapilau to West Makaleha | PIL-C reintro | 6 | 1 | 0 |
| Keawapilau to West Makaleha | LEH-A *in situ* | 2 | 2 | 0 |
| Keawapilau to West Makaleha | LEH-B *in situ* | 6 | 100 | 3 |
| Keawapilau to West Makaleha | LEH-C reintro | 7 | 0 | 0 |
| Makaha | MAK-A reintro | 20 | 0 | 0 |
| Totals for all populations | | 136 | 576 | 205 |

**Population Units:** Three Manage for Stability Population Units (MFS PU) are required for this taxon as it is found in the Makua Action Area. All PUs are MFS, as there are no Genetic Storage Population Units.

**Table 6.** Stabilization Goal Status, Yes/No/Partial refers to whether threat is mitigated.

| | PU Stability Target | MU Threat Control | | | | | Genetic Storage |
|---|---|---|---|---|---|---|---|
| **Population Unit** | **100 reproducing plants** | **Ungulate** | **Slugs** | **Rodent** | **Fire** | **Weeds** | **% Completed** |
| Kahanahaiki to Pahole | No | Yes | No | Partial | No | Yes | 100% |
| Keawapilau to West Makaleha | No | Yes | Partial | Partial | No | Yes | 100% |
| Makaha | No | Yes | Yes | Yes | No | Yes | N/A |

## Population Unit Kahanahaiki to Pahole

The Army natural resource program on Oahu (OANRP) began to outplant *S. obovata* into the Kahanahaiki to Pahole PU in 1999. A seedling was recently observed in the original outplanting site after years of no management in the area, which indicates the seedbank can persist long after reintroduced plants perish. The original outplantings were immature plants grown from seed, collected from the remaining *in situ* plants (MMR-A, PAH-C, LEH-A, PIL-B) and from seed collected from living collection plants (PAH-A and PIL-A). The Kahanahaiki to Pahole PU currently consists of three reintroduction sites that are monitored regularly, and have had fluctuating numbers of seedlings and immature plants. One site is in Kahanahaiki (MMR-G, Fig. 13), and two sites in Pahole (PAH-D and PAH-E, Figs. 14 and 15).

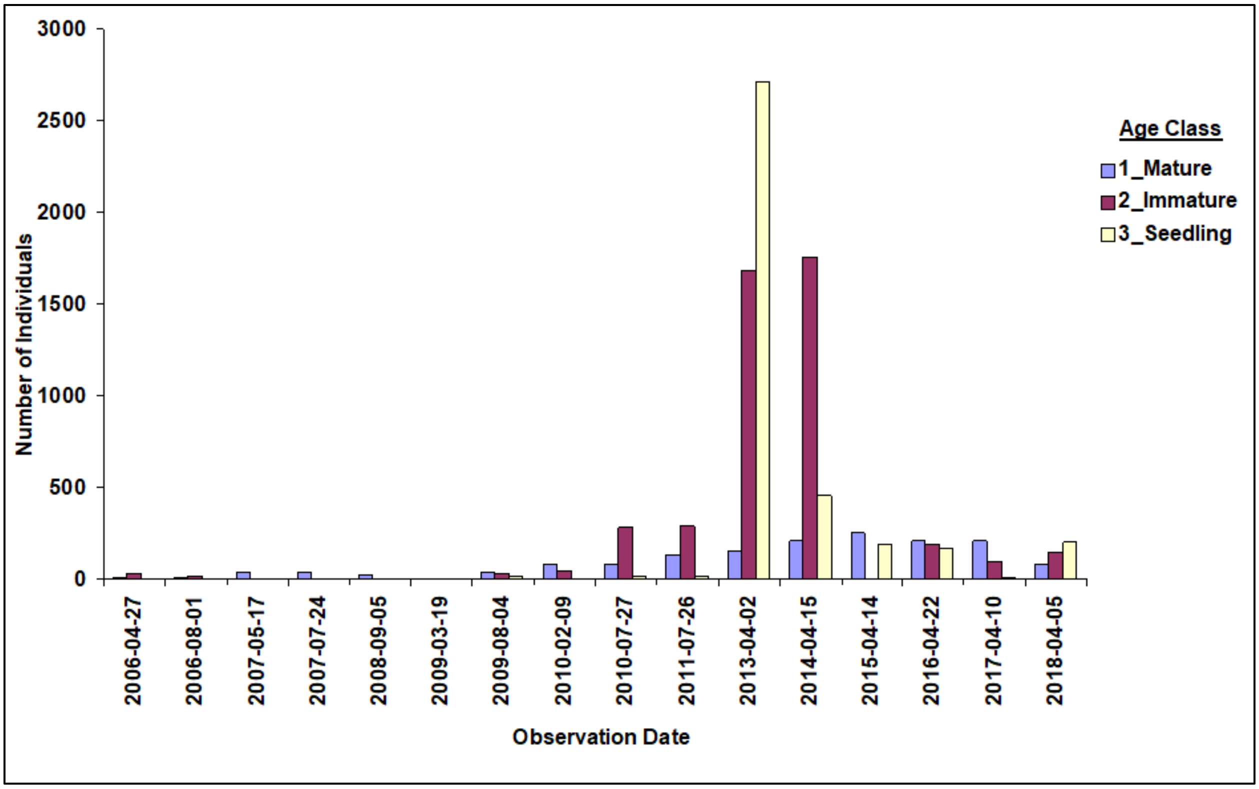



**Figure 13.** Schobo MMR-G reintroduction site population structure for seedlings, immature, and mature plants

Planting at the MMR-G site began in 2006 and outplants yielded mature plants within a few years. There was an increase in recruitment observed between 2010 and 2014, perhaps due to more open canopy in parts of the reintroduction area. Since 2013, many seedlings and immature plants have died, and the total number of plants have declined (Fig.13). The population size has not changed much over the past three years, with approximately 450 total plants. However, the population structure has changed from a majority mature plants to a majority seedling age class. This single population accounts for over 95% of the total plants in the Kahanahaiki to Pahole PU.

Planting at the PAH-D site began in 2003 and outplants yielded mature plants within a few years. The most recent outplanting was in 2011 but since then the population has been in steep decline, with only four mature plants remaining (Fig. 14). Similar population trends have been observed for PAH-E as well, with the most recent ouplanting in 2013, and currently only three mature plants remaining (Fig. 15). Increased weed encroachment and invasive canopy that limited light levels was the likely cause of decline.

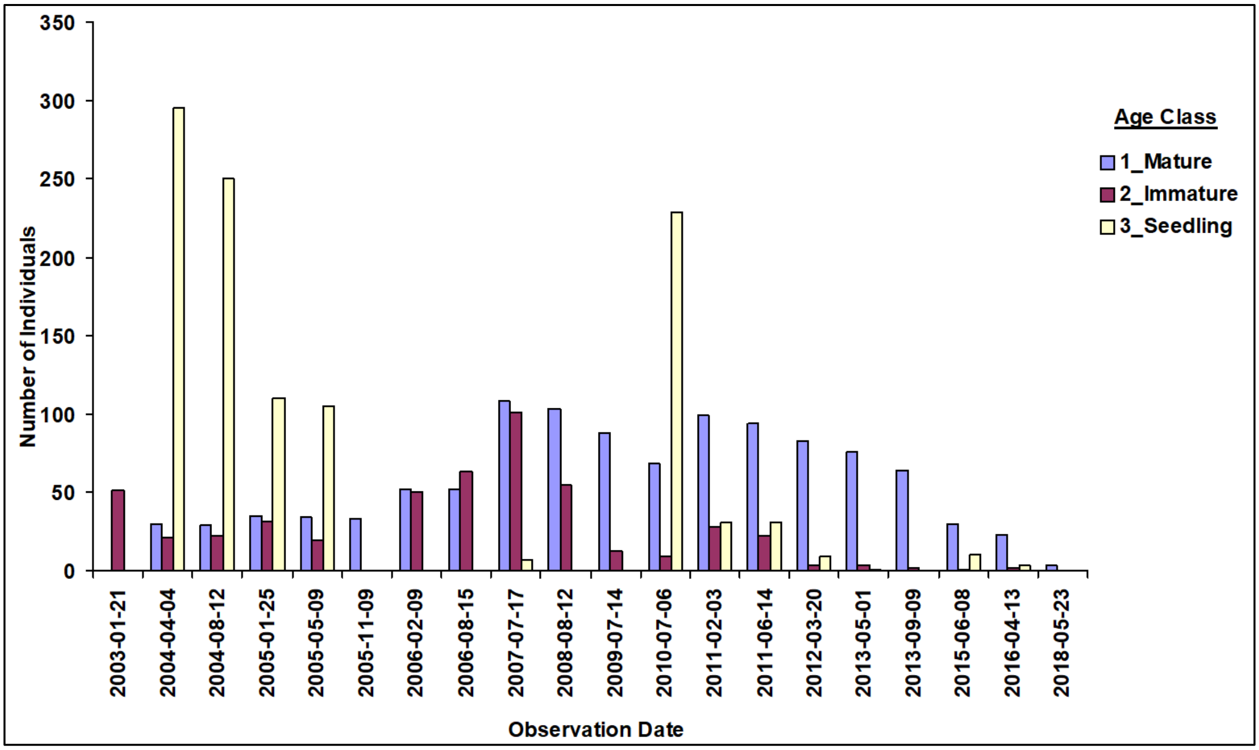



**Figure 14.** Schobo PAH-D reintroduction site population structure for seedlings, immature, and mature plants

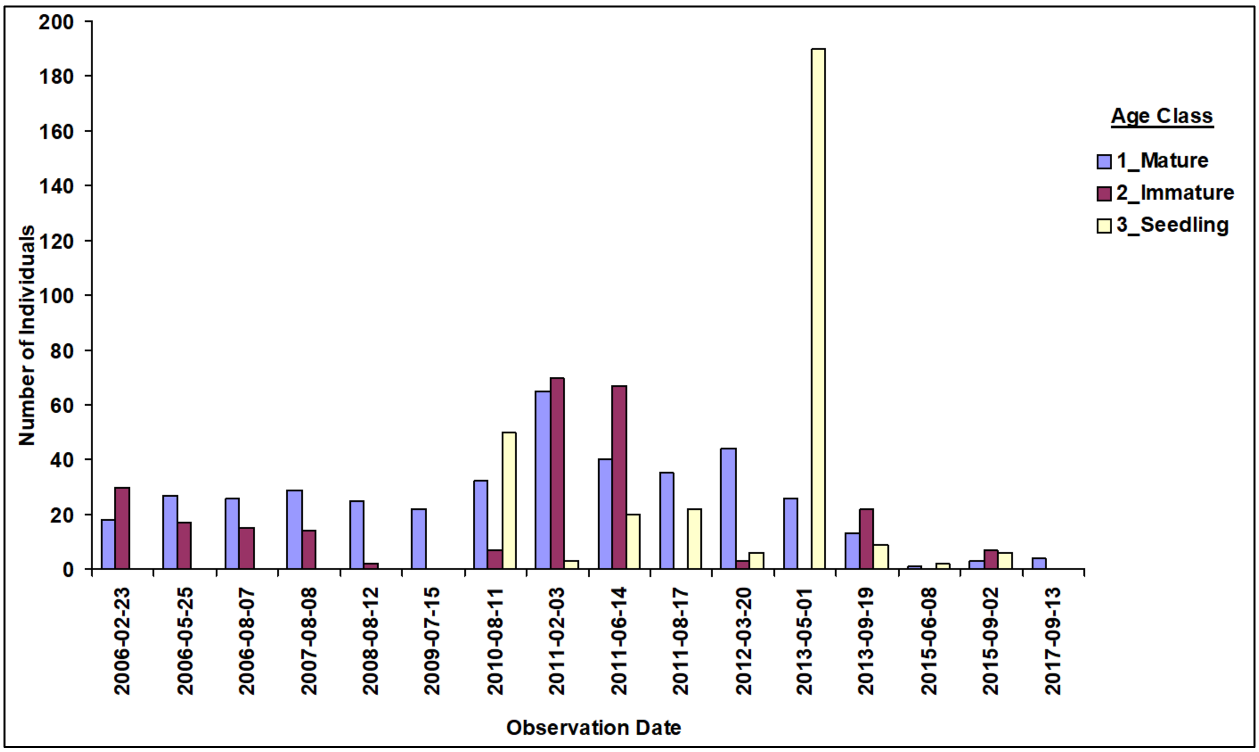



**Figure 15.** Schobo PAH-E reintroduction population structure for seedlings, immature, and mature plants

## Population Unit Keawapilau to West Makaleha

Plants at the LEH-B population site in the Keawapilau to West Makaleha PU have been monitored regularly and typically take one to two years to mature and survive for one to two years after maturation. The majority of plants die in less than 5 years, while some have survived longer. This stresses the importance of regeneration through the seed bank for this species. Outplanting sites may need to be initiated with a large number of outplants in order to establish a seedbank that can replace the short-lived outplants within 5 years of planting.

Two *in situ* populations (LEH-B and PIL-B) in the Keawapilau to West Makaleha PU account for over 95% of the total plants in this PU (Figs. 16 and 18). The LEH-B population had a large increase in immature plants and seedlings between 2010 and 2014, with over 2000 plants observed during monitoring (Fig. 16). However, this PU has not reached the stability goal to maintain ≥100 mature plants since 2012. These numbers have since declined, with only 25 total mature plants in the PU as of the most recent monitoring. Additionally, the reintroduction site PIL-C has had a similar decline in total plants, despite slug control at the site (Fig. 19). The PIL-B (Fig.18) population currently has the highest number of immature plants amongst all populations in this PU, with over 300 immature plants present, followed by the LEH-B site with over 100 immature plants. One other reintroduction site, PIL-C, was attempted in this PU, but has had a recent decline in population (Fig. 19). This was observed in both reintroduction sites in the PU.

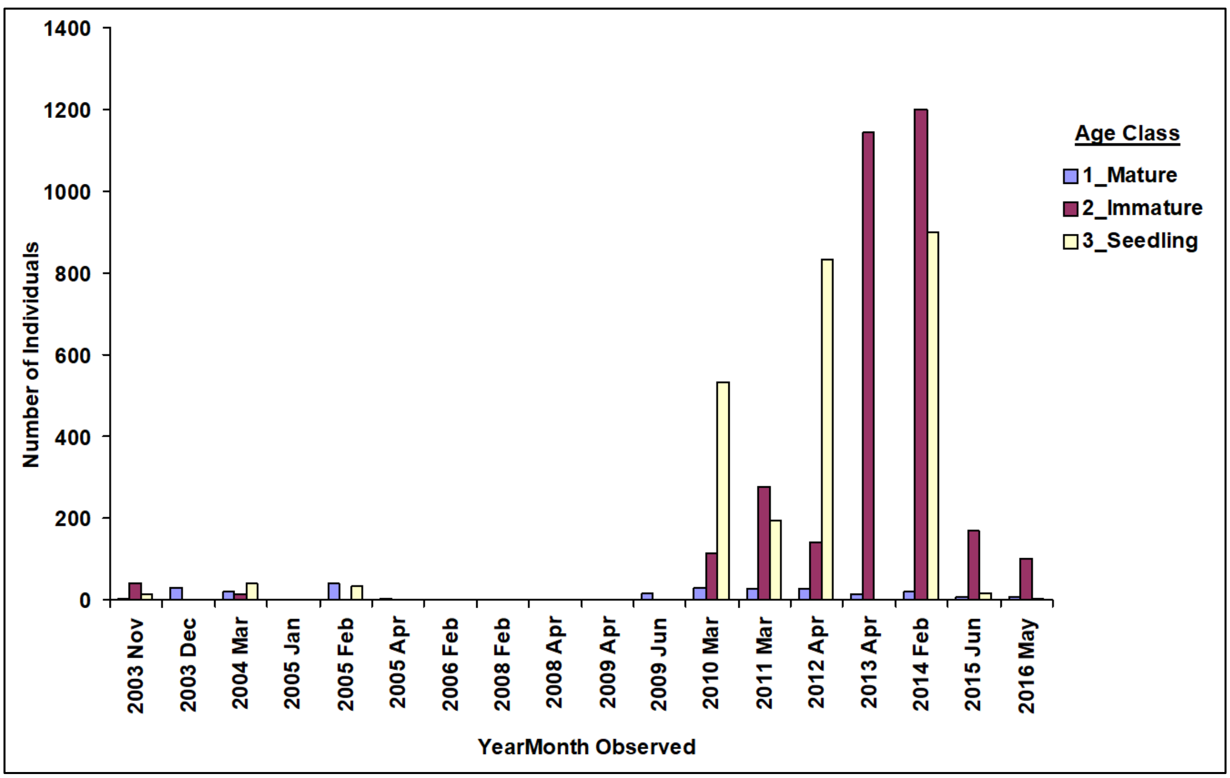



**Figure 16.** Schobo LEH-B *in situ* site population structure for seedlings, immature, and mature plants

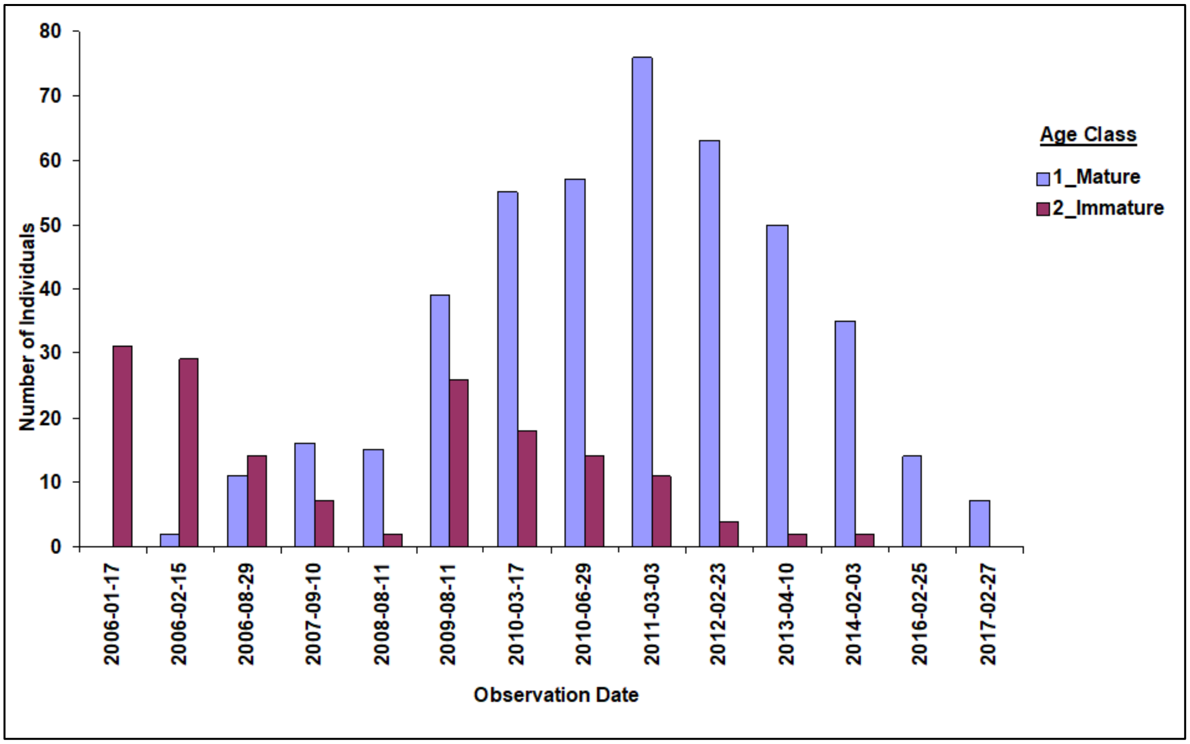



**Figure 17.** Schobo LEH-C reintroduction site population structure for seedlings, immature, and mature plants

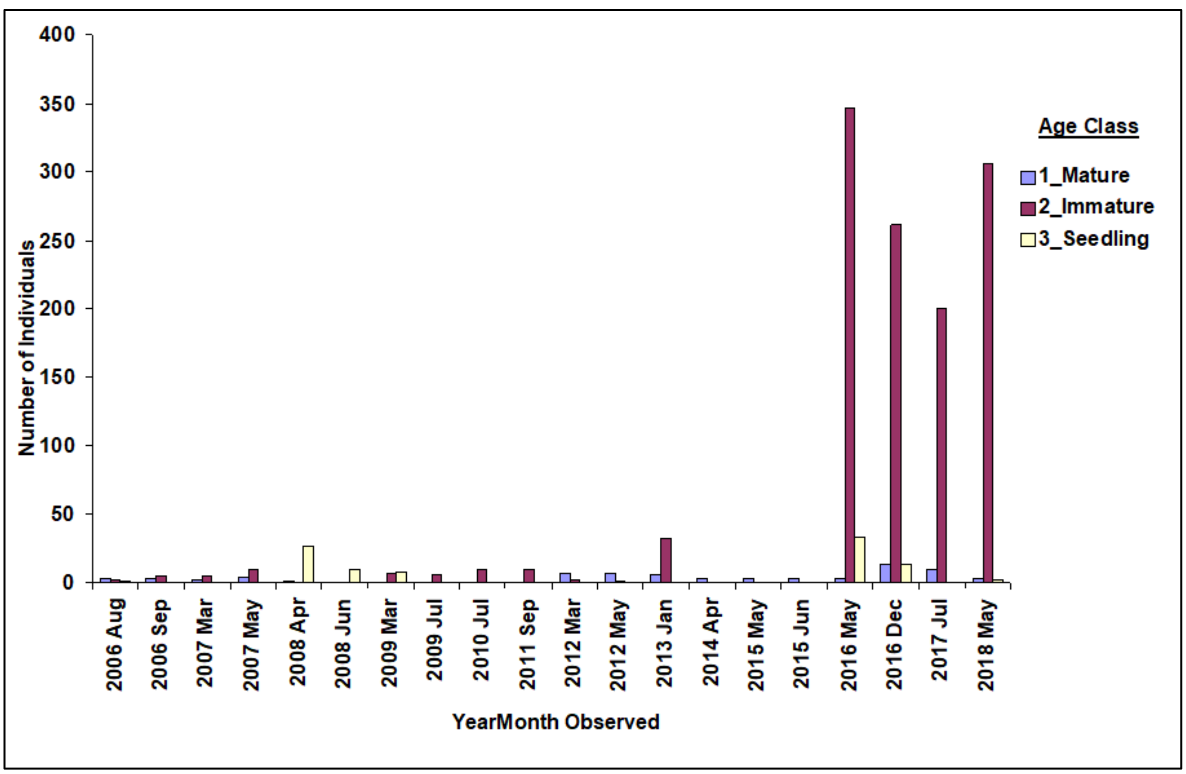



**Figure 18.** Schobo PIL-B *in situ* site population structure for seedlings, immature, and mature plants

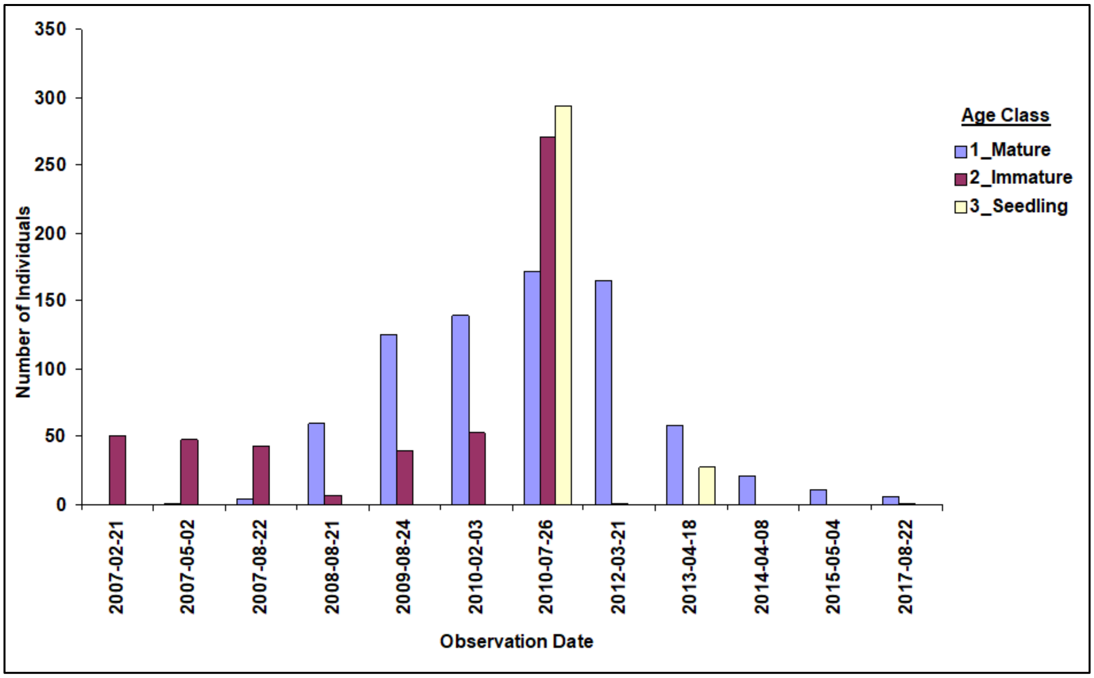



**Figure 19.** Schobo PIL-C population structure for seedlings, immature, and mature plants

# Population Unit Makaha

The Makaha reintroduction site MAK-A was established in 2014 with 200 individuals planted (Fig. 20). These plants matured over the following two years, but have since declined to just 20 mature plants, and sparse recruitment of seedlings observed. It is likely the outplanting site conditions in this area are too wet and the surrounding habitat too dense for seedling recruitment.

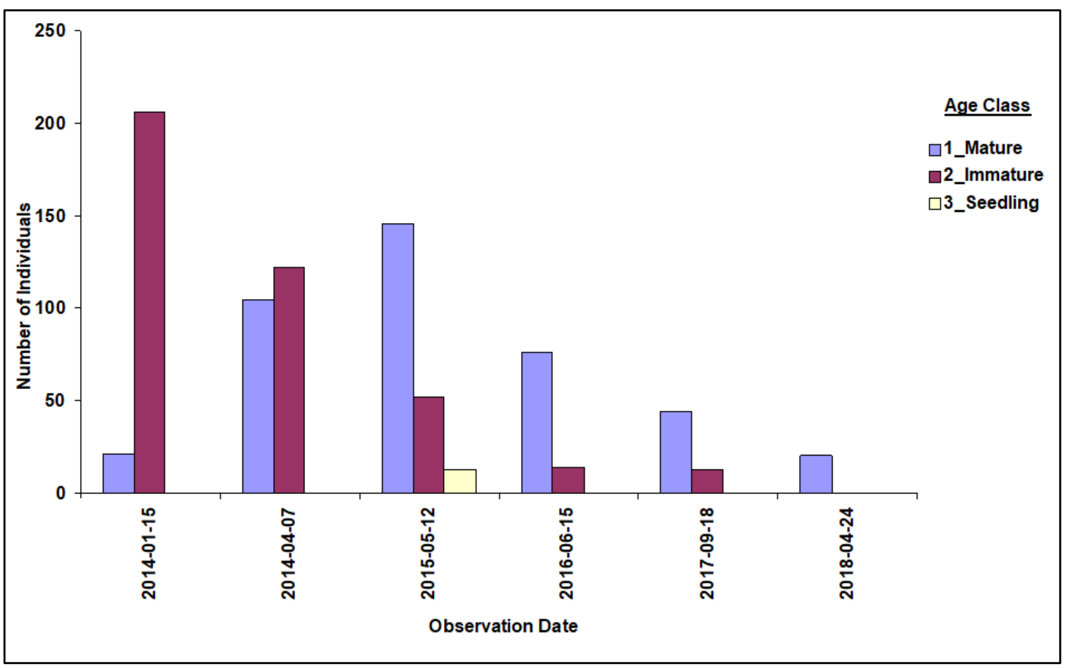



**Figure 20.** Schobo MAK-A population structure for seedlings, immature, and mature plants

**Outplanting considerations from 2003 MIP:** *S. obovata* was classified as *Alsinidendron obovatum* in 2003. "Since *A. obovatum* is a naturally selfing plant (Weller pers. comm. 2000) plants from different stocks should not be mixed together during outplantings. *A. trinerve*, like *A. obovatum*, is an endangered plant. The ranges of these two species do not overlap geographically. *A. trinerve* is known only from the sides of Kaala and on the ridge between Kaala and Puu Kalena to the south. The two *Alsinidendron* also occur in different habitats. *A. trinerve* occurs in wetter forests and at higher elevation than *A. obovatum. A. obovatum* should not be introduced within the range or habitat of *A. trinerve.* In many cases *A. obovatum* is located in the same drainages as its relative. *S. nuttallii, S. pentamera,* and *S. kaalae*. Natural hybridization between species of *Schiedea* has been documented in the Waianae Mountains. Although hybridization between species of *Schiedea* and *Alsinidendron* have yet to be found in nature or created experimentally, the possibility of hybridization between the two exists, so *Alsinidendron* should not be outplanted near *Schiedea* species. Due to the large gap between northern plants and possibly extirpated southern plants, it is presumed that the southern plants are, or were, genetically distinct. If rediscovered, the southern stock should be preserved separately from the northern stocks. Northern stocks should not be planted in the southern Waianae Mountains as long as there remains some chance that southern plants still persist. Outplanting lines have been drawn limiting the outplanting of the northern and southern stocks to their respective ends of the mountain range."

**Current Outplanting considerations and plan:** There have been ten outplantings sites of *S. obovata*. Six outplanting sites in the Kahanahaiki to Pahole PU, three in the Keawapilau to West Makaleha PU, and one in the Makaha PU. The first outplanting site was established in 1999 in the Pahole PU. The number of individuals to be planted at each site was previously determined by factoring in the survivorship of previous plantings and the number of mature recruits produced by the surviving outplants. Previous outplanting data has shown that approximately 400 outplants are needed to produce 100 mature plants within 5 years. However, longer term monitoring of outplanting sites has shown more complex factors related to site establishment, in addition to the total number of outplants attempted. An experimental site was established in 2009 in Kahanahaiki. The experimental site included over 500 outplants, and had over 90% survival after one year, however, survival was less than 10% after five years. The number of outplants attempted does not always equate to stable populations. It should be noted that outplants for this experimental site were also relatively small (less than 10cm tall).

Additional factors such as changing site conditions, plant size, threats from slugs and rats, and associated species present in outplanting sites are factors that should be prioritized in future outplantings. Previous research on the effects of precipitation and herbivory on *S. obovata* showed that plant size was directly related to outplanting survival and fruiting (Bailic-Murphy and Gaoue 2018). Small plants less than 8cm were most susceptible to drought, and also benefit the most from molluscicide treatment. This research concluded that early stage plant vitality has the greatest impact on population dynamics, and establishment of outplants is critical to population structure. Future outplantings should be established near the best current sites, with slug and rat control, and larger size plants used for initial outplanting.

Previous studies determined the fitness of outplants grown from seed produced by outcrossing and selfing the available stocks of *S. obovata* (Weisenberger 2012). These studies showed that the relative fitness of plants increases when parents are from different populations. Mixed source reintroductions were implemented at the Makaha PU, while single source reintroductions were implemented in Kahanahaiki to Pahole and Keawapilau to West Makaleha PUs. The Makaha reintroduction had less than 10% survival within five years, and very little recruitment observed. While a mixed source populations were used for this reintroduction, similar poor results were observed for reintroduction sites from single source founders (Figs. 16, 18, and 19).

## Reintroduction Plan

Priority for reintroductions will be to establish a new site in Makaha. The previous site in the Makaha II fence showed the lowest survival of any outplanting at five years with less than 10% overall survival and very low recruitment. The elevation at the current outplanting may be too high and a more suitable site will be scoped inside the Makaha I fence. As with all new outplanting sites, habitat and micro-site conditions that promote recruitment and stage class transitions to immature and mature plants should be prioritized. New outplanting sites should take into account the effects of climate change and drought, as well as weed control strategies, for long-term survival and reproduction. A site survey will be conducted in the Makaha, prioritizing the areas of Makai Gulch, Giant Ohia, and the area surrounding the *Hesperomannia oahuensis* MAK-A *in situ* site.

A majority of the plants encompassing the Kahanahaiki to Pahole PU are from a single population site, MMR-G. While this site does not meet the goal for reproducing individuals, there are robust numbers of immatures (167 plants) and seedlings (200 plants). This site will be monitored to see if these individual develop into mature plants over the next year or two, with additional outplants added to the site. An additional outplanting site will be established near the MMR-G site, and a site survey will be conducted near the Aunty Barbara area to determine the most suitable area. The Pahole outplanting sites in this PU were originally successful over the first five years following initial outplanting, but have recently declined. Additional plants will not be added to the Pahole sites and efforts will be focused on the additional site in Kahanahaiki, as this area benefits from better threat control and improved habitat resulting from common native reintroductions.

The Keawapilau to West Makaleha is similar to the Kahanahaiki to Pahole PU in that the majority of individuals are found in just one population, PIL-B. However, this is an in situ population, in contrast to the reintro site in Kahanahaiki. While this population has only three mature plants, there are over 300 immature individuals present. The population structure has fluctuated over the years, but has never met the goal for number of mature plants. This site will be monitored for any major changes in the number of immature plants, as well as the number of individuals developing into mature plants. Augmentation to this site will likely be needed in the future, and will be determined following the next monitoring.

The proposed outplanting sites are designed to meet the stability goal for the minimum number of reproducing individuals, as currently no PU contains 100 reproducing individuals. Future outplantings in the southern Waianae Mountains should be considered, considering the plants were last observed there in the 1970’s.

**Table 7.** Current and proposed outplantings of *S. obovata* to meet stabilization goal of 100 reproducing individuals per PU.

| Manage for Stability Population Units | Reintroduction Site(s) | Total Plants to be planted | Propagule Type | Propagule Population(s) Source | Plant Size | Year 2018-2019 # of plants | Year 2019-2020 # of plants | Year 2020 2021 # of plants |
|---|---|---|---|---|---|---|---|---|
| Kahanahaiki to Pahole | MMR-G | 80 | Immature plants | MMR-A | >10cm | 0 | 40 | 40 |
| Kahanahaiki to Pahole | MMR-I* | 350 | Immature plants | PAH-A | >10cm | 100 | 150 | 100 |
| Makaha | MAK-B* | 350 | Immature plants | Mixed source | >10cm | 100 | 150 | 100 |
| The propagule type for each planting will be immature plants grown from seeds collected from wild or outplanted plants. An asterisk (*) indicates outplantings that have not yet been initiated. | | | | | | | | |

## Monitoring Plan

All extant *in situ* sites (LEH-A, LEH-B, PIL-B) will be monitored annually using the Hawaii Rare Plant Restoration Group (HRPRG) Monitoring Form to record population structure and the age class, reproductive status and vigor of all known plants. The sites will be searched for new seedlings and all new juvenile plants will be tagged as long as the health and safety of the plants and the site are not jeopardized. This monitoring data will serve to document the populations at the remaining sites to guide *in situ* threat management and genetic storage needs as these sites decline.

The managed reintroduction sites in all PUs will be monitored annually in the winter (January-March) using the HRPRG form to record population structure, age class, reproductive status and vigor. All outplants will be accounted for along with a total population census. Monitoring data will be updated to determine if replacement into mature class size is occurring and at what rate. This data will be used to guide future outplanting. The ratio of the total number of mature recruits over the total number of plants outplanted will be used to guide the number of outplants needed to establish 100 mature recruits.

**Threats:** The primary threat to *S. obovata* that were known at the time the Makua Implementation Plan (MIP) was finalized (2003) included feral pigs. All populations are currently in ungulate-free fenced areas, which are monitored for damage from treefall and potential ungulate ingress under fences due to erosion. Predation of plants and seedlings by rodents and slugs has been documented, and have had a negative effect on seedling survival and plant development. Rats are known to eat maturing fruit and slugs have been seen on seedlings. Rat and slug control has been initiated in many populations where native snails are absent, however, an increase in seedlings was not observed compared to sites not currently controlled for slugs. Various alien plant species threaten *S. obovata* by altering its habitat and competing with it for sunlight, moisture, nutrients, and growing space. Weed control is essential to improve habitat quality, which is beneficial to maintain reproducing populations and continued recruitment of immature plants. Fungal pathogens are not currently an issue with this species but should be noted if observed during annual monitoring. Selection of outplanting sites will be prioritized to include areas with current rat control and the absence of rare snails, so slug control can be implemented.

## Genetic Storage Plan

Besides collections of fruit made for genetic storage and propagation, all other fruit has been left to mature on the plants. Fruit not eaten by rats was left to senesce and fall below the plants where germination has been observed. Fruit at some PUs have been hand-dispersed by OANRP staff while conducting work in the area via smearing fruits across various substrates, although results from these informal trials were limited to a few seedlings, and it was unclear if these were from fruit smears or natural germination of fruit falling to the ground. Conducting a formal trial using fruit smears will be beneficial to determine strategies for seedling recruitment.

**Table 8.** Action plan for maintaining genetic storage representation, and providing propagules for reintroductions

| Propagule type used for meeting genetic storage goal | Source for propagules | Genetic Storage Method used to meet the goal | Proposed re-collection interval for seed storage | Seed storage testing ongoing | Plan for maintaining genetic storage |
|---|---|---|---|---|---|
| Seeds | Reintroductions | Seed Storage: -18C / 20% RH | ≥20 years† | Yes | Single-source and Mixed Reintroductions |
| †Seeds in storage of this species have not shown a decline in viability. The viability tests are conducted every five years. Re-collection intervals will continually be extended until a decline in viability is detected. | | | | | |

## Future Management Considerations

All three PUs do not currently meet the MIP goals for minimum reproducing individuals. While at least one site in the Kahanahaiki to Pahole PU, as well as two sites in the Keawapilau to West Makaleha PU have over 100 immature plants, new outplanting sites near the current best performing sites will be established within these PUs. The effects of extreme weather events, fires, and long drought periods make individual sites susceptible to be being wiped out, while having plants spread across multiple sites within a PU give the species a better chance for long term survival.

In past years, recruitment following initial outplanting had been encouraging. However, more recently these recruits have failed to develop into mature plants and replenish the seed bank. This has led to decreases in both the mature and immature plant totals. The primary strategy for this taxon, in addition to outplanting, will be to focus on improving habitat through weed control, common outplantings, and threat control of rats and slugs. As recruitment has been sporadic for populations of *S. obovata*, and seedling survival limited, continued outplantings to maintain stable population numbers will be focused on two new sites where threat control and habitat improvement has already begun.

As all PUs currently meet the genetic storage requirement 100%. Collecting fruit from reintroduction sites will only be required as seed storage interval testing determines when seed collections expire. Makaha PU will require a new reintroduction in order to achieve goals for mature plant numbers. Survival and the development of immature plants to maturity will determine the timeline for outplanting sites in the

Keawapilau to West Makaleha and Kahanahaiki to Pahole PUs. Management efforts will also include monitoring as well as the feasibility of adding molluscicide to populations that do not show improved recruitment. OANRP will use results from *in situ* monitoring and current outplanting sites to finalize timeline, stock, and locations for future reintroductions. An assessment of plant growth and vigor will be used to determine if mixed stock outplantings are equally represented by each founder, or if founders from certain PUs show higher survival in each outplanting site. In order to establish reintroduction sites that become stable, the following should be considered to improve plant survival and reproduction:

**Habitat site selection** (large scale and micro-site locations): OANRP proposes selecting a new introduction site for the Makaha PU. Habitat and micro-site conditions with native understory that promote recruitment and stage class transitions to immature and mature plants should be prioritized. New outplanting sites should take into account the effects of fire risk, as well as weed control strategies, for long-term survival and reproduction. Potential habitat in the Southern Waianae Mountains should be considered for future outplanting sites as well.

**Pollination and dispersal:** OANRP could conduct pollinator observations using game cameras to determine what is potentially pollinating *S. obovata*, if certain sites have more visitation by pollinators than others, or if areas have more potential pollinators than others. Fruit set in most populations seems to be adequate for reproduction, given the high amount of seed per propagule, so perhaps focusing on rodent and slug control should be prioritized instead.

**Threat Control**: OANRP will focus on establishing outplanting sites in areas where threat control methods for rodents and slugs are implemented, and native snails are not present. A24 automatic rat traps have been an improvement in some areas as they require far less labor than previously used snap traps. All outplantings are contained in fences to control ungulates, have weed and rat control, and some receive slug control if rare native snails are not present. Increased rat control grids directly around outplanting sites may be necessary if natural recruitment and goals for population structure are not met.

## References

Bialic-Murphy L and O.G. Gaoue. 2018. Low inter-annual precipitation has a greater negative effect than seedling herbivory on the population dynamics of a short-lived herb, *Schiedea obovata*. Ecology and Evolution **8**:176-184.

Ellshoff, Z. E., J. M. Yoshioka, J. E. Canfield, and D. R. Herbst. 1991. Endangered and threatened wildlife and plants; determination of endangered status for 26 plants from the Waianae Mountains, Island of Oahu, Hawaii. Federal Register **56**:55770-55786.

Giambelluca, T.W., Q. Chen, A. Frazier, J.Price, Y.L. Chen, P.S. Chen, J. Eischeid, and D. Delparte. 2011. The Rainfall Atlas of Hawaii. http://rainfall.geography.hawaii.edu. University of Hawaii, Honolulu.

Makua Implementation Team (MIT). 2003. Final Makua Implementation Plan. Prepared for the U.S. Army Garrison, Schofield Barracks, HI.

PRISM. 2018. Prism Climate Group. Oregon State University. http//prism.oregonstate.edu.

Wagner, W. L., S. G. Weller, and A. K. Sakai. 2005. Monograph of Schiedea (Caryophyllaceae - Alsinoideae. Systematic Botany Monographs **72**:1-169.

Weller, S. G., A. K. Sakai, A. E. Rankin, A. Golonka, B. Kutcher, and K. E. Ashby. 1998. Dioecy and the evolution of pollination systems in *Schiedea* and *Alsinidendron* (Caryophyllaceae: Alsinoideae) in the Hawaiian Islands. American Journal of Botany **85**:1377-1388.

Weisenberger, L. A. 2012. Inbreeding depression, outbreeding depression and heterosis in rare species in the genus Schiedea (Caryophyllaceae) on O`ahu. University of Hawai'i at Manoa, Honolulu.

# Threat Control Summary  Makua Implementation Plan

## Action Area: In

### TaxonName: Alectryon macrococcus var. macrococcus

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Keawapilau** | Manage for stability | 0 | Yes | Partial | Partial | No | No |
| **Makua** | Manage for stability | 4 | Partial 100% | Partial 25% | No | No | No |
| **South Mohiakea** | Genetic Storage | 2 | Yes | No | No | No | No |
| **West Makaleha** | Genetic Storage | 3 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Alectryon macrococcus var. macrococcus

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Central Kaluaa to Central Waieli** | Manage for stability | 2 | Partial 0% | Partial 0% | No | No | No |
| **Makaha** | Manage for stability | 11 | Yes | Partial 91% | Partial 100% | No | No |
| **Waianae Kai** | Genetic Storage | 0 | No | No | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Cenchrus agrimonioides var. agrimonioides

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki and Pahole** | Manage for stability | 195 | Yes | Partial 99% | Partial 35% | No | No |
| **Kuaokala** | Genetic Storage | 1 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Cenchrus agrimonioides var. agrimonioides

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Central Ekahanui** | Manage for stability | 203 | Yes | Partial 100% | Yes | No | No |
| **Makaha and Waianae Kai** | Manage for stability | 164 | Partial 96% | Partial 100% | Partial 96% | No | No |
| **South Huliwai** | Genetic Storage | 22 | No | Partial 100% | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary   Makua Implementation Plan

## Action Area: In

### TaxonName: Cyanea grimesiana subsp. obatae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Pahole to West Makaleha** | Manage for stability | 61 | Yes | Partial 100% | Partial 31% | Partial 31% | No |

## Action Area: Out

### TaxonName: Cyanea grimesiana subsp. obatae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kaluaa** | Manage for stability | 97 | Yes | Partial 58% | Partial 98% | No | No |
| **Makaha** | Genetic Storage | 11 | Yes | Partial 100% | Yes | Yes | No |
| **North branch of South Ekahanui** | Manage reintroduction for stability | 82 | Yes | Partial 100% | Yes | Yes | No |
| **Palikea (South Palawai)** | Manage for stability | 914 | Yes | Partial 100% | Yes | Partial 14% | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Cyanea longiflora

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kapuna to West Makaleha** | Manage for stability | 89 | Yes | Partial 98% | No | Partial 89% | No |
| **Pahole** | Manage for stability | 58 | Yes | Partial 100% | No | Partial 98% | No |

## Action Area: Out

### TaxonName: Cyanea longiflora

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Makaha and Waianae Kai** | Manage for stability | 116 | Yes | Partial 100% | Yes | Yes | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Cyanea superba subsp. superba

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Manage reintroduction for stability | 46 | Yes | Partial 100% | Yes | Partial 43% | No |
| **Pahole to Kapuna** | Manage reintroduction for stability | 95 | Yes | Partial 100% | Partial 60% | No | No |

## Action Area: Out

### TaxonName: Cyanea superba subsp. superba

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Makaha** | Manage reintroduction for stability | 39 | Yes | Partial 0% | Yes | No | No |
| **Manuwai** | Manage reintroduction for stability | 0 | Yes | Partial | Partial | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Cyrtandra dentata

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Manage for stability | 25 | Yes | Partial 100% | Yes | No | No |
| **Kawaiiki (Koolaus)** | Manage for stability | 2 | No | No | No | No | No |
| **Opaeula (Koolaus)** | Manage for stability | 35 | Partial 100% | Partial 57% | Partial 54% | Partial 54% | No |
| **Pahole to West Makaleha** | Manage for stability | 330 | Partial 100% | Partial 96% | No | No | No |

## Action Area: Out

### TaxonName: Cyrtandra dentata

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Central Makaleha** | Genetic Storage | 3 | No | No | No | No | No |

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Delissea waianaeensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Keawapilau** | Manage for stability | 140 | Yes | Partial 100% | Partial 21% | No | No |
| **Kaluakauila** | Manage reintroduction for storage | 7 | Yes | Partial 100% | No | No | No |
| **Kapuna** | Manage reintroduction for storage | 93 | Yes | Partial 100% | No | No | No |
| **Palikea Gulch** | Genetic Storage | 1 | No | No | No | No | Partial 100% |
| **South Mohiakea** | Genetic Storage | 12 | Yes | Partial 100% | Yes | No | No |

## Action Area: Out

### TaxonName: Delissea waianaeensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Ekahanui** | Manage for stability | 196 | Yes | Partial 99% | Yes | Partial 99% | No |
| **Kaluaa** | Manage for stability | 425 | Yes | Partial 99% | Partial 76% | Partial 76% | No |
| **Kealia** | Genetic Storage | 4 | No | No | No | No | No |
| **Manuwai** | Manage reintroduction for stability | 132 | Yes | Partial 100% | Yes | No | No |
| **Palawai** | Genetic Storage | 24 | Partial 96% | No | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Dubautia herbstobatae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Keaau** | Genetic Storage | 70 | No | No | No | No | No |
| **Makaha/Ohikilolo** | Genetic Storage | 229 | No | No | No | No | No |
| **Ohikilolo Makai** | Manage for stability | 133 | Yes | Partial 75% | No | No | No |
| **Ohikilolo Mauka** | Manage for stability | 373 | Yes | Partial 15% | No | No | No |

## Action Area: Out

### TaxonName: Dubautia herbstobatae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kamaileunu** | Genetic Storage | 0 | No | No | No | No | No |
| **Makaha** | Manage for stability | 41 | No | Partial 44% | Partial 44% | No | No |
| **Waianae Kai** | Genetic Storage | 10 | Partial 0% | Partial 0% | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Euphorbia celastroides var. kaenana

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **East Kahanahaiki** | Genetic Storage | 2 | No | No | No | No | No |
| **Kaluakauila** | Genetic Storage | 11 | No | Partial 100% | No | No | No |
| **Makua** | Manage for stability | 85 | Yes | Partial 100% | No | No | Partial 100% |
| **North Kahanahaiki** | Genetic Storage | 115 | No | No | No | No | No |
| **Puaakanoa** | Manage for stability | 140 | No | Partial 46% | No | No | No |

## Action Area: Out

### TaxonName: Euphorbia celastroides var. kaenana

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **East of Alau** | Manage for stability | 20 | No | Partial 100% | No | No | No |
| **Kaena** | Manage for stability | 880 | No | Partial 100% | No | No | No |
| **Keawaula** | Genetic Storage | 42 | No | No | No | No | No |
| **Waianae Kai** | Genetic Storage | 34 | No | No | No | No | No |

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Euphorbia herbstii

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kapuna to Pahole** | Manage for stability | 33 | Yes | Partial 100% | No | Partial 82% | No |
| **Manuwai** | Manage reintroduction for stability | 0 | Yes | No | No | No | No |

## Action Area: Out

### TaxonName: Euphorbia herbstii

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kaluaa** | Manage reintroduction for stability | 2 | Yes | Partial 100% | No | No | No |
| **Makaha** | Manage reintroduction for storage | 2 | Yes | Partial 100% | Yes | No | No |

(shaded) = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Flueggea neowawraea

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Kapuna** | Manage for stability | 5 | Yes | Partial 60% | Partial 20% | No | No |
| **Ohikilolo** | Manage for stability | 1 | Yes | No | No | No | No |
| **West Makaleha** | Genetic Storage | 2 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Flueggea neowawraea

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Central and East Makaleha** | Genetic Storage | 4 | No | No | No | No | No |
| **Halona** | Genetic Storage | 1 | No | No | No | No | No |
| **Kauhiuhi** | Genetic Storage | 1 | No | No | No | No | No |
| **Makaha** | Manage for stability | 7 | Partial 57% | Partial 86% | Partial 57% | No | No |
| **Manuwai** | Manage reintroduction for stability | 0 | Yes | Partial | No | No | No |
| **Mt. Kaala NAR** | Genetic Storage | 2 | No | No | No | No | No |
| **Nanakuli, south branch** | Genetic Storage | 1 | No | No | No | No | No |
| **Waianae Kai** | Genetic Storage | 1 | No | No | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Gouania vitifolia

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Keaau** | Manage for stability | 47 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Gouania vitifolia

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Makaha (Future Introduction)** | Manage reintroduction for stability | 0 | Yes | No | No | No | No |
| **Manuwai (Future Introduction)** | Manage reintroduction for stability | 0 | Yes | No | No | No | No |
| **Waianae Kai** | Genetic Storage | 1 | Yes | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Hesperomannia oahuensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Haleauau** | Manage for stability | 1 | Yes | Partial 100% | Partial 100% | No | No |
| **Pahole NAR** | Manage reintroduction for stability | 3 | Yes | Partial 100% | Yes | No | No |

## Action Area: Out

### TaxonName: Hesperomannia oahuensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Makaha** | Manage for stability | 11 | Yes | Partial 55% | Yes | Partial 55% | No |
| **Pualii** | Manage reintroduction for stability | 14 | Yes | Partial 100% | Yes | No | No |
| **Waianae Kai** | Genetic Storage | 0 | Yes | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Hibiscus brackenridgei subsp. mokuleianus

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Keaau** | Manage for stability | 82 | Yes | Partial 100% | No | No | No |
| **Makua** | Manage for stability | 95 | Yes | Partial 100% | No | No | Partial 100% |

## Action Area: Out

### TaxonName: Hibiscus brackenridgei subsp. mokuleianus

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Haili to Kawaiu** | Manage for stability | 82 | No | Partial 96% | No | No | No |
| **Manuwai** | Manage reintroduction for stability | 70 | Yes | Partial 100% | No | No | No |
| **Waialua** | Genetic Storage | 49 | Partial 37% | No | No | No | Partial 100% |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary  Makua Implementation Plan

## Action Area:  In

### TaxonName: Kadua degeneri subsp. degeneri

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Pahole** | Manage for stability | 102 | Yes | Partial 100% | Partial 0% | No | No |

## Action Area:  Out

### TaxonName: Kadua degeneri subsp. degeneri

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Alaiheihe and Manuwai** | Manage for stability | 75 | Partial 96% | Partial 96% | No | No | No |
| **Central Makaleha and West Branch of East Makaleha** | Manage for stability | 17 | No | No | No | No | No |
| **East branch of East Makaleha** | Genetic Storage | 0 | No | No | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Kadua parvula

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Ohikilolo** | Manage for stability | 90 | Yes | Partial 100% | No | No | No |

## Action Area: Out

### TaxonName: Kadua parvula

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Ekahanui** | Manage reintroduction for stability | 58 | Yes | Partial 100% | Yes | No | No |
| **Halona** | Manage for stability | 31 | No | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Melanthera tenuifolia

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Genetic Storage | 1 | Partial 100% | No | No | No | No |
| **Kaluakauila** | Genetic Storage | 4 | Yes | No | No | No | No |
| **Keawaula** | Genetic Storage | 200 | No | No | No | No | No |
| **Ohikilolo** | Manage for stability | 570 | Partial 100% | Partial 9% | No | No | Partial 9% |

## Action Area: Out

### TaxonName: Melanthera tenuifolia

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kamaileunu and Waianae Kai** | Manage for stability | 815 | No | Partial 8% | Partial 10% | No | No |
| **Mt. Kaala NAR** | Manage for stability | 131 | Yes | Partial 61% | No | No | No |

(shaded) = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Neraudia angulata

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kaluakauila** | Manage reintroduction for stability | 258 | Yes | Partial 100% | No | No | No |
| **Kapuna** | Genetic Storage | 0 | No | No | No | No | No |
| **Makua** | Manage for stability | 45 | Yes | Partial 96% | No | No | No |
| **Punapohaku** | Genetic Storage | 2 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Neraudia angulata

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Halona** | Genetic Storage | 4 | No | No | No | No | No |
| **Leeward Puu Kaua** | Genetic Storage | 9 | No | No | No | No | No |
| **Makaha** | Manage for stability (backup site) | 82 | Partial 98% | Partial 96% | No | No | No |
| **Manuwai** | Manage for stability | 97 | Yes | Partial 100% | No | No | No |
| **Waianae Kai Makai** | Genetic Storage | 13 | Yes | No | No | No | Partial 100% |
| **Waianae Kai Mauka** | Manage for stability | 11 | Yes | No | Partial 100% | No | No |

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Nototrichium humile

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Genetic Storage | 28 | Partial 100% | Partial 64% | Partial 64% | No | No |
| **Kaluakauila** | Manage for stability | 133 | Yes | Partial 100% | No | No | No |
| **Keaau** | Genetic Storage | 20 | No | No | No | No | No |
| **Keawaula** | Genetic Storage | 109 | No | No | No | No | No |
| **Makua (East rim)** | Genetic Storage | 1 | No | No | No | No | No |
| **Makua (south side)** | Manage for stability | 50 | Partial 100% | Partial 74% | No | No | No |
| **Punapohaku** | Genetic Storage | 178 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Nototrichium humile

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kaimuhole and Palikea Gulch** | Genetic Storage | 29 | No | No | No | No | Partial 100% |
| **Keawapilau** | Genetic Storage | 1 | No | No | No | No | No |
| **Kolekole** | Genetic Storage | 12 | Partial 33% | No | No | No | No |
| **Makaha** | Genetic Storage | 22 | No | Partial 64% | No | No | No |
| **Manuwai** | Manage reintroduction for stability | 111 | Yes | Partial 100% | No | No | No |
| **Nanakuli** | Genetic Storage | 0 | No | No | No | No | No |
| **Puu Kaua (Leeward side)** | Genetic Storage | 2 | No | No | No | No | No |
| **Waianae Kai** | Manage for stability | 134 | Partial 97% | Partial 97% | No | No | Partial 97% |

(shaded) = Threat to Taxon within Population Unit
No Shading = Absence of threat to Taxon within Population Unit
Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled
No=All PopRefSites within Population Unit have no threat control
Partial%=Percent of mature plants in Population Unit that have threat controlled
Partial 100%= All PopRefSites within Population Unit have threat partially controlled
Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Phyllostegia kaalaensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Keawapilau to Kapuna** | Manage reintroduction for stability | 0 | Yes | Partial | No | No | No |
| **Pahole** | Manage reintroduction for stability | 0 | Yes | Partial | No | No | No |
| **Palikea Gulch** | Genetic Storage | 0 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Phyllostegia kaalaensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Makaha** | Manage reintroduction for stability | 0 | Yes | Partial | Yes | No | No |
| **Manuwai** | Manage reintroduction for stability | 0 | Yes | Partial | No | No | No |
| **Waianae Kai** | Genetic Storage | 0 | No | No | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Plantago princeps var. princeps

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **North Mohiakea** | Manage for stability | 28 | Yes | No | No | No | No |
| **Ohikilolo** | Manage for stability | 24 | Partial 100% | Partial 100% | No | No | No |
| **Pahole** | Genetic Storage | 4 | Yes | Partial 100% | No | No | No |

## Action Area: Out

### TaxonName: Plantago princeps var. princeps

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Ekahanui** | Manage for stability | 5 | Yes | Partial 100% | Yes | No | No |
| **Halona** | Manage for stability | 6 | No | No | No | No | No |
| **North Palawai** | Genetic Storage | 1 | No | No | No | No | No |
| **Waieli** | Manage reintroduction for storage | 5 | Yes | Partial 100% | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Pritchardia kaalae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Ohikilolo** | Manage for stability | 131 | Yes | Partial 95% | Partial 92% | No | No |
| **Ohikilolo East and West Makaleha** | Manage reintroduction for stability | 11 | Yes | Partial 100% | No | No | No |

## Action Area: Out

### TaxonName: Pritchardia kaalae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Makaha** | Genetic Storage | 1 | No | No | No | No | No |
| **Makaleha to Manuwai** | Manage for stability | 123 | Partial 2% | No | No | No | No |
| **Waianae Kai** | Genetic Storage | 4 | No | No | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Sanicula mariversa

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Keaau** | Manage for stability | 0 | Yes | Partial | No | No | No |
| **Ohikilolo** | Manage for stability | 0 | Yes | Partial | No | No | No |

## Action Area: Out

### TaxonName: Sanicula mariversa

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kamaileunu** | Manage for stability | 31 | Yes | No | No | No | No |
| **Puu Kawiwi** | Genetic Storage | 0 | Yes | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Schiedea kaalae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Pahole** | Manage for stability | 40 | Yes | Partial 98% | No | Partial 98% | No |

## Action Area: Out

### TaxonName: Schiedea kaalae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahana** | Genetic Storage | 8 | Yes | No | No | No | No |
| **Kaluaa and Waieli** | Manage for stability | 141 | Yes | Partial 4% | No | Partial 4% | No |
| **Maakua (Koolaus)** | Manage for stability | 10 | No | No | No | No | No |
| **Makaua (Koolaus)** | Genetic Storage | 85 | Yes | No | No | No | No |
| **North Palawai** | Genetic Storage | 0 | Yes | No | No | No | No |
| **South Ekahanui** | Manage for stability | 170 | Yes | Partial 100% | Yes | Partial 99% | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Schiedea nuttallii

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Pahole** | Manage for stability | 141 | Yes | Partial 100% | Partial 94% | Partial 98% | No |
| **Kapuna-Keawapilau Ridge** | Manage for stability | 75 | Yes | Partial 100% | Yes | Partial 100% | No |

## Action Area: Out

### TaxonName: Schiedea nuttallii

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Makaha** | Manage reintroduction for stability | 121 | Yes | Partial 100% | Yes | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Schiedea obovata

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki to Pahole** | Manage for stability | 91 | Yes | Partial 100% | Partial 92% | Partial 97% | No |
| **Keawapilau to West Makaleha** | Manage for stability | 25 | Yes | Partial 92% | No | Partial 60% | No |

## Action Area: Out

### TaxonName: Schiedea obovata

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Makaha** | Manage reintroduction for stability | 20 | Yes | Partial 100% | Yes | Yes | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Tetramolopium filiforme

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahanahaiki** | Genetic Storage | 40 | No | No | No | No | No |
| **Kalena** | Manage for stability | 26 | Yes | No | No | No | No |
| **Keaau** | Genetic Storage | 30 | No | No | No | No | No |
| **Makaha/Ohikilolo Ridge** | Genetic Storage | 350 | No | No | No | No | No |
| **Ohikilolo** | Manage for stability | 1740 | Partial 100% | Partial 41% | No | No | No |
| **Puhawai** | Manage for stability | 0 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Tetramolopium filiforme

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Waianae Kai** | Manage for stability | 20 | No | Partial 0% | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Makua Implementation Plan

## Action Area: In

### TaxonName: Viola chamissoniana subsp. chamissoniana

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Keaau** | Genetic Storage | 40 | No | No | No | No | No |
| **Makaha/Ohikilolo Ridge** | Genetic Storage | 0 | No | No | No | No | No |
| **Ohikilolo** | Manage for stability | 107 | Yes | Partial 35% | No | No | No |
| **Puu Kumakalii** | Manage for stability | 44 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Viola chamissoniana subsp. chamissoniana

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Halona** | Manage for stability | 16 | No | Partial 81% | No | No | No |
| **Kamaileunu** | Genetic Storage | 35 | No | No | No | No | No |
| **Makaha** | Manage for stability | 29 | Yes | No | Partial 38% | No | No |
| **Makaleha** | Genetic Storage | 19 | No | No | No | No | No |
| **Puu Hapapa** | Genetic Storage | 6 | No | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary  Oahu Implementation Plan

## Action Area: In

### TaxonName: Abutilon sandwicense

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kaawa to Puulu** | Manage for stability | 27 | Partial 48% | Partial 41% | No | No | Partial 19% |
| **Kahanahaiki** | Manage reintroduction for stability | 69 | Yes | Partial 100% | Partial 100% | No | No |
| **Kaluakauila** | Manage reintroduction for storage | 0 | Yes | Partial | No | No | No |
| **Keaau** | Genetic Storage | 0 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Abutilon sandwicense

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **East Makaleha** | Genetic Storage | 0 | No | No | No | No | No |
| **Ekahanui and Huliwai** | Manage for stability | 54 | Yes | Partial 100% | Partial 98% | No | No |
| **Halona** | Genetic Storage | 10 | Partial 100% | No | No | No | No |
| **Makaha Makai** | Manage for stability | 92 | Partial 75% | Partial 75% | No | No | No |
| **Makaha Mauka** | Genetic Storage | 29 | No | No | No | No | No |
| **North Mikilua** | Genetic Storage | 9 | Yes | No | No | No | No |
| **Waianae Kai** | Genetic Storage | 0 | No | No | No | No | Partial |
| **West Makaleha** | Genetic Storage | 0 | No | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Oahu Implementation Plan

## Action Area: In

### TaxonName: Cyanea acuminata

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Helemano-Punaluu Summit Ridge to North Kaukonahua** | Manage for stability | 81 | No | No | No | No | No |
| **Kahana and South Kaukonahua** | Genetic Storage | 2 | No | No | No | No | No |
| **Makaleha to Mohiakea** | Manage for stability | 195 | Partial 95% | Partial 88% | No | No | No |

## Action Area: Out

### TaxonName: Cyanea acuminata

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kahana and Makaua** | Genetic Storage | 11 | No | No | No | No | No |
| **Kaipapau and Koloa** | Genetic Storage | 70 | Partial 0% | No | No | No | No |
| **Kaluanui and Maakua** | Manage for stability | 123 | No | No | No | No | No |
| **Puukeahiakahoe** | Genetic Storage | 3 | No | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary  Oahu Implementation Plan

## Action Area: In

### TaxonName: Cyanea koolauensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kaipapau, Koloa and Kawainui** | Manage for stability | 113 | Partial 85% | Partial 73% | No | No | No |
| **Kamananui-Kawainui Ridge** | Genetic Storage | 6 | No | No | No | No | No |
| **Kaukonahua** | Genetic Storage | 8 | No | No | No | No | No |
| **Kawaiiki** | Genetic Storage | 4 | No | No | No | No | No |
| **Lower Opaeula** | Genetic Storage | 1 | No | No | No | No | No |
| **Opaeula to Helemano** | Manage for stability | 21 | Partial 48% | Partial 38% | No | No | No |
| **Poamoho** | Manage for stability | 20 | No | No | No | No | No |

## Action Area: Out

### TaxonName: Cyanea koolauensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Halawa** | Genetic Storage | 4 | No | No | No | No | No |
| **Waialae Nui** | Genetic Storage | 2 | No | No | No | No | No |
| **Waiawa to Waimano** | Genetic Storage | 11 | Partial 45% | No | No | No | No |
| **Wailupe** | Genetic Storage | 1 | No | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Oahu Implementation Plan

## Action Area: In

### TaxonName: Eugenia koolauensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Aimuu** | Genetic Storage | 8 | No | No | No | No | No |
| **Kaiwikoele and Kamananui** | Genetic Storage | 17 | Partial 0% | No | No | No | No |
| **Kaleleiki** | Genetic Storage | 14 | Partial 50% | Partial 50% | No | No | No |
| **Kaunala** | Manage for stability | 15 | Partial 93% | No | No | No | No |
| **Malaekahana** | Genetic Storage | 0 | No | No | No | No | No |
| **Ohiaai and East Oio** | Genetic Storage | 1 | No | No | No | No | No |
| **Oio** | Manage for stability | 6 | Partial 83% | Partial 17% | No | No | No |
| **Pahipahialua** | Manage for stability | 18 | Yes | Partial 100% | No | No | No |

## Action Area: Out

### TaxonName: Eugenia koolauensis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Hanaimoa** | Genetic Storage | 1 | No | No | No | No | No |
| **Palikea and Kaimuhole** | Genetic Storage | 1 | No | No | No | No | Partial 100% |

(shaded) = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Oahu Implementation Plan

## Action Area: In

### TaxonName: Gardenia mannii

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Haleauau** | Manage for stability | 60 | Partial 100% | Partial 98% | Partial 97% | No | No |
| **Helemano and Poamoho** | Manage for stability | 23 | Partial 4% | No | No | No | No |
| **Kaiwikoele, Kamananui, and Kawainui** | Genetic Storage | 13 | No | No | No | No | No |
| **Lower Peahinaia** | Manage for stability | 9 | Partial 56% | Partial 56% | No | No | No |
| **South Kaukonahua** | Genetic Storage | 2 | No | No | No | No | No |
| **Upper Opaeula/Helemano** | Genetic Storage | 1 | Yes | Partial 100% | No | No | No |

## Action Area: Out

### TaxonName: Gardenia mannii

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Ihiihi-Kawainui ridge** | Genetic Storage | 2 | No | No | No | No | No |
| **Kaluaa and Maunauna** | Genetic Storage | 1 | No | No | No | No | No |
| **Kamananui-Malaekahana Summit Ridge** | Genetic Storage | 3 | No | No | No | No | No |
| **Kapakahi** | Genetic Storage | 2 | No | No | No | No | No |
| **Pukele** | Genetic Storage | 1 | No | No | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Oahu Implementation Plan

## Action Area: In

### TaxonName: Hesperomannia swezeyi

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kamananui to Kaluanui** | Manage for stability | 134 | Partial 4% | No | No | No | No |
| **Kaukonahua** | Manage for stability | 55 | No | No | No | No | No |
| **Lower Opaeula** | Manage for stability | 11 | No | No | No | No | No |
| **Poamoho** | Genetic Storage | 13 | Partial 8% | No | No | No | No |

## Action Area: Out

### TaxonName: Hesperomannia swezeyi

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Niu-Waimanalo Summit Ridge** | Genetic Storage | 1 | No | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary  Oahu Implementation Plan

## Action Area: In

### TaxonName: Labordia cyrtandrae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **East Makaleha to North Mohiakea** | Manage for stability | 275 | Partial 89% | Partial 91% | Partial 57% | Partial 57% | No |

## Action Area: Out

### TaxonName: Labordia cyrtandrae

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Koloa** | Manage reintroduction for stability | 3 | Partial 100% | Partial 0% | No | No | No |

(shaded) = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary  Oahu Implementation Plan

## Action Area: In

### TaxonName: Phyllostegia hirsuta

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Haleauau to Mohiakea** | Manage for stability | 47 | Partial 100% | Partial 96% | No | Partial 77% | No |
| **Helemano and Opaeula** | Genetic Storage | 1 | Partial 0% | Partial 0% | No | No | No |
| **Helemano and Poamoho** | Genetic Storage | 2 | No | No | No | No | No |
| **Kaipapau and Kawainui** | Genetic Storage | 4 | No | No | No | No | No |
| **Kaukonahua** | Genetic Storage | 0 | No | No | No | No | No |
| **Kawaiiki** | Genetic Storage | 0 | No | No | No | No | No |
| **Koloa** | Manage for stability | 26 | Partial 92% | Partial 88% | No | No | No |

## Action Area: Out

### TaxonName: Phyllostegia hirsuta

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Hapapa to Kaluaa** | Genetic Storage | 0 | Partial | Partial | No | No | No |
| **Kaluanui and Punaluu** | Genetic Storage | 5 | No | No | No | No | No |
| **Makaha-Waianae Kai Ridge** | Genetic Storage | 1 | No | No | No | No | No |
| **Palawai** | Genetic Storage | 0 | No | No | No | No | No |
| **Puu Palikea** | Manage reintroduction for stability | 22 | Yes | Partial 100% | Yes | Yes | No |
| **Waiamano** | Genetic Storage | 1 | No | No | No | No | No |

[shaded box] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Oahu Implementation Plan

## Action Area: In

### TaxonName: Phyllostegia mollis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Mohiakea** | Genetic Storage | 1 | Yes | No | No | No | No |

## Action Area: Out

### TaxonName: Phyllostegia mollis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Ekahanui** | Manage for stability | 1 | Yes | Partial 100% | Yes | Partial 100% | No |
| **Kaluaa** | Manage for stability | 42 | Yes | Partial 100% | No | No | No |
| **Pualii** | Manage reintroduction for stability | 0 | Yes | Partial | No | No | No |
| **Waieli** | Genetic Storage | 0 | Partial | No | No | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Oahu Implementation Plan

## Action Area: In

### TaxonName: Schiedea trinervis

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kalena to East Makaleha** | Manage for stability | 288 | Partial 89% | Partial 92% | No | No | No |

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Threat Control Summary Oahu Implementation Plan

## Action Area: In

### TaxonName: Stenogyne kanehoana

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Haleauau** | Manage reintroduction for stability | 136 | Partial 100% | Partial 100% | No | No | No |

## Action Area: Out

### TaxonName: Stenogyne kanehoana

| PopulationUnitName | ManagementDesignation | # Mature Plants | Ungulates Managed | Weeds Managed | Rats Managed | Slugs Managed | Fire Managed |
|---|---|---|---|---|---|---|---|
| **Kaluaa** | Manage reintroduction for stability | 5 | Yes | Partial 100% | No | No | No |
| **Makaha** | Manage reintroduction for stability | 0 | Yes | Partial | Yes | No | No |

[shaded] = Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Alectryon macrococcus var. macrococcus** | | | | | | | | | | | | | | |
| Kahanahaiki to Keawapilau | Manage for stability | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makua | Manage for stability | 4 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 33% |
| South Mohiakea | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 50% |
| West Makaleha | Genetic Storage | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Alectryon macrococcus var. macrococcus** | | | | | | | | | | | | | | |
| Central Kaluaa to Central Waieli | Manage for stability | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha | Manage for stability | 11 | 0 | 10 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 11 | 11 | 52% |
| Waianae Kai | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 12 | 0 | 0 | 0 | 22 | 0 | 0 | 0 | 14 | 14 |

## Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Cenchrus agrimonioides var. agrimonioides** | | | | | | | | | | | | | | |
| Kahanahaiki and Pahole | Manage for stability | 64 | 26 | 49 | 71 | 56 | 0 | 21 | 43 | 17 | 0 | 5 | 26 | 52% |
| Kuaokala | Genetic Storage | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Cenchrus agrimonioides var. agrimonioides** | | | | | | | | | | | | | | |
| Central Ekahanui | Manage for stability | 67 | 36 | 34 | 50 | 27 | 0 | 37 | 19 | 3 | 0 | 1 | 5 | 10% |
| Makaha and Waianae Kai | Manage for stability | 7 | 3 | 6 | 7 | 4 | 0 | 7 | 3 | 0 | 0 | 3 | 4 | 31% |
| South Huliwai | Genetic Storage | 22 | 12 | 19 | 28 | 20 | 0 | 15 | 15 | 4 | 0 | 1 | 5 | 12% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 161 | 80 | 108 | 156 | 107 | 0 | 81 | 80 | 24 | 0 | 11 | 41 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Cyanea grimesiana subsp. obatae** | | | | | | | | | | | | | | |
| Pahole to West Makaleha | Manage for stability | 4 | 17 | 12 | 16 | 16 | 0 | 6 | 15 | 15 | 0 | 3 | 15 | 94% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Cyanea grimesiana subsp. obatae** | | | | | | | | | | | | | | |
| Kaluaa | Manage for stability | 2 | 1 | 1 | 3 | 3 | 0 | 1 | 3 | 3 | 0 | 1 | 3 | 100% |
| North branch of South Ekahanui | Manage reintroduction for stability | 0 | 0 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 0 | 2 | 100% |
| Palikea (South Palawai) | Manage for stability | 11 | 1 | 11 | 15 | 15 | 5 | 7 | 15 | 15 | 5 | 3 | 15 | 68% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 19 | 26 | 36 | 36 | 7 | 15 | 35 | 35 | 7 | 7 | 35 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Cyanea longiflora** | | | | | | | | | | | | | | |
| Kapuna to West Makaleha | Manage for stability | 10 | 21 | 16 | 24 | 24 | 9 | 7 | 24 | 24 | 9 | 1 | 24 | 92% |
| Pahole | Manage for stability | 56 | 149 | 25 | 61 | 61 | 1 | 9 | 58 | 58 | 1 | 1 | 59 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Cyanea longiflora** | | | | | | | | | | | | | | |
| Makaha and Waianae Kai | Manage for stability | 7 | 2 | 3 | 4 | 4 | 1 | 2 | 4 | 4 | 1 | 2 | 4 | 40% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 73 | 172 | 44 | 89 | 89 | 11 | 18 | 86 | 86 | 11 | 4 | 87 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Cyanea superba subsp. superba** | | | | | | | | | | | | | | |
| Kahanahaiki | Manage reintroduction for stability | 0 | 0 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 2 | 3 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 2 | 3 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Cyrtandra dentata** | | | | | | | | | | | | | | |
| Kahanahaiki | Manage for stability | 25 | 53 | 23 | 36 | 36 | 0 | 3 | 35 | 35 | 0 | 1 | 35 | 73% |
| Kawaiiki (Koolaus) | Manage for stability | 2 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Opaeula (Koolaus) | Manage for stability | 35 | 161 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 6% |
| Pahole to West Makaleha | Manage for stability | 330 | 484 | 0 | 94 | 94 | 0 | 4 | 94 | 94 | 0 | 1 | 94 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Cyrtandra dentata** | | | | | | | | | | | | | | |
| Central Makaleha | Genetic Storage | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 395 | 717 | 23 | 132 | 132 | 0 | 7 | 131 | 131 | 0 | 2 | 131 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Delissea waianaeensis** | | | | | | | | | | | | | | |
| Kahanahaiki to Keawapilau | Manage for stability | 3 | 2 | 11 | 14 | 14 | 1 | 0 | 14 | 14 | 0 | 0 | 14 | 100% |
| Palikea Gulch | Genetic Storage | 1 | 0 | 6 | 7 | 7 | 3 | 0 | 7 | 7 | 3 | 0 | 7 | 100% |
| South Mohiakea | Genetic Storage | 12 | 16 | 7 | 15 | 15 | 0 | 0 | 13 | 13 | 0 | 0 | 13 | 68% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Delissea waianaeensis** | | | | | | | | | | | | | | |
| Ekahanui | Manage for stability | 2 | 1 | 4 | 6 | 6 | 0 | 0 | 6 | 6 | 0 | 0 | 6 | 100% |
| Kaluaa | Manage for stability | 5 | 0 | 5 | 9 | 9 | 0 | 0 | 9 | 9 | 0 | 0 | 9 | 90% |
| Kealia | Genetic Storage | 4 | 13 | 4 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 63% |
| Palawai | Genetic Storage | 24 | 30 | 8 | 30 | 30 | 0 | 0 | 28 | 28 | 0 | 0 | 28 | 88% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 51 | 62 | 45 | 86 | 86 | 4 | 0 | 82 | 82 | 3 | 0 | 82 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Dubautia herbstobatae** | | | | | | | | | | | | | | |
| Keaau | Genetic Storage | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha/Ohikilolo | Genetic Storage | 229 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0% |
| Ohikilolo Makai | Manage for stability | 133 | 4 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0% |
| Ohikilolo Mauka | Manage for stability | 373 | 27 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Dubautia herbstobatae** | | | | | | | | | | | | | | |
| Kamaileunu | Genetic Storage | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 100% |
| Makaha | Manage for stability | 23 | 2 | 16 | 18 | 0 | 0 | 24 | 13 | 0 | 0 | 16 | 16 | 41% |
| Waianae Kai | Genetic Storage | 10 | 4 | 0 | 5 | 0 | 0 | 3 | 4 | 0 | 0 | 3 | 3 | 30% |

| **Total Current Mature** | **Total Current Imm.** | **Total Dead and Repres.** | **Total # Plants w/ >=10 Seeds in SeedLab** | **Total # Plants w/ >=10 Est Vaible Seeds in SeedLab** | **Total # Plants w/ >=1 Microprop** | **Total # Plants w/ >=1 Army Nursery** | **Total # Plants w/ >=50 Seeds in SeedLab** | **Total # Plants w/ >=50 Est Viable Seeds in SeedLab** | **Total # Plants w/ >=3 in Microprop** | **Total # Plants w/ >=3 Army Nursery** | **Total # Plants that Met Goal** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 838 | 37 | 17 | 29 | 0 | 0 | 28 | 23 | 0 | 0 | 20 | 20 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Euphorbia celastroides var. kaenana** | | | | | | | | | | | | | | |
| East Kahanahaiki | Genetic Storage | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Kaluakauila | Genetic Storage | 11 | 3 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makua | Manage for stability | 85 | 0 | 31 | 77 | 74 | 0 | 0 | 61 | 53 | 0 | 0 | 53 | 100% |
| North Kahanahaiki | Genetic Storage | 115 | 36 | 4 | 14 | 14 | 0 | 0 | 11 | 8 | 0 | 0 | 8 | 16% |
| Puaakanoa | Manage for stability | 140 | 2 | 4 | 51 | 45 | 0 | 0 | 33 | 31 | 0 | 0 | 31 | 62% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Euphorbia celastroides var. kaenana** | | | | | | | | | | | | | | |
| East of Alau | Manage for stability | 20 | 2 | 6 | 26 | 26 | 0 | 0 | 24 | 21 | 0 | 0 | 21 | 81% |
| Kaena | Manage for stability | 880 | 274 | 7 | 68 | 67 | 0 | 0 | 66 | 58 | 0 | 0 | 58 | 100% |
| Keawaula | Genetic Storage | 42 | 3 | 6 | 31 | 27 | 0 | 0 | 18 | 10 | 0 | 0 | 10 | 21% |
| Waianae Kai | Genetic Storage | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1329 | 320 | 58 | 270 | 255 | 0 | 0 | 213 | 181 | 0 | 0 | 181 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Euphorbia herbstii** | | | | | | | | | | | | | | |
| Kapuna to Pahole | Manage for stability | 7 | 6 | 56 | 31 | 31 | 0 | 26 | 17 | 12 | 0 | 12 | 21 | 42% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 6 | 56 | 31 | 31 | 0 | 26 | 17 | 12 | 0 | 12 | 21 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Flueggea neowawraea** | | | | | | | | | | | | | | |
| Kahanahaiki to Kapuna | Manage for stability | 5 | 0 | 2 | 2 | 2 | 0 | 4 | 2 | 2 | 0 | 1 | 2 | 29% |
| Ohikilolo | Manage for stability | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 50% |
| West Makaleha | Genetic Storage | 2 | 0 | 1 | 1 | 1 | 0 | 6 | 1 | 1 | 0 | 2 | 2 | 67% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Flueggea neowawraea** | | | | | | | | | | | | | | |
| Central and East Makaleha | Genetic Storage | 4 | 0 | 3 | 1 | 1 | 0 | 7 | 1 | 1 | 0 | 6 | 6 | 86% |
| Halona | Genetic Storage | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 50% |
| Kauhiuhi | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha | Manage for stability | 7 | 0 | 4 | 2 | 1 | 0 | 11 | 2 | 0 | 0 | 4 | 4 | 36% |
| Mt. Kaala NAR | Genetic Storage | 2 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 1 | 0 | 1 | 2 | 50% |
| Nanakuli, south branch | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 100% |
| Waianae Kai | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| **Total Current Mature** | **Total Current Imm.** | **Total Dead and Repres.** | **Total # Plants w/ >=10 Seeds in SeedLab** | **Total # Plants w/ >=10 Est Vaible Seeds in SeedLab** | **Total # Plants w/ >=1 Microprop** | **Total # Plants w/ >=1 Army Nursery** | **Total # Plants w/ >=50 Seeds in SeedLab** | **Total # Plants w/ >=50 Est Viable Seeds in SeedLab** | **Total # Plants w/ >=3 in Microprop** | **Total # Plants w/ >=3 Army Nursery** | **Total # Plants that Met Goal** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 0 | 14 | 9 | 7 | 0 | 34 | 9 | 5 | 0 | 17 | 19 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Gouania vitifolia** | | | | | | | | | | | | | | |
| Keaau | Manage for stability | 47 | 2 | 22 | 58 | 50 | 0 | 7 | 49 | 33 | 0 | 2 | 33 | 66% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Gouania vitifolia** | | | | | | | | | | | | | | |
| Waianae Kai | Genetic Storage | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 3 | 23 | 58 | 50 | 0 | 9 | 49 | 33 | 0 | 2 | 33 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Hesperomannia oahuensis** | | | | | | | | | | | | | | |
| Haleauau | Manage for stability | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Hesperomannia oahuensis** | | | | | | | | | | | | | | |
| Makaha | Manage for stability | 5 | 1 | 1 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 2 | 2 | 33% |
| Waianae Kai | Genetic Storage | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 1 | 3 | 2 | 1 | 0 | 5 | 0 | 0 | 0 | 2 | 2 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Hibiscus brackenridgei subsp. mokuleianus** | | | | | | | | | | | | | | |
| Keaau | Manage for stability | 0 | 3 | 7 | 6 | 6 | 0 | 6 | 6 | 6 | 0 | 6 | 6 | 86% |
| Makua | Manage for stability | 8 | 0 | 35 | 35 | 34 | 0 | 36 | 34 | 33 | 0 | 32 | 35 | 81% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Hibiscus brackenridgei subsp. mokuleianus** | | | | | | | | | | | | | | |
| Haili to Kawaiu | Manage for stability | 3 | 2 | 16 | 7 | 4 | 0 | 18 | 3 | 0 | 0 | 17 | 17 | 89% |
| Waialua | Genetic Storage | 49 | 85 | 28 | 18 | 11 | 0 | 64 | 8 | 0 | 0 | 62 | 62 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 90 | 86 | 66 | 55 | 0 | 124 | 51 | 39 | 0 | 117 | 120 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Kadua degeneri subsp. degeneri** | | | | | | | | | | | | | | |
| Kahanahaiki to Pahole | Manage for stability | 102 | 100 | 20 | 76 | 76 | 0 | 0 | 67 | 62 | 0 | 0 | 62 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Kadua degeneri subsp. degeneri** | | | | | | | | | | | | | | |
| Alaiheihe and Manuwai | Manage for stability | 17 | 9 | 20 | 32 | 32 | 1 | 0 | 31 | 29 | 1 | 0 | 30 | 81% |
| Central Makaleha and West Branch of East Makaleha | Manage for stability | 17 | 32 | 25 | 39 | 35 | 0 | 2 | 34 | 30 | 0 | 1 | 30 | 71% |
| East branch of East Makaleha | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 136 | 141 | 65 | 147 | 143 | 1 | 2 | 132 | 121 | 1 | 1 | 122 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Kadua parvula** | | | | | | | | | | | | | | |
| Ohikilolo | Manage for stability | 40 | 145 | 51 | 78 | 74 | 0 | 1 | 73 | 66 | 0 | 0 | 66 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Kadua parvula** | | | | | | | | | | | | | | |
| Halona | Manage for stability | 31 | 4 | 31 | 72 | 70 | 0 | 27 | 62 | 56 | 0 | 15 | 58 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | 149 | 82 | 150 | 144 | 0 | 28 | 135 | 122 | 0 | 15 | 124 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Melanthera tenuifolia** | | | | | | | | | | | | | | |
| Kahanahaiki | Genetic Storage | 1 | 0 | 22 | 11 | 0 | 0 | 10 | 5 | 0 | 0 | 9 | 9 | 39% |
| Kaluakauila | Genetic Storage | 4 | 80 | 0 | 9 | 0 | 0 | 8 | 1 | 0 | 0 | 6 | 6 | 100% |
| Keawaula | Genetic Storage | 200 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Ohikilolo | Manage for stability | 570 | 11 | 19 | 16 | 0 | 1 | 5 | 13 | 0 | 0 | 5 | 5 | 10% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Melanthera tenuifolia** | | | | | | | | | | | | | | |
| Kamaileunu and Waianae Kai | Manage for stability | 815 | 246 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Mt. Kaala NAR | Manage for stability | 131 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1721 | 411 | 41 | 36 | 0 | 1 | 23 | 19 | 0 | 0 | 20 | 20 |

## Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Neraudia angulata** | | | | | | | | | | | | | | |
| Kapuna | Genetic Storage | 0 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 100% |
| Makua | Manage for stability | 20 | 4 | 34 | 9 | 9 | 0 | 32 | 9 | 8 | 0 | 16 | 20 | 40% |
| Punapohaku | Genetic Storage | 2 | 0 | 2 | 1 | 1 | 0 | 4 | 1 | 0 | 0 | 3 | 3 | 75% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Neraudia angulata** | | | | | | | | | | | | | | |
| Halona | Genetic Storage | 4 | 10 | 17 | 2 | 0 | 0 | 8 | 2 | 0 | 0 | 4 | 4 | 19% |
| Leeward Puu Kaua | Genetic Storage | 9 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha | Manage for stability (backup site) | 3 | 8 | 12 | 6 | 1 | 0 | 14 | 6 | 0 | 0 | 9 | 9 | 60% |
| Manuwai | Manage for stability | 0 | 3 | 4 | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 4 | 4 | 100% |
| Waianae Kai Makai | Genetic Storage | 13 | 0 | 1 | 1 | 0 | 0 | 11 | 1 | 0 | 0 | 9 | 9 | 64% |
| Waianae Kai Mauka | Manage for stability | 7 | 2 | 9 | 4 | 0 | 0 | 11 | 2 | 0 | 0 | 5 | 5 | 31% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 58 | 27 | 81 | 28 | 13 | 0 | 87 | 23 | 8 | 0 | 52 | 56 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Nototrichium humile** | | | | | | | | | | | | | | |
| Kahanahaiki | Genetic Storage | 28 | 1 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 3 | 3 | 11% |
| Kaluakauila | Manage for stability | 133 | 45 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Keaau | Genetic Storage | 20 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Keawaula | Genetic Storage | 109 | 22 | 1 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 7 | 7 | 14% |
| Makua (East rim) | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makua (south side) | Manage for stability | 43 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Punapohaku | Genetic Storage | 178 | 77 | 1 | 0 | 0 | 0 | 35 | 0 | 0 | 0 | 27 | 27 | 54% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Nototrichium humile** | | | | | | | | | | | | | | |
| Kaimuhole and Palikea Gulch | Genetic Storage | 29 | 1 | 12 | 0 | 0 | 0 | 42 | 0 | 0 | 0 | 37 | 37 | 90% |
| Keawapilau | Genetic Storage | 1 | 0 | 4 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 4 | 4 | 80% |
| Kolekole | Genetic Storage | 12 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 6 | 6 | 50% |
| Makaha | Genetic Storage | 22 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Nanakuli | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Puu Kaua (Leeward side) | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Waianae Kai | Manage for stability | 134 | 130 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 4 | 4 | 8% |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Total Current Mature** | **Total Current Imm.** | **Total Dead and Repres.** | **Total # Plants w/ >=10 Seeds in SeedLab** | **Total # Plants w/ >=10 Est Vaible Seeds in SeedLab** | **Total # Plants w/ >=1 Microprop** | **Total # Plants w/ >=1 Army Nursery** | **Total # Plants w/ >=50 Seeds in SeedLab** | **Total # Plants w/ >=50 Est Viable Seeds in SeedLab** | **Total # Plants w/ >=3 in Microprop** | **Total # Plants w/ >=3 Army Nursery** | **Total # Plants that Met Goal** | |
| | | 712 | 315 | 19 | 1 | 0 | 0 | 112 | 0 | 0 | 0 | 88 | 88 | |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Phyllostegia kaalaensis** | | | | | | | | | | | | | | |
| Keawapilau to Kapuna | Manage reintroduction for stability | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 100% |
| Pahole | Manage reintroduction for stability | 0 | 0 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 2 | 100% |
| Palikea Gulch | Genetic Storage | 0 | 0 | 3 | 2 | 0 | 3 | 3 | 0 | 0 | 3 | 3 | 3 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Phyllostegia kaalaensis** | | | | | | | | | | | | | | |
| Waianae Kai | Genetic Storage | 0 | 0 | 2 | 1 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 2 | 100% |

| **Total Current Mature** | **Total Current Imm.** | **Total Dead and Repres.** | **Total # Plants w/ >=10 Seeds in SeedLab** | **Total # Plants w/ >=10 Est Vaible Seeds in SeedLab** | **Total # Plants w/ >=1 Microprop** | **Total # Plants w/ >=1 Army Nursery** | **Total # Plants w/ >=50 Seeds in SeedLab** | **Total # Plants w/ >=50 Est Viable Seeds in SeedLab** | **Total # Plants w/ >=3 in Microprop** | **Total # Plants w/ >=3 Army Nursery** | **Total # Plants that Met Goal** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 8 | 4 | 1 | 8 | 8 | 0 | 0 | 8 | 8 | 8 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Plantago princeps var. princeps** | | | | | | | | | | | | | | |
| North Mohiakea | Manage for stability | 28 | 43 | 9 | 20 | 20 | 0 | 1 | 19 | 17 | 0 | 1 | 17 | 46% |
| Ohikilolo | Manage for stability | 0 | 0 | 17 | 19 | 18 | 0 | 0 | 14 | 14 | 0 | 0 | 14 | 82% |
| Pahole | Genetic Storage | 4 | 5 | 4 | 6 | 5 | 0 | 1 | 5 | 5 | 0 | 0 | 5 | 63% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Plantago princeps var. princeps** | | | | | | | | | | | | | | |
| Ekahanui | Manage for stability | 5 | 50 | 67 | 69 | 67 | 0 | 0 | 59 | 42 | 0 | 0 | 42 | 84% |
| Halona | Manage for stability | 6 | 9 | 22 | 22 | 22 | 0 | 0 | 22 | 18 | 0 | 0 | 18 | 64% |
| North Palawai | Genetic Storage | 1 | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 67% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 44 | 107 | 121 | 138 | 134 | 0 | 2 | 121 | 98 | 0 | 1 | 98 |

## Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Pritchardia kaalae** | | | | | | | | | | | | | | |
| Ohikilolo | Manage for stability | 72 | 1178 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Pritchardia kaalae** | | | | | | | | | | | | | | |
| Makaha | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaleha to Manuwai | Manage for stability | 123 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Waianae Kai | Genetic Storage | 4 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 | 1194 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Sanicula mariversa** | | | | | | | | | | | | | | |
| Keaau | Manage for stability | 0 | 43 | 27 | 44 | 42 | 0 | 0 | 24 | 8 | 0 | 0 | 8 | 30% |
| Ohikilolo | Manage for stability | 0 | 97 | 51 | 56 | 41 | 0 | 0 | 22 | 17 | 0 | 0 | 17 | 34% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Sanicula mariversa** | | | | | | | | | | | | | | |
| Kamaileunu | Manage for stability | 31 | 182 | 26 | 69 | 69 | 0 | 2 | 54 | 42 | 0 | 2 | 42 | 84% |
| Puu Kawiwi | Genetic Storage | 0 | 0 | 2 | 3 | 3 | 0 | 0 | 3 | 2 | 0 | 0 | 2 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 322 | 106 | 172 | 155 | 0 | 2 | 103 | 69 | 0 | 2 | 69 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Schiedea kaalae** | | | | | | | | | | | | | | |
| Pahole | Manage for stability | 1 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Schiedea kaalae** | | | | | | | | | | | | | | |
| Kahana | Genetic Storage | 5 | 0 | 4 | 2 | 1 | 9 | 9 | 0 | 0 | 9 | 9 | 9 | 100% |
| Kaluaa and Waieli | Manage for stability | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 100% |
| Maakua (Koolaus) | Manage for stability | 10 | 0 | 0 | 1 | 1 | 6 | 4 | 0 | 0 | 6 | 4 | 6 | 60% |
| Makaua (Koolaus) | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 100% |
| North Palawai | Genetic Storage | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 100% |
| South Ekahanui | Manage for stability | 7 | 1 | 10 | 17 | 16 | 14 | 12 | 14 | 7 | 14 | 10 | 16 | 94% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 1 | 17 | 24 | 22 | 34 | 29 | 18 | 11 | 34 | 27 | 36 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Schiedea nuttallii** | | | | | | | | | | | | | | |
| Kahanahaiki to Pahole | Manage for stability | 9 | 0 | 44 | 41 | 37 | 2 | 42 | 33 | 17 | 2 | 40 | 42 | 84% |
| Kapuna-Keawapilau Ridge | Manage for stability | 0 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 1 | 0 | 2 | 2 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 0 | 46 | 43 | 39 | 2 | 44 | 35 | 18 | 2 | 42 | 44 |

# Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Schiedea obovata** | | | | | | | | | | | | | | |
| Kahanahaiki to Pahole | Manage for stability | 0 | 0 | 5 | 5 | 5 | 1 | 4 | 5 | 5 | 1 | 4 | 5 | 100% |
| Keawapilau to West Makaleha | Manage for stability | 12 | 408 | 77 | 81 | 80 | 0 | 73 | 80 | 78 | 0 | 63 | 78 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 408 | 82 | 86 | 85 | 1 | 77 | 85 | 83 | 1 | 67 | 83 |

# Genetic Storage Summary Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Tetramolopium filiforme** | | | | | | | | | | | | | | |
| Kahanahaiki | Genetic Storage | 40 | 0 | 28 | 92 | 54 | 0 | 0 | 52 | 1 | 0 | 0 | 1 | 2% |
| Kalena | Manage for stability | 26 | 16 | 7 | 9 | 8 | 0 | 9 | 9 | 8 | 0 | 6 | 8 | 24% |
| Keaau | Genetic Storage | 30 | 41 | 0 | 17 | 15 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 3% |
| Makaha/Ohikilolo Ridge | Genetic Storage | 350 | 200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Ohikilolo | Manage for stability | 1740 | 1042 | 38 | 141 | 57 | 0 | 0 | 46 | 6 | 0 | 0 | 6 | 12% |
| Puhawai | Manage for stability | 0 | 0 | 5 | 4 | 4 | 0 | 0 | 4 | 4 | 0 | 0 | 4 | 80% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Tetramolopium filiforme** | | | | | | | | | | | | | | |
| Waianae Kai | Manage for stability | 20 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2206 | 1299 | 78 | 264 | 139 | 0 | 9 | 113 | 20 | 0 | 6 | 20 |

## Genetic Storage Summary    Makua Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Viola chamissoniana subsp. chamissoniana** | | | | | | | | | | | | | | |
| Keaau | Genetic Storage | 40 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha/Ohikilolo Ridge | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Ohikilolo | Manage for stability | 107 | 233 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Puu Kumakalii | Manage for stability | 44 | 0 | 0 | 12 | 0 | 0 | 8 | 3 | 0 | 0 | 7 | 7 | 16% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Viola chamissoniana subsp. chamissoniana** | | | | | | | | | | | | | | |
| Halona | Manage for stability | 16 | 5 | 6 | 4 | 0 | 2 | 3 | 1 | 0 | 1 | 3 | 3 | 14% |
| Kamaileunu | Genetic Storage | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha | Manage for stability | 29 | 24 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 2 | 2 | 7% |
| Makaleha | Genetic Storage | 19 | 9 | 2 | 8 | 0 | 0 | 11 | 1 | 0 | 0 | 11 | 11 | 52% |
| Puu Hapapa | Genetic Storage | 6 | 1 | 7 | 7 | 0 | 0 | 6 | 4 | 0 | 0 | 6 | 6 | 46% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 296 | 282 | 15 | 32 | 0 | 2 | 37 | 9 | 0 | 1 | 29 | 29 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Abutilon sandwicense** | | | | | | | | | | | | | | |
| Kaawa to Puulu | Manage for stability | 27 | 187 | 0 | 19 | 14 | 0 | 0 | 14 | 2 | 0 | 0 | 2 | 7% |
| Kahanahaiki | Manage reintroduction for stability | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 100% |
| Keaau | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Abutilon sandwicense** | | | | | | | | | | | | | | |
| East Makaleha | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Ekahanui and Huliwai | Manage for stability | 2 | 26 | 11 | 11 | 10 | 0 | 1 | 10 | 9 | 0 | 0 | 9 | 69% |
| Halona | Genetic Storage | 10 | 5 | 0 | 3 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0% |
| Makaha Makai | Manage for stability | 92 | 133 | 2 | 78 | 59 | 0 | 9 | 72 | 36 | 0 | 2 | 36 | 72% |
| Makaha Mauka | Genetic Storage | 29 | 16 | 7 | 25 | 17 | 0 | 0 | 22 | 3 | 0 | 0 | 3 | 8% |
| North Mikilua | Genetic Storage | 9 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Waianae Kai | Genetic Storage | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0% |
| West Makaleha | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 169 | 378 | 22 | 139 | 103 | 0 | 11 | 122 | 50 | 0 | 3 | 51 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Alectryon macrococcus var. macrococcus** | | | | | | | | | | | | | | |
| Kahanahaiki to Keawapilau | Manage for stability | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makua | Manage for stability | 4 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 33% |
| South Mohiakea | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 50% |
| West Makaleha | Genetic Storage | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Alectryon macrococcus var. macrococcus** | | | | | | | | | | | | | | |
| Central Kaluaa to Central Waieli | Manage for stability | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha | Manage for stability | 11 | 0 | 10 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 11 | 11 | 52% |
| Waianae Kai | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 12 | 0 | 0 | 0 | 22 | 0 | 0 | 0 | 14 | 14 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders | | | Partial Storage Status | | | | Storage Goals | | | | Storage Goals Met | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Current Mature | Current Imm. | Dead and Repres. | # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | # Plants that Met Goal | % Completed Genetic Storage Requirement |
| **Action Area: In** | | | | | | | | | | | | | | |
| **Cyanea acuminata** | | | | | | | | | | | | | | |
| Helemano-Punaluu Summit Ridge to North Kaukonahua | Manage for stability | 81 | 77 | 0 | 13 | 13 | 1 | 0 | 13 | 13 | 1 | 0 | 13 | 26% |
| Kahana and South Kaukonahua | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaleha to Mohiakea | Manage for stability | 195 | 89 | 0 | 10 | 10 | 0 | 2 | 10 | 10 | 0 | 0 | 10 | 20% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Cyanea acuminata** | | | | | | | | | | | | | | |
| Kahana and Makaua | Genetic Storage | 11 | 3 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0% |
| Kaipapau and Koloa | Genetic Storage | 70 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Kaluanui and Maakua | Manage for stability | 123 | 126 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Puukeahiakahoe | Genetic Storage | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 485 | 325 | 0 | 24 | 24 | 1 | 2 | 24 | 23 | 1 | 0 | 23 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Cyanea grimesiana subsp. obatae** | | | | | | | | | | | | | | |
| Pahole to West Makaleha | Manage for stability | 4 | 17 | 12 | 16 | 16 | 0 | 6 | 16 | 16 | 0 | 2 | 16 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Cyanea grimesiana subsp. obatae** | | | | | | | | | | | | | | |
| Kaluaa | Manage for stability | 2 | 1 | 1 | 3 | 3 | 0 | 1 | 3 | 3 | 0 | 1 | 3 | 100% |
| North branch of South Ekahanui | Manage reintroduction for stability | 0 | 0 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 0 | 2 | 100% |
| Palikea (South Palawai) | Manage for stability | 11 | 1 | 11 | 15 | 15 | 5 | 7 | 15 | 15 | 5 | 3 | 15 | 68% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 19 | 26 | 36 | 36 | 7 | 15 | 36 | 36 | 7 | 6 | 36 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Cyanea koolauensis** | | | | | | | | | | | | | | |
| Kaipapau, Koloa and Kawainui | Manage for stability | 113 | 12 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 2% |
| Kamananui-Kawainui Ridge | Genetic Storage | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Kaukonahua | Genetic Storage | 8 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Kawaiiki | Genetic Storage | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Lower Opaeula | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Opaeula to Helemano | Manage for stability | 21 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Poamoho | Manage for stability | 20 | 19 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 5% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Cyanea koolauensis** | | | | | | | | | | | | | | |
| Halawa | Genetic Storage | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Waialae Nui | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Waiawa to Waimano | Genetic Storage | 11 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Wailupe | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 191 | 49 | 0 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 0 | 2 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Cyrtandra dentata** | | | | | | | | | | | | | | |
| Kahanahaiki | Manage for stability | 25 | 53 | 23 | 36 | 36 | 0 | 3 | 35 | 35 | 0 | 1 | 35 | 73% |
| Kawaiiki (Koolaus) | Manage for stability | 2 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Opaeula (Koolaus) | Manage for stability | 35 | 161 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 6% |
| Pahole to West Makaleha | Manage for stability | 330 | 484 | 0 | 94 | 94 | 0 | 4 | 94 | 94 | 0 | 1 | 94 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Cyrtandra dentata** | | | | | | | | | | | | | | |
| Central Makaleha | Genetic Storage | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 395 | 717 | 23 | 132 | 132 | 0 | 7 | 131 | 131 | 0 | 2 | 131 |

# Genetic Storage Summary Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Delissea waianaeensis** | | | | | | | | | | | | | | |
| Kahanahaiki to Keawapilau | Manage for stability | 3 | 2 | 11 | 14 | 14 | 1 | 0 | 14 | 14 | 0 | 0 | 14 | 100% |
| Palikea Gulch | Genetic Storage | 1 | 0 | 6 | 7 | 7 | 3 | 0 | 7 | 7 | 3 | 0 | 7 | 100% |
| South Mohiakea | Genetic Storage | 12 | 16 | 7 | 15 | 15 | 0 | 0 | 13 | 13 | 0 | 0 | 13 | 68% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Delissea waianaeensis** | | | | | | | | | | | | | | |
| Ekahanui | Manage for stability | 2 | 1 | 4 | 6 | 6 | 0 | 0 | 6 | 6 | 0 | 0 | 6 | 100% |
| Kaluaa | Manage for stability | 5 | 0 | 5 | 9 | 9 | 0 | 0 | 9 | 9 | 0 | 0 | 9 | 90% |
| Kealia | Genetic Storage | 4 | 13 | 4 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 63% |
| Palawai | Genetic Storage | 24 | 30 | 8 | 30 | 30 | 0 | 0 | 28 | 28 | 0 | 0 | 28 | 88% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 51 | 62 | 45 | 86 | 86 | 4 | 0 | 82 | 82 | 3 | 0 | 82 |

# Genetic Storage Summary Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Eugenia koolauensis** | | | | | | | | | | | | | | |
| Aimuu | Genetic Storage | 8 | 10 | 3 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 10 | 10 | 91% |
| Kaiwikoele and Kamananui | Genetic Storage | 17 | 26 | 4 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 24 | 24 | 100% |
| Kaleleiki | Genetic Storage | 14 | 46 | 12 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 13 | 13 | 50% |
| Kaunala | Manage for stability | 15 | 39 | 8 | 0 | 0 | 2 | 35 | 0 | 0 | 0 | 21 | 21 | 91% |
| Malaekahana | Genetic Storage | 0 | 4 | 1 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 4 | 4 | 100% |
| Ohiaai and East Oio | Genetic Storage | 1 | 1 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 2 | 100% |
| Oio | Manage for stability | 6 | 2 | 9 | 0 | 0 | 1 | 14 | 0 | 0 | 1 | 7 | 7 | 47% |
| Pahipahialua | Manage for stability | 18 | 6 | 20 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 20 | 20 | 53% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Eugenia koolauensis** | | | | | | | | | | | | | | |
| Hanaimoa | Genetic Storage | 1 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 2 | 67% |
| Palikea and Kaimuhole | Genetic Storage | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81 | 134 | 61 | 0 | 0 | 3 | 160 | 0 | 0 | 1 | 105 | 105 |

# Genetic Storage Summary Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Flueggea neowawraea** | | | | | | | | | | | | | | |
| Kahanahaiki to Kapuna | Manage for stability | 5 | 0 | 2 | 2 | 2 | 0 | 4 | 2 | 2 | 0 | 1 | 2 | 29% |
| Ohikilolo | Manage for stability | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 50% |
| West Makaleha | Genetic Storage | 2 | 0 | 1 | 1 | 1 | 0 | 6 | 1 | 1 | 0 | 2 | 2 | 67% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Flueggea neowawraea** | | | | | | | | | | | | | | |
| Central and East Makaleha | Genetic Storage | 4 | 0 | 3 | 1 | 1 | 0 | 7 | 1 | 1 | 0 | 6 | 6 | 86% |
| Halona | Genetic Storage | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 50% |
| Kauhiuhi | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha | Manage for stability | 7 | 0 | 4 | 2 | 1 | 0 | 11 | 2 | 0 | 0 | 4 | 4 | 36% |
| Mt. Kaala NAR | Genetic Storage | 2 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 1 | 0 | 1 | 2 | 50% |
| Nanakuli, south branch | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 100% |
| Waianae Kai | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 0 | 14 | 9 | 7 | 0 | 34 | 9 | 5 | 0 | 17 | 19 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Gardenia mannii** | | | | | | | | | | | | | | |
| Haleauau | Manage for stability | 2 | 0 | 6 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 2 | 2 | 25% |
| Helemano and Poamoho | Manage for stability | 23 | 0 | 2 | 1 | 1 | 0 | 19 | 1 | 1 | 0 | 16 | 16 | 64% |
| Kaiwikoele, Kamananui, and Kawainui | Genetic Storage | 13 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0% |
| Lower Peahinaia | Manage for stability | 9 | 0 | 3 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 5 | 5 | 42% |
| South Kaukonahua | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 50% |
| Upper Opaeula/Helemano | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Gardenia mannii** | | | | | | | | | | | | | | |
| Ihiihi-Kawainui ridge | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Kaluaa and Maunauna | Genetic Storage | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 100% |
| Kamananui-Malaekahana Summit Ridge | Genetic Storage | 3 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 67% |
| Kapakahi | Genetic Storage | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Pukele | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 59 | 0 | 12 | 1 | 1 | 0 | 39 | 1 | 1 | 0 | 29 | 29 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Hesperomannia swezeyi** | | | | | | | | | | | | | | |
| Kamananui to Kaluanui | Manage for stability | 134 | 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Kaukonahua | Manage for stability | 55 | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Lower Opaeula | Manage for stability | 11 | 15 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Poamoho | Genetic Storage | 13 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Hesperomannia swezeyi** | | | | | | | | | | | | | | |
| Niu-Waimanalo Summit Ridge | Genetic Storage | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 214 | 186 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# Genetic Storage Summary Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Labordia cyrtandrae** | | | | | | | | | | | | | | |
| East Makaleha to North Mohiakea | Manage for stability | 68 | 0 | 0 | 8 | 8 | 3 | 6 | 8 | 8 | 3 | 4 | 11 | 22% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 68 | 0 | 0 | 8 | 8 | 3 | 6 | 8 | 8 | 3 | 4 | 11 |

## Genetic Storage Summary Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Phyllostegia hirsuta** | | | | | | | | | | | | | | |
| Haleauau to Mohiakea | Manage for stability | 11 | 2 | 6 | 7 | 7 | 8 | 10 | 6 | 2 | 8 | 10 | 10 | 59% |
| Helemano and Opaeula | Genetic Storage | 1 | 4 | 4 | 2 | 2 | 1 | 4 | 1 | 0 | 1 | 4 | 4 | 80% |
| Helemano and Poamoho | Genetic Storage | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Kaipapau and Kawainui | Genetic Storage | 4 | 0 | 0 | 1 | 1 | 4 | 4 | 0 | 0 | 4 | 4 | 4 | 100% |
| Kaukonahua | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Kawaiiki | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Koloa | Manage for stability | 9 | 2 | 1 | 3 | 2 | 5 | 6 | 1 | 0 | 5 | 6 | 6 | 60% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Phyllostegia hirsuta** | | | | | | | | | | | | | | |
| Hapapa to Kaluaa | Genetic Storage | 0 | 7 | 12 | 8 | 7 | 7 | 12 | 5 | 4 | 7 | 10 | 11 | 92% |
| Kaluanui and Punaluu | Genetic Storage | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha-Waianae Kai Ridge | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 100% |
| Palawai | Genetic Storage | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Waiamano | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | 18 | 25 | 21 | 19 | 25 | 37 | 13 | 6 | 25 | 35 | 36 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Phyllostegia kaalaensis** | | | | | | | | | | | | | | |
| Keawapilau to Kapuna | Manage reintroduction for stability | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 100% |
| Pahole | Manage reintroduction for stability | 0 | 0 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 2 | 100% |
| Palikea Gulch | Genetic Storage | 0 | 0 | 3 | 2 | 0 | 3 | 3 | 0 | 0 | 3 | 3 | 3 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Phyllostegia kaalaensis** | | | | | | | | | | | | | | |
| Waianae Kai | Genetic Storage | 0 | 0 | 2 | 1 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 2 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 8 | 4 | 1 | 8 | 8 | 0 | 0 | 8 | 8 | 8 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders | | | Partial Storage Status | | | | Storage Goals | | | | Storage Goals Met | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Current Mature | Current Imm. | Dead and Repres. | # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | # Plants that Met Goal | % Completed Genetic Storage Requirement |
| **Action Area: In** | | | | | | | | | | | | | | |
| **Phyllostegia mollis** | | | | | | | | | | | | | | |
| Mohiakea | Genetic Storage | 1 | 0 | 7 | 6 | 6 | 7 | 7 | 3 | 2 | 7 | 5 | 7 | 88% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Phyllostegia mollis** | | | | | | | | | | | | | | |
| Ekahanui | Manage for stability | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 100% |
| Kaluaa | Manage for stability | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 100% |
| Pualii | Manage reintroduction for stability | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 100% |
| Waieli | Genetic Storage | 0 | 0 | 6 | 5 | 5 | 6 | 5 | 4 | 4 | 6 | 4 | 6 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 17 | 15 | 15 | 16 | 16 | 10 | 7 | 16 | 12 | 17 |

# Genetic Storage Summary Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Plantago princeps var. princeps** | | | | | | | | | | | | | | |
| North Mohiakea | Manage for stability | 28 | 43 | 9 | 20 | 20 | 0 | 0 | 19 | 19 | 0 | 0 | 19 | 51% |
| Ohikilolo | Manage for stability | 0 | 0 | 17 | 19 | 18 | 0 | 0 | 14 | 14 | 0 | 0 | 14 | 82% |
| Pahole | Genetic Storage | 4 | 5 | 2 | 6 | 5 | 0 | 1 | 5 | 5 | 0 | 0 | 5 | 83% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Plantago princeps var. princeps** | | | | | | | | | | | | | | |
| Ekahanui | Manage for stability | 5 | 50 | 67 | 69 | 67 | 0 | 0 | 59 | 42 | 0 | 0 | 42 | 84% |
| Halona | Manage for stability | 6 | 9 | 22 | 22 | 22 | 0 | 0 | 22 | 18 | 0 | 0 | 18 | 64% |
| North Palawai | Genetic Storage | 1 | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 67% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 44 | 107 | 119 | 138 | 134 | 0 | 1 | 121 | 100 | 0 | 0 | 100 |

# Genetic Storage Summary Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Schiedea kaalae** | | | | | | | | | | | | | | |
| Pahole | Manage for stability | 1 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Schiedea kaalae** | | | | | | | | | | | | | | |
| Kahana | Genetic Storage | 5 | 0 | 4 | 2 | 1 | 9 | 9 | 0 | 0 | 9 | 9 | 9 | 100% |
| Kaluaa and Waieli | Manage for stability | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 100% |
| Maakua (Koolaus) | Manage for stability | 10 | 0 | 0 | 1 | 1 | 6 | 4 | 0 | 0 | 6 | 4 | 6 | 60% |
| Makaua (Koolaus) | Genetic Storage | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 100% |
| North Palawai | Genetic Storage | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 100% |
| South Ekahanui | Manage for stability | 7 | 1 | 10 | 17 | 16 | 14 | 12 | 14 | 7 | 14 | 10 | 16 | 94% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 1 | 17 | 24 | 22 | 34 | 29 | 18 | 11 | 34 | 27 | 36 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | Current Imm. | Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | # Plants >= 10 Est Viable in SeedLab | # Plants >=1 Microprop | # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | # Plants >= 50 Est. Viable in SeedLab | # Plants >=3 in Microprop | # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Schiedea trinervis** | | | | | | | | | | | | | | |
| Kalena to East Makaleha | Manage for stability | 296 | 351 | 14 | 92 | 91 | 1 | 0 | 91 | 89 | 1 | 0 | 89 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 296 | 351 | 14 | 92 | 91 | 1 | 0 | 91 | 89 | 1 | 0 | 89 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Stenogyne kanehoana** | | | | | | | | | | | | | | |
| Haleauau | Manage reintroduction for stability | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 100% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Stenogyne kanehoana** | | | | | | | | | | | | | | |
| Kaluaa | Manage reintroduction for stability | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 100% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 2 |

# Genetic Storage Summary    Oahu Implementation Plan

| Population Unit Name | Management Designation | # of Potential Founders: Current Mature | # of Potential Founders: Current Imm. | # of Potential Founders: Dead and Repres. | Partial Storage Status: # Plants >= 10 in SeedLab | Partial Storage Status: # Plants >= 10 Est Viable in SeedLab | Partial Storage Status: # Plants >=1 Microprop | Partial Storage Status: # Plants >=1 Army Nursery | Storage Goals: # Plants >= 50 in SeedLab | Storage Goals: # Plants >= 50 Est. Viable in SeedLab | Storage Goals: # Plants >=3 in Microprop | Storage Goals: # Plants >=3 Army Nursery | Storage Goals Met: # Plants that Met Goal | % Completed Genetic Storage Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Action Area: In** | | | | | | | | | | | | | | |
| **Viola chamissoniana subsp. chamissoniana** | | | | | | | | | | | | | | |
| Keaau | Genetic Storage | 40 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha/Ohikilolo Ridge | Genetic Storage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Ohikilolo | Manage for stability | 107 | 233 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Puu Kumakalii | Manage for stability | 44 | 0 | 0 | 12 | 0 | 0 | 8 | 3 | 0 | 0 | 7 | 7 | 16% |
| **Action Area: Out** | | | | | | | | | | | | | | |
| **Viola chamissoniana subsp. chamissoniana** | | | | | | | | | | | | | | |
| Halona | Manage for stability | 16 | 5 | 6 | 4 | 0 | 2 | 3 | 1 | 0 | 1 | 3 | 3 | 14% |
| Kamaileunu | Genetic Storage | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Makaha | Manage for stability | 29 | 24 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 1 | 1 | 3% |
| Makaleha | Genetic Storage | 19 | 9 | 2 | 8 | 0 | 0 | 11 | 1 | 0 | 0 | 11 | 11 | 52% |
| Puu Hapapa | Genetic Storage | 6 | 1 | 7 | 7 | 0 | 0 | 6 | 4 | 0 | 0 | 6 | 6 | 46% |

| Total Current Mature | Total Current Imm. | Total Dead and Repres. | Total # Plants w/ >=10 Seeds in SeedLab | Total # Plants w/ >=10 Est Vaible Seeds in SeedLab | Total # Plants w/ >=1 Microprop | Total # Plants w/ >=1 Army Nursery | Total # Plants w/ >=50 Seeds in SeedLab | Total # Plants w/ >=50 Est Viable Seeds in SeedLab | Total # Plants w/ >=3 in Microprop | Total # Plants w/ >=3 Army Nursery | Total # Plants that Met Goal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 296 | 282 | 15 | 32 | 0 | 2 | 33 | 9 | 0 | 1 | 28 | 28 |

## Appendix 4-6: Updated Recollection Intervals

One of the most important tasks of the Army Seed Lab is to monitor the viability of seeds in storage and to determine the seed storage potential of managed taxa. Depending on the quantity of seed in a collection, seeds are withdrawn at intervals through time- initially, at five years and then every five or ten years after that- to assess the viability of collections in storage. In addition, research collections are set aside to research species storage behavior, such as preferred storage condition for each taxa, and to assess the longevity of genetic storage collections. Seed viability of research collections in storage is tested through time- after 6 months, 1 year, 2 years, 5 years, and every five years after that- under different storage conditions (varying temperatures and relative humidity). Genetic storage collections for each taxa are held at preferred storage conditions that maintain the highest viability over the longest period of time. It is important to test seeds at regular intervals in order to detect significant declines in viability as they happen. When a significant decline in viability is detected in a collection at its preferred storage condition, genetic erosion of the collection has begun and the collection no longer contains the same amount of genetic diversity that it did when it was initially harvested. It is important to regenerate the collection or recollect once a significant decline in viability is detected in order to maintain viable and genetically diverse collections. We define a species re-collection interval as the amount of time it takes for a collection's viability to drop to 70% of its initial viability, or a decline in viability no greater than 30%. For example, if the initial viability of 100% of species X falls below 70% after ten years, the re-collection interval of species X would be set as ten years. If testing reveals no decline in viability, the re-collection interval is set for five years past the most recent viability test. For example, if no decline is detected in seed of species X after ten years of testing, the re-collection interval would be set at 15 years and testing would continue at five year intervals. In general, re-collection intervals are based on tests from just a few collections. However, the analysis of tests from more recent collections can provide supporting trends in storage longevity. The Army Seed Conservation Lab database includes re-collection intervals for most IP taxa. Once the interval is reached for a given collection, it no longer counts towards genetic storage requirements. Either the recollection interval is increased based on testing data or re-collection from the original source or representative outplanting, or the regeneration of that collection in the greenhouse is required. Re-collection intervals are expected to change through time as new data becomes available. However, eventually a maximum interval will be established on a per species basis. Retesting of some collections and species may be necessary in the following cases: where seed sample sizes are small; tests are conducted under known suboptimal conditions; where high variation in testing results is detected; or where results for a given species are significantly different than those of closely related species. The table below lists updated re-collection intervals resulting from the most recent analysis completed during this reporting year.

### Recollection Interval Table

| Species | Previous Re-Collection Interval | Updated Re-Collection Interval | Length of Time Tested (Years) | Preferred Storage Conditions | Comments |
|---|---|---|---|---|---|
| *Abutilon sandwicense* | ≥10 | 10 | 11 | D20 | Viability decline detected at 11 years. Further testing is required as there is a lot of variability in testing results. |
| *Alectryon macrococcus* var. *macrococcus* | ----------- | ---------------- | ----------- | ------------- | Recalcitrant/desiccation intolerant seed. Does not store under conventional seed banking conditions |

**Recollection Interval Table (continued)**

| Species | Previous Re-Collection Interval | Updated Re-Collection Interval | Length of Time Tested (Years) | Preferred Storage Conditions | Comments |
|---|---|---|---|---|---|
| *Cenchrus agrimonioides* var. *agrimonioides* | ≥10 | ≥20 | 15 | D20 | |
| *Cyanea acuminata* | ≥5 | ≥15 | 10 | C20 | |
| *Cyanea grimesiana* ssp. *obatae* | ≥10 | ≥15 | 10 | C20 | |
| *Cyanea koolauensis* | 5 to 10 | 5 to 10 | 5 | C20 | |
| *Cyanea longiflora* | 10 | ≥15 | 10 | C20 | |
| *Cyanea superba* ssp. *superba* | ≥10 | ≥20 | 15 | C20 | |
| *Cyrtandra dentata* | 10 | ≥15 | 10 | D20 | |
| *Delissea waianaeensis* | ≥15 | ≥20 | 15 | C20 | |
| *Dubautia herbstobatae* | ≥15 | 15 | 15 | D20 | Viability decline detected at 15 year testing. |
| *Eugenia koolauensis* | ---------- | --------------- | ----------- | ------------- | Recalcitrant/desiccation intolerant seed. Does not store under conventional seed banking conditions |
| *Euphorbia celastroides* var. *kaenana* | ≥10 | ≥15 | 10 | D20 | |
| *Euphorbia herbstii* | 5 to 10 | ≥15 | 10 | D20 | |
| *Flueggea neowawraea* | 10 | 10 | 15 | D20 | Viability decline detected at 10 and 15 year testing. |
| *Gardenia mannii* | none | ≥5 | 1 | C20 | |
| *Gouania vitifolia* | ≥5 | ≥10 | 5 | D20 | |
| *Hesperomannia oahuensis* | none | none | | D20 | Difficult to obtain enough seeds for testing |
| *Hesperomannia swezeyi* | ≥5 | ≥10 | 7 | D20 | |
| *Hibiscus brackenridgei* subsp. *mokuleianus* | ≥10 | ≥15 | 12 | D20 | |
| *Kadua degeneri* var. *degeneri* | ≥5 | ≥15 | 10 | D20 | |
| *Kadua parvula* | ≥5 | ≥15 | 10 | D20 | |
| *Labordia cyrtandrae* | ≥5 | ≥10 | 7 | C20 | |
| *Melanthera tenuifolia* | ≥5 | ≥20 | 15 | D20 | |
| *Neraudia angulata* | ≥5 | ≥5 | 10 | | Viability decline detected at 10 year testing |
| *Nototrichium humile* | ≥10 | ≥15 | 10 | D20 | |
| *Phyllostegia hirsuta* | none | none | | | Difficult to obtain seeds for testing |
| *Phyllostegia kaalaensis* | none | 5 to 10 | 10 | C20 | Further testing required. Difficult to obtain seeds for testing |
| *Phyllostegia mollis* | ≥5 | 10 | 10 | D20 | Decline detected at 10 years. Further testing required |
| *Plantago princeps* var. *princeps* | ≥10 | ≥15 | 12 | D20 | |

**Recollection Interval Table (continued)**

| Species | Previous Re-Collection Interval | Updated Re-Collection Interval | Length of Time Tested (Years) | Preferred Storage Conditions | Comments |
|---|---|---|---|---|---|
| *Pritchardia kaalae* | ---------- | ------------- | ----------- | ------------ | Seems to be desiccation intolerant and freeze sensitive. Does not store under conventional seed bank conditions |
| *Sanicula mariversa* | 5 | ≥20 | 15 | D20 | |
| *Schiedea kaalae* | ≥5 | ≥20 | 15 | D20 | |
| *Schiedea nuttallii* | ≥5 | ≥20 | 15 | D20 | |
| *Schiedea obovata* | ≥10 | ≥20 | 15 | D20 | |
| *Schiedea trinervis* | ≥15 | ≥20 | 15 | D20 | |
| *Stenogyne kanehoana* | none | none | | | Difficult to obtain seeds for testing |
| *Tetramolopium filiforme* | ≥15 | ≥20 | 15 | D20 | |
| *Viola chamissoniana* ssp. *chamissoniana* | ≥15 | ≥20 | 15 | D20 | |

**D20= seed storage at -18°C; C20= seed storage at 5°C**

# Management Plan for *Achatinella mustelina* ESU-E Initial Release of Excess Laboratory Snails at the Ekahanui Temporary Enclosure and the Palikea North Enclosure

2018

Army Natural Resource Program – Oahu (OANRP)

# Contents

# I. Background and Purpose

Following documentation of population decline of *Achatinella mustelina* evolutionarily significant unit (ESU) 'E' (OANRP 2014), the U.S. Fish and Wildlife Service approved the Army Natural Resource Program - Oahu (OANRP) plans in 2015 to construct a permanent predator-proof enclosure at Palikea North to protect these snails in accordance with the U.S. Army's responsibility for rare snail stabilization. Construction of the Palikea North enclosure was completed and habitat restoration efforts began in 2017. Suitable levels of habitat restoration for a full release of all laboratory snails and translocation of any remaining wild ESU-E snails is not expected for a few more years.

In order to temporarily maintain all remaining ESU-E snails in a highly protected location pending completion of a larger permanent enclosure with restored habitat at Palikea, two small temporary enclosures were designed and built in 2016 to house these snails in Ekahanui. Unfortunately those enclosures were not successful given high mortality rates within less than one year of initial translocations (OANRP 2016). By nine months, there was 65% and 82% confirmed mortality of the original 42 snails at the sites, and no live snails were found. The cause of mortality remains unknown, but it is conjectured that it was possibly due to the lack of weathering of the construction materials, having insufficiently dense vegetation, and/or snails dying while crawling on the screen walls which do not allow snails to form an airtight seal during dry weather estivation.

Plans were subsequently made to maintain ESU-E *A. mustelina* at the new Snail Extinction Prevention Program (SEPP) laboratory after environmental chambers became available for these snails. As of September 2018, 185 snails were moved to the SEPP laboratory, where they have been reproducing at a rate projected to surpass the holding capacity of the incubators by the end of November 2018. At that time, approximately 100 snails must be released to accommodate the continually expanding laboratory population.

OANRP plans to release half of these excess snails at one of the Ekahanui temporary enclosures (the second temporary enclosure was removed), and the other half at the Palikea North enclosure (FIG. 1). The Ekahanui temporary enclosure is now considered a feasible release site as it has weathered for over two years, the vegetation has become denser (FIG. 2), and modifications are planned to create a network of solid substrate to provide more pathways for snail movement on which snails may estivate. Though vegetation cover is currently low throughout the Palikea North enclosure, there are clusters of dense vegetation containing the snail host plant *Freycinetia arborea* deemed feasible for release (FIG. 3). Shade cloth and sprinkler systems are planned for use at both sites to enhance shade and moisture levels.

Releasing snails in two separate locations will allow for a comparison of success from which subsequent decisions regarding the release of future excess snails can be made. While neither of the release sites are optimal, they were determined to be the best among alternate options discussed during the 2018 Implementation Team meeting and in consultation with SEPP. Returning snails to their original wild sites was considered inappropriate, as they cannot be adequately protected from predators. Building a new temporary enclosure in appropriate habitat outside the enclosure at Palikea was deemed too risky, as it could potentially repeat the same problems initially encountered with the temporary enclosures at Ekahanui. Transferring snails to a laboratory at the Honolulu Zoo was not considered, as appropriate facilities to maintain snails will not be available for another year. Remaining ESU-E *A. mustelina* at the wild sites will not be moved into the enclosures at this time.

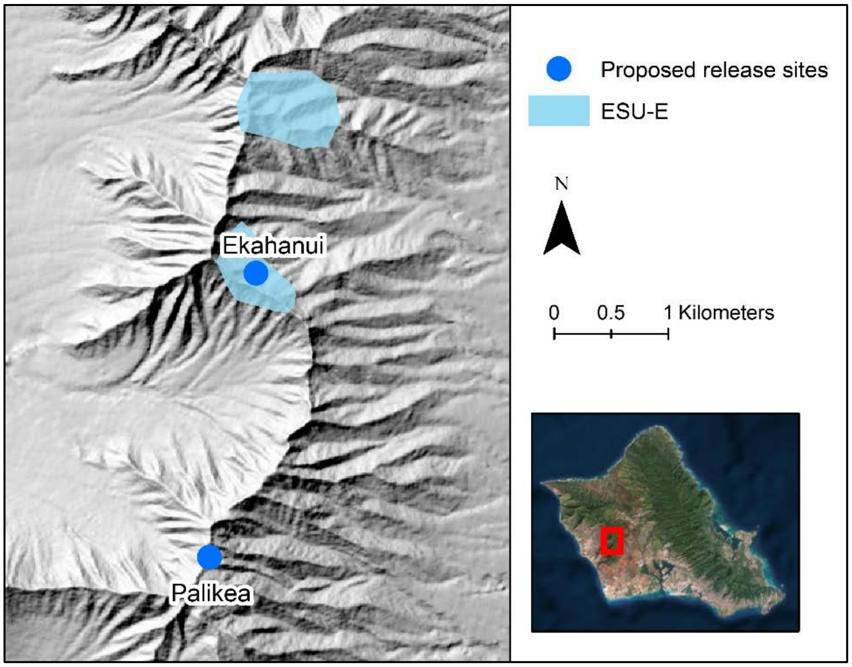



**Figure 1.** Location of the Ekahanui temporary enclosure and the Palikea North enclosure in relation to the ESU-E population areas.

**Figure 2.** Vegetation inside the Ekahanui temporary enclosure, July 2018

**Figure 3.** View of one of the more dense clusters of vegetation, proposed for the initial release of snails at the Palikea North enclosure, September 2018.

The purpose of this management plan is:

1) To outline and guide the management and maintenance of the release sites.

2) To guide the release and monitoring of *A. mustelina* at the enclosures.

3) To guide the evaluation of success and planning for next steps.

The management actions proposed in this plan were generated from the standpoint of providing the overflow laboratory snails with the best possible opportunities for success among non-ideal options. Data derived from monitoring used in association with the planned evaluation process will guide the decision-making process for the release of future excess laboratory snails. It will also provide a second opportunity to assess the utility of temporary enclosures, and may help guide the evaluation of small-scale habitat readiness within the Palikea North enclosure.

# II. Enclosure Structures

## A. Design

### 1. Ekahanui Temporary Enclosure

The enclosure encompasses ca. 24 $m^2$ and is ~5 m by 5 m and 3m tall, framed with untreated lumber, fully screened on all sides and the top with polyester-coated galvanized steel mesh, and has a wood-framed mesh door on the downslope wall (FIG. 4). The mesh excludes predators *Euglandina rosea*, rodents, and *Trioceros jacksonii xantholophus* (Jackson's chameleon). The enclosure will be examined to ensure that the integrity of the bottom is intact. Structural connectivity between vegetation will be mounted via a network of cut *Psidium cattleianum* branches to promote movement on substrate other than the wall mesh.

**Figure 4.** Photograph of the temporary enclosure structure at Ekahanui, July 2018

### 2. Palikea North Enclosure

The Palikea North enclosure measures ca. 2500 $m^2$ and was designed similar to that of the Hapapa enclosure (Rohrer et al. 2016), but with a few modifications. The wall structure consists of 4"x4" reinforced plastic posts in concrete footings with a 2"x12" baseboard installed 5" below ground level and a 2"x6" top board measuring at a height of 60" for the frame (FIG. 5). A high-density polyethylene (HDPE) geomembrane sheet creates the wall barrier. The rat hood is attached at the top edge of the HDPE geomembrane and has a minimum 6" diameter. To prevent incursion from the bottom of the fence and erosion control, the HDPE geomembrane extends from the wall by a foot, lies on the ground and is held down by the Geoweb® geocells filled with gravel. Similar to the Hapapa enclosure, the *E. rosea* barriers consist of an angle barrier, cut mesh and electrical wires. The angle barrier is attached to the wall with a minimum of 8" above the ground from the bottom edge to allow ease of checking under the angle. The cut mesh attaches just above the angle and the electrical barrier is added to a 2" x 1.5" board just below the hood.

**Figure 5.** Palikea North enclosure design: wall frame inside of enclosure (left), and outside wall with *E. rosea* barrier, rat hood, and erosion control (right).

The release site within the enclosure measures ca. 32 $m^2$ will be additionally surrounded by a plywood wall approximately 18" tall and buried 6" below ground level, with an electric barrier along the inside of the wall to prevent *A. mustelina* from leaving the area. The electronic barrier will be of a similar design as the main enclosure wall. The electronics will deter snails from crossing the barrier, but will not harm them. The purpose of the supplemental wall is to prevent snails from traversing into areas of sparse vegetation where they may encounter environmental stress, and to facilitate monitoring of survival and mortality within a confined area. Materials are already on site and weathering; the wall will be constructed in the month prior to the release.

## B. Enclosure Structure Monitoring and Maintenance

Both release sites will be visually monitored at least on a monthly basis to ensure the integrity of the barriers remain intact. The A game camera will be installed outside the Ekahanui temporary enclosure programmed to email photographs of the structure three times per day to facilitate a timely maintenance response in the event that a tree fall or rock fall damages the enclosure. Intelesense Technologies provides a comprehensive integrated monitoring service for the Palikea North enclosure, wherein staff will receive email alerts in the event of conductivity failure of the electronic barrier.

## C. Habitat

### 1. Ekahanui Temporary Enclosure

An area containing native vegetation including snail host species was chosen for the site of the Ekahanui temporary enclosure. Plant species present are predominately *Pisonia umbellifera*, *Planchonella sandwicensis*, and *Pipturus albidus*. Outplanted *Chrysodracon forbesii* are also present. While vegetation was fairly sparse following the initial construction, it has since filled in more and started to grow through the mesh ceiling. Any vegetation growth that threatens to compromise the integrity of the enclosure will be trimmed to prevent damage to the structure. Supplementation with native outplants is not planned as the enclosure is sufficiently vegetated. The enclosure receives partial shade from the surrounding trees and has a steep northeast aspect.

## 2. Palikea North Enclosure

The enclosure currently contains diverse, sparse native vegetation, including trees, shrubs and ferns present prior to clearing and construction, as well as over two thousand outplants, transplants, and progeny from seed sowing and natural recruitment that are somewhat evenly distributed throughout the enclosure. However, because the snails will be released into a dense cluster of vegetation enclosed by an electronic barrier, discussion of the habitat will be specific to that area. The release site measures approximately 8m by 5m, and is dominated by native vegetation, primarily *F. arborea*, *Coprosma longifolia*, *Kadua affinis*, *Metrosideros polymorpha*, *Cibotium chamissoi*, *Nephrolepis exaltata* subsp. *hawaiiensis*, *P. albidus*, and *Bidens torta*. Vegetation height is approximately 1-2 m above ground level in most areas, with small trees as tall as 4 m. Following the clearing of non-native vegetation and the initiation of vegetation restoration efforts, native vegetation has increased and is expected to continue to expand in the release site (as well as throughout the enclosure) (FIG. 6). As restoration efforts are ongoing for the enclosure, additional outplants may be incorporated to enhance vegetative cover and connectivity within the release site. Species planned for outplanting in the fall of 2018 include *Scaevola gaudichaudiana*, *C. longifolia*, *Clermontia oblongifolia*, *Ilex anomala*, *P. albidus*, and *Labordia kaalae*, any of which may be used at the release site as needed. Seed sows are also planned for *P. albidus* and *B. torta*.

**Figure 6.** Photographs of the proposed release area in September 2017 (left) and in July 2018 (right), showing the expansion of native vegetation over 10 months from natural regeneration and outplantings. The circled area shows the approximate location of the planned barrier wall.

Shade will be provided by a shade cloth, and an automatic sprinkler system will be installed to provide supplemental moisture. Weed maintenance will occur as needed to control primarily for invasion of the fast-growing colonizer *Phytolacca octandra* that has been recruiting throughout the enclosure as well as the invasive grasses *Paspalum conjugatum* and *Ehrharta stipoides*. These weeds are easily hand-pulled when small, and will not require the use of herbicide.

The enclosure is free of rodents, following the installation of six Victor® rat snap traps, one Victor® mouse snap trap, and five Goodnature® A24 self-resetting rat traps which eliminated the small resident population within the enclosure once construction of the walls and barriers was completed. Four tracking tunnels have been used to confirm the absence of rodent activity. The enclosure is also devoid of non-native snails and slugs, as the area has been repeatedly and systematically searched for *E. rosea* in accordance with the protocol set forth in the OANRP restoration plan (OANRP 2017), and as the area has been treated with molluscicide (Ferroxx®). No *E. rosea* have been found in over a year. Mollusclde applications ceased in October 2017, and any residual material should no longer be harmful to *A. mustelina* by the time of their release, as it is ineffective after six weeks.

## D. Predator Control and Monitoring

### 1. Rodents

In addition to the existing grid of A24 rat traps located throughout Ekahanui MU, two additional A24s will be installed outside the enclosure, and two Victor® rat snap traps will be maintained along the base of the wall inside the Ekahanui enclosure. A rodent tracking tunnel will also be placed within the enclosure to detect rat presence. The snap traps and tracking tunnel will remain unbaited to avoid attracting rodents from the outside.

The Palikea North enclosure lies within a large scale rat grid of A24 traps that span the Palikea management unit that suppresses rodent populations. The enclosure wall and hood prevent ingress by rats. A vegetation-free buffer of 2 m along the inside and outside wall of the enclosure will help keep vegetation growing on the inside from hanging out, and vegetation on the outside from allowing a rat to jump and reach a branch to get inside. As a precaution in the event of ingress, e.g., as a result of a tree fall that compromises the wall barrier, the A24 traps and tracking tunnels noted above will continue to be utilized and maintained quarterly to ensure the safety of *A. mustelina*. The A24 traps will be baited with a Goodnature® long-life chocolate rat lure and fitted with an automatic lure pump that steadily delivers fresh bait and prevents the growth of mold within the bait canisters.

### 2. *Euglandina rosea*

Though numerous searches for *E. rosea* were conducted at the Ekahanui enclosure in association with the previous attempt to maintain *A. mustelina* at this site, no searches have been conducted since 2016. For this reason, the enclosure will be systematically surveyed three times by a team of two personnel for one hour during the day prior to the snail release. Three levels of *E. rosea* control will be utilized to maintain/achieve eradication within the enclosure. High removal effort (if *E. rosea* are found): 2 staff search for 1 hour 1 day a week for 4 weeks. Medium removal effort (following completion of high removal effort and no additional *E. rosea* are found): 2 staff search for 1 hour 1 day every 2 weeks for 4 weeks. Low removal effort (following completion of medium removal effort and no additional *E. rosea* are found): 2 staff search for 1 hour 1 day every month.

As no *E. rosea* have been found in over one year at the Palikea North enclosure, staff will continue to follow the protocol set forth in the restoration plan (OANRP 2017), with three staff dedicating a minimum of 14 staff hours one day quarterly, thoroughly covering the entire enclosure and searching all vegetation, including the release area. Staff also monitor the angle barrier at least quarterly and remove any *E. rosea* found within it (FIG. 7).

**Figure 7.** Monitoring of the angle barrier at Hapapa snail enclosure. The angle barrier at Palikea North enclosure is similarly monitored with the use of a mirror to view *E. rosea* trapped within it.

### 3. Jackson's Chameleon

One Jackson's Chameleon had been found in the Ekahanui area previously, and the level of threat is unknown. As the enclosure is completely enclosed by mesh along the walls and top, breaches are not anticipated, though during searches for *E. rosea*, staff will also search for chameleons.

Jackson's Chameleons are also known to be present in the area surrounding the Palikea North enclosure, as two have been seen within close proximity to the enclosure in recent years. The level of threat at this location is also unknown. During the clearing of non-native vegetation prior to the enclosure construction, no chameleons were found. Similarly, during *E. rosea* searches following construction completion, staff were also searching for Jackson's, and none were found. Staff will continue to monitor for the presence of Jackson's Chameleons during the quarterly *E. rosea* searches, including the release area. If any chameleons are found in the enclosure, OANRP will develop a removal protocol.

## E. Environmental Monitoring

Environmental conditions at the release sites should not include extended periods of extreme heat (> 90°F) or low relative humidity (< 60%). Data loggers (HOBO® Pro v2 U23-001) with solar radiation shields (HOBO® RS1) will be installed at each release site to record hourly temperature and relative humidity. Data will be offloaded monthly to monitor environmental conditions at each site.

# III. *Achatinella mustelina* Reintroduction and Monitoring Plan

## A. Phase 1: Pre-release

Because mortality was not confirmed for 35% of the *A. mustelina* previously released in the Ekahanui temporary enclosure, thorough searches of the enclosure will be conducted prior to release of laboratory snails. The enclosure will be systematically surveyed by a team of two personnel for one hour on two separate dates at least two weeks apart and with at least one intervening episode of rainy weather between surveys. At least one of these surveys will take place at night, when snails area more easily detected. The purpose of conducting a second search following rainy weather is to increase the likelihood of finding any snails that may be out of view during the first survey, and which may remain in estivation in the same out-of-view location if the weather remains dry between monitoring dates. If live snails are found, they will be photographed for identification purposes, and may remain within the enclosure. Ground shell searches of the entirety of the enclosure will also be conducted on the same dates as the live snail searches, and any shells found will be similarly photographed for identification. All shells found will be removed from the enclosure. This may be done simultaneously with *E. rosea* searches.

The Palikea North enclosure was repeatedly searched for the presence of ESU-F *A. mustelina* (OANRP 2017) prior to construction, and all discovered snails were moved into the ESU-F enclosure at Palikea South. Staff continued to search for any possible missed *A. mustelina* during the numerous intensive *E. rosea* searches, and none were found. Additional searches for ESU-F *A. mustelina* are not necessary, however the ground should be cleared of shells prior to release in preparation for documenting mortality of released ESU-E snails.

Only sub-adult snails (> 8 mm) will be selected for release, as they may be more likely than smaller snails to survive the stresses of release from the laboratory into the wild. Smaller snails in wild populations are also documented as having lower rates of survival than larger ones (Hadfield et al. 1993). Snails released from the laboratory will include a combination of some born in the lab as well as some captive snails originally collected from wild populations. Adult snails (>18 mm), all of which derive from wild populations, will be maintained in the laboratory to better ensure survival of reproductive individuals, and to safeguard genetic diversity in the lab and for future populations. Snail survivorship (for all size classes) in the laboratory is generally considerably higher than that in the wild. All snails selected for release will be photographed (including both side views) and assigned a unique identification, to be maintained in a HotSpotter© photo-identification database. This will allow staff to track individual snails over time using the HotSpotter© algorithm for matching unique individuals based on shell patterns (Stewart et al. 2013) (FIG. 8), and to estimate population totals following their release. Staff will also collect vegetation from the release sites for use in the incubators in the weeks leading up to their release, to acclimate snails to the enclosure microfauna.

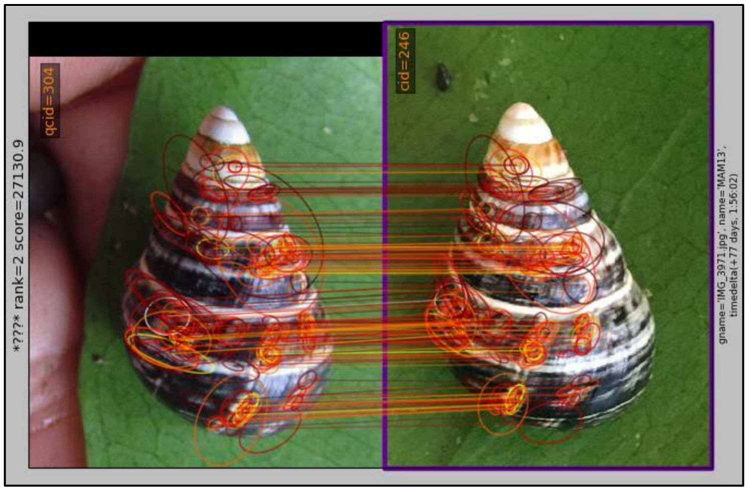



**Figure 8.** Example of an *A. mustelina* individual identified from an image in a HotSpotter© database based on matching "hotspots" on the shell surface.

## B. Phase 2: Release

The snail release will occur upon laboratory populations reaching maximum capacity, projected to occur by the end of November 2018 at the start of the rainy season. In early December 2018, 50 sub-adult snails will be randomly selected for each of the release sites. Snails will be transported in adequately ventilated portable terraria containing live vegetation from their incubators. At Ekahanui, snails will be placed in small screened baskets containing vegetation from the terraria and hung in host trees (FIG. 9). The baskets will be open at the top to allow the snails to gradually exit into the vegetation. In order to facilitate the movement of snails from these containers into host plants, small branches will be placed in the baskets to create a bridge between the basket and host plant, and squirt bottles will be used to wet the container and vegetation as needed. The snails will be subsequently observed to ensure successful movement out of the baskets and onto the host plants. At Palikea, snails will be placed directly within *F. arborea*. The releases will occur during relatively cool, humid conditions to reduce heat stress.

**Figure 9.** Example of a screen basket used for *A. mustelina* released at the Hapapa snail enclosure. Similar baskets will be used for the initial release of ESU-E snails at the Ekahanui temporary enclosure.

### C. Phase 3: Monitoring

To quantify population trends and assess if the released snail populations are self-sustaining over time, a timed-count monitoring (TCM). During TCM, both sites will be systematically surveyed by a team of two personnel for one hour per site during the day, with the total number of observed snails documented. The location of each snail identified will be communicated between the surveyors to minimize double counting. To ensure consistency between survey periods, a minimum of one personnel with previous experience conducting timed-count monitoring will be present.

To estimate population size and track the fate of individual snails, capture-mark-recapture (CMR) monitoring will be jointly conducted during the course of TCM. HotSpotter© photo identification software will be used to track individuals. Photographs will be taken of all snails within reach. Time utilized for this monitoring will not be included within the time allotted for timed-count monitoring. Population size estimates will be obtained using closed system models in the program MARK. Use of this method in a closed system with a known initial population size will help assess the utility of the HotSpotter© technology as well as population size modeling for *A. mustelina*. Each site will have unique issues factoring into the likelihood of detection. It is anticipated that most snails found at the Palikea North enclosure will be reachable for photography due to the predominantly low staure of the vegetation, however many will likely remain undetected due to the dense structure of the vegetation, particularly deep within the *F. arborea*. While relatively more snails may be detected at the Ekahanui enclosure, many will be too high to photograph with appropriate detail for identification. As a result, CMR sampling will consist of a subset of the population at both sites, but it should nonetheless allow for population modelling if snails are actively moving around in the vegetation.

Mortality will be documented by collecting shells from the ground. Ground shell plot (GSP) monitoring will be done at each site by searching for snails on the ground across the entire enclosure/release area. Each shell will be examined to ensure that it does not contain a live snail. All shells will be removed, documented by size class, photographed for use with HotSpotter© photo identification software, and retained in an open container inside the enclosure to mitigate erroneous mortality observations.

Monitoring will occur weekly for two weeks following the release to determine if there are any immediate catastrophic die-offs associated with the release. If mortality rates are not problematic, the monitoring frequency will then proceed to every two weeks for the next six weeks to determine if there are major die-offs as a delayed response to the release or some other cause. Barring unsatisfactory mortality rates by eight weeks, the monitoring interval will then proceed to monthly for the next two months, after which success will be evaluated and next steps will be determined.

## IV. Evaluation of Success and Next Steps

Upon completion of the monitoring described above, approximately four months following the initial release, laboratory snail populations are projected to approach maximum capacity again, and decisions must be made regarding plans for the next ca. 100 snails that will need to be released at that time. In order to make decisions regarding the next steps for release of additional excess lab snails, the relative success of each site must be evaluated.

Annual survivorship ranging from 21% to 57% has been documented for wild populations of *A. mustelina* at various sites and times for various size classes and combinations of size classes, with larger snails tending to have greater survivorship rates than smaller ones (Hadfield et al. 1993, Hall et al. 2010). In a study of a growing population of *A. mustelina* at Pahole that was not undergoing apparent predation, estimated annual survivorship of snails most comparable to the subadult size class intended for the release at the Ekahanui and Palikea enclosures was 31%. As such, if the released snails follow this trend, they may reasonably have a mortality rate of around 6.3 per month, and ≥ 81% survival at four months may be considered to be highly successful.

Because of the exceptionally low mortality rates typically occurring in the laboratory, snails with low fitness may be surviving under laboratory conditions that would otherwise suffer mortality in the wild where they would suffer greater environmental stress. It is anticipated that many snails of low fitness may not survive, resulting in higher mortality rates, particularly in the early weeks post-release.

Snails previously translocated from wild populations to the Ekahanui enclosure had between 20% to 40% survivorship by four months. Survival rates of released lab snails above this rate will be considered moderately successful relative to that of the translocated wild snails. However, survival at or below this rate may present a cause for concern, and will be considered to be low and insufficiently successful.

A die-off of the vast majority of snails, where ≤ 10% of released snails survive by four months will be considered very low success and unsatisfactory. A total loss of all snails by that time would be considered a failure.

In summary, the ranking of survival rates are:

| Survival rate (%) | Success rank |
|---|---|
| 81-100 | High |
| 41-80 | Moderate |
| 11-40 | Low |
| 1-10 | Very low |
| 0 | Failure |

Decisions regarding the next release of excess laboratory snails will take into account the success rankings outlined above in association with survival rates. In the event that both release sites are deemed to have acceptable survival rates, the next set of snails will be added to both sites. Should one site have acceptable survival but the other does not, the snails will only be added to the site with acceptable survival. If both sites have unacceptable survival rates, considerations will be made for whether or not to release additional snails at these sites, or if an alternate release plan will have to be developed. If both sites completely fail by four months, alternate plans may have to be made.

Though presently considered inappropriate or too risky as discussed above, alternate plans in the event of total failure after four months could include 1) returning snails to their original wild sites, 2) building a new temporary enclosure in appropriate habitat outside the enclosure at Palikea, or 3) moving snails to the Honolulu Zoo if appropriate facilities to maintain them become available before conditions in the SEPP laboratory become too crowded.

The next release should be timed such that it happens prior to the start of the hot and dry season, preferably in early April, to avoid undue environmental stress as laboratory snails transition to the outdoors. For this reason, decisions regarding the release must be made in a timely manner. It should also include sufficient numbers of snails such that the laboratory population does not reach maximum capacity prior to the start of the next rainy season.

# V. Timeline

The following timeline conveys the planned management events through March 2019. The timeline events beginning in April 2019 are approximated premised on a best case scenario for success at both release sites, to be determined in March 2019, and re-assessed thereafter as deemed necessary.

**Table 1.** Timeline of planned (though March 2019) and approximated (beginning in April 2019) management events associated with the release of ESU-E *A. mustelina* snails from the laboratory.

| Event | Month | Year |
|---|---|---|
| Plywood on site to allow for weathering | Aug | 2018 |
| 3 *E. rosea* searches at Ekahanui (2 day, one night) | Jul-Nov | |
| Examination of Ekahanui enclosure integrity | Oct | |
| Outplant and/or seed sow at Palikea | Nov | |
| Installation of plywood wall with electronics at release site in Palikea | mid-Nov | |
| Installation of cut *P. cattleianum* branch structural network at Ekahanui | mid-Nov | |
| Collect vegetation for laboratory snails from enclosures | mid-Nov | |
| Install shade cloth and sprinkler systems at both sites | mid-Nov | |
| Photograph snails in lab prior to release | mid-Nov | |
| 1st release: 50 subadult snails at each site | early Dec | |
| Monitor snails weekly for 2 weeks at each site (TCM, GSP, CMR) | Dec | |
| Monitor snails every 2 weeks for six weeks at each site (TCM, GSP, CMR) | Dec-Jan | |
| Monitor snails monthly for 2 months (TCM, GSP, CMR) | Feb-Mar | 2019 |
| Evaluate success and determine next steps | late Mar | |
| 2nd release: est. 50 snails at each site | early Apr | |
| Monitor snails weekly for 2 weeks at each site (TCM, GSP, CMR) | Apr | |
| Monitor snails every 2 weeks for six weeks at each site (TCM, GSP, CMR) | Apr-May | |
| Monitor snails monthly for 5 months (TCM, GSP, CMR) | Jun-Oct | |
| 3rd release: est. 50 snails at each site | Nov | |
| Monitoring begins on a quarterly basis (TCM, GSP, CMR) | Nov | |
| 4th release: est. 50 snails at each site | Mar | 2020 |
| 5th release: release all remaining captive snails at Palikea | Nov | |
| Translocate Ekahanui temporary enclosure snails to Palikea | Nov | |
| Translocate any remaining wild ESU-E snails to Palikea | Nov | |
| Translocate any remaining wild ESU-E snails to Palikea | Jan | 2021 |
| Translocate any remaining wild ESU-E snails to Palikea | Mar | |

# VI. References Cited

Hadfield, M. G., Miller, S. E., & Carwile, A. H. 1993. The decimation of endemic Hawaiian tree snails by alien predators. American Zoologist 33: 610-622.

Hall, K. T., Baker, M. B., & Hadfield, M. G. 2010. Using dispersal rates to guide translocation across impermeable wildlife reserve boundaries: Hawaiian tree snails as a practical example. Malacologia 52: 67-80.

OANRP. 2016. Chapter 5: *Achatinella mustelina* management *in* Status Report for the Makua and Oahu Implementation Plans. https://www.pcsuhawaii.org/projects/oanrp/reports/2016/07.pdf.

OANRP. 2017. Appendix 5-5: Palikea North Enclosure Restoration Plan *in* Status Report for the Makua and Oahu Implementation Plans. https://pcsuhawaii.org/projects/oanrp/reports/2017/A5-5.pdf.

Rohrer, J., Costello, V., Tanino, J., Bialic-Murphy, L., Akamine, M., Sprague, J., Joe, S., & Smith, C. 2016. Development of tree snail protection enclosures: from design to implementation. PCSU technical report #194. https://scholarspace.manoa.hawaii.edu/bitstream/10125/40823/1/v194.pdf.

Stewart, S. V., Sundaresan, S. R., Berger-Wolf, T. Y., Rubenstein, D. I., & Crall, J.P. 2013. HotSpotter – Patterned species instance recognition. Proceedings of the 2013 IEEE Workshop on Applications of Computer Vision (WACV). 230-237.

# 3-Points Enclosure Restoration Plan

**Goals of Restoration:**

- Restore vegetation in the enclosure to 75-100% native canopy with a continuous mid-story in 5 years or less.
- Restore a diverse range of known host plants for *Achatinella mustelina*.

**Measures of Vegetation Rehabilitation Success:**

- Increasing native understory and canopy as measured by annual vegetation monitoring.
- Increasing native cover as visually represented by UAS imagery and photopoints
- *A. mustelina* utilizing canopy and understory vegetation after release with low mortality rates as measured by ground shell plots.
- Stable or increasing *A. mustelina* population as measured by quarterly timed-count monitoring

**Restoration Approaches and Site Considerations:**

- ***All gear, plants, and vegetation going into the enclosure should be thoroughly inspected for Euglandina rosea and slugs.***

***Predator removal:***

Rats

The enclosure area currently exists within the West Makaleha rat grid. After the hood is secured to the new enclosure wall, rat removal will begin inside. Four A24s and four tracking tunnels will be utilized to ensure the safety of the *A. mustelina*. These tools will be monitored every four months. A vegetation-free buffer of 2m along the inside and outside wall of the enclosure will help keep vegetation growing on the inside from hanging out and vegetation on the outside from allowing a rat to jump and reach a branch to get inside.

*Euglandina rosea*

*Euglandina rosea* can be very cryptic and hard to find. Therefore, the ground must be raked and swept with a leaf blower to remove any leaves, twigs, or branches. All grass and *Dicranopteris linearis* (uluhe) will be removed to facilitate searching for *E. rosea*. After the fence wall is complete and *E. rosea* barriers in place and functional, *E. rosea* sweeps inside will be initiated.

The *E. rosea* removal effort will occur during the day when they are easier to find and will consist of ground sweeps, understory search, and canopy survey with binoculars. The search hours are divided up as follows: 9 person hours performing a ground sweep in areas of minimal vegetation, three person hours spent searching understory vegetation, and two person hours searching the canopy with binoculars. The removal effort is set at different levels based on the degree of risk as described below. Each level is to be triggered under varied conditions outlined in a flow chart below. This effort will be time consuming considering the native vegetation and large trees in the enclosure.

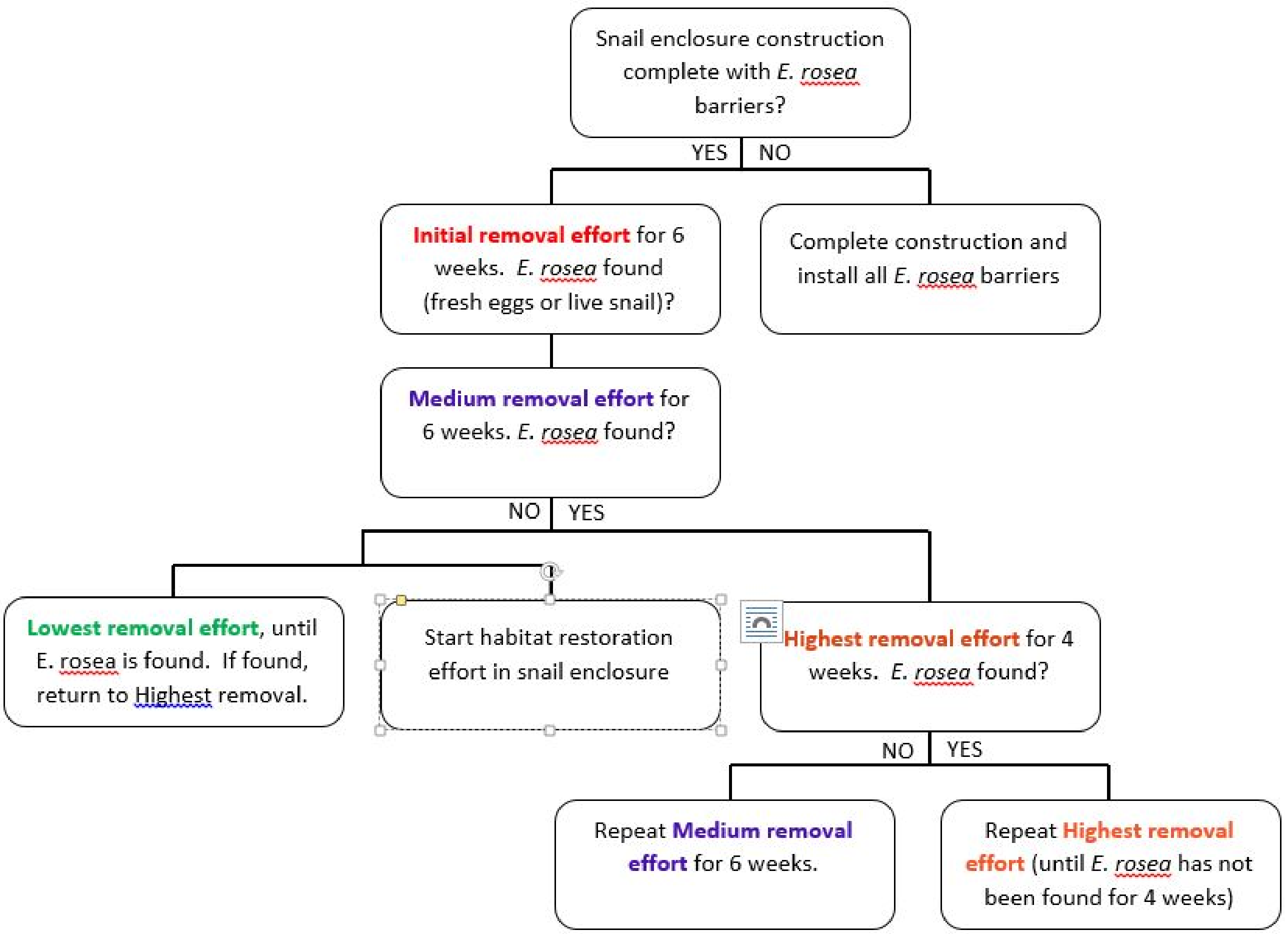
If *E. rosea* persist within the enclosure after three months of searching, the enclosure will be subdivided by installing a short wall with electrical barrier to section off the enclosure. Each section would then follow the flow chart independently.

**Initial removal effort = Unknown risk of *E. rosea* in enclosure:** Three staff spend one day a week at minimum 14 person hours per day for 6 weeks. This would total to a minimum 90 hours for the first month and a half.

**Highest removal effort = severe risk of *E. rosea* in enclosure:** 3 staff spend one day a week at 14 minimum hours per day for 4 weeks. This would total to a minimum 60 hours for the month.

**Medium removal effort = some risk of *E. rosea* in enclosure**: 3 staff spend one day every other week at 14 minimum hours per day for 6 weeks. This would total to a minimum 45 hours for the month and a half.

**Lowest removal effort = low risk of *E. rosea* in enclosure:** 3 staff dedicate a minimum of 14 staff hours one day every 3 months to search interior.




Initial removal effort requires six consecutive weeks of searching and removing *E. rosea* from within the snail enclosure. After the initial removal effort, medium removal effort takes place. If *E. rosea* are discovered at any point in the surveys the highest level of removal is triggered for four weeks. Four consecutive weeks of high level effort must be completed without finding any *E. rosea* before effort shifts to the medium level and subsequently low if nothing is found. Thus if *E. rosea* is found in the fourth week of high level effort, another four weeks of high level are initiated. Time required to complete sweeps may change over time as the enclosure becomes increasingly vegetated through restoration efforts.

### *Trioceros jacksonii* ssp. *xantholophus* (Jackson's Chameleons)

No Jackson's chameleons have ever been recorded from the area but during *E. rosea* searches, staff will also be looking for Jackson's chameleons and removing them. If any chameleons are discovered the Army natural resource program on Oahu (OANRP) will develop removal protocols.

### Slugs

It would be ideal to remove slugs from within the snail enclosure prior to any habitat restoration efforts, especially seed sowing, with the use of Ferroxx. To ensure non-targets are not harmed, the following protocol will be conducted as outlined below:

- A minimum of three night snail surveys will be conducted to encompass the area of proposed Ferroxx use (snail enclosure) using ladders and climbing trees when possible
- If snails are found, they will be temporarily moved to LEH-C or LEH-D and a subsequent survey must be performed on another night until no snails are found during a night survey
- Ferroxx is active for six weeks so no snails we be moved back into enclosure within three months of last application

### Weeding**:**

Prior to clearing in preparation for snail enclosure construction, parts of the enclosure area were dominated by a dense groundcover of uluhe (*D. linearis*), blackberry (*Rubus argutus*), and koster's curse (*Clidemia hirta*), and a canopy of *Metrosideros polymorpha*. Between 2001 and 2017, weeding was conducted in this part of the 3-Points area, and focused on trail and fence maintenance, alien grass control, improving rare taxa habitat, and some general understory clearing. Part of this area was open, and included large patches of invasive grasses and *R. argutus*. In December 2015, December 2016, and March 2017, common native were outplanted in the area, and weeds were controlled around these plantings. Species planted include *Antidesma platyphyllum, Clermontia kakeana, Clermontia persicifolia, Coprosma longifolia, Metrosideros polymorpha*, and *Perrotetia sandwicensis*.

Vegetation clearing for the snail enclosure began in January 2018. Efforts focused on removing all alien understory, clearing *D. linearis*, removing *Psidium cattleianum* canopy, and trimming native trees as needed to open up the enclosure corridor. The total area within the snail enclosure is approximately 1,280m². Open areas are quickly colonized by sun-loving alien plants, particularly grasses, asters, and *R. argutus*. The primary goal of weed control is to maintain a low cover of weeds across the entire snail enclosure, and improve habitat for *A. mustelina*. Restoration is planned, and regular sweeps will be necessary to maintain low weed cover.

Alien plants in snail enclosure site before and after clearing:

| Species | Growth Form | Species | Growth Form |
|---|---|---|---|
| *Ageratina riparia* | Shrub | *Ageratum conyzoides* | Shrub |
| *Blechnum appendiculatum* | Fern | *Buddleja asiatica* | Shrub |
| *Clidemia hirta* | Shrub | *Cuphea carthagenesis* | Shrub |
| *Cyclosorus parasiticus* | Fern | *Erechtites valerianifolia* | Herb |
| *Melinus minutifolia* | Grass | *Nephrolepis brownii* | Fern |
| *Paspalum conjugatum* | Grass | *Passiflora suberosa* | Vine |
| *Psidium cattleianum* | Tree | *Rubus argutus* | Herb |
| *Rubus rosifolis* | Herb | *Stachytarpheta* spp. | Shrub |
| *Sporobolus indicus* | Grass | *Youngia japonica* | Herb |

- Zero tolerance: *Blechnum appendiculatum*, *Nephrolepis brownii*, *R. argutus*, alien grasses

As of September 2018, construction of the snail enclosure is approaching completion, but weeds have not been fully removed from its interior. Treatment should focus first on controlling all weeds within the enclosure, as this will facilitate predator removal efforts. This effort will be led by the Snail Technician, in conjunction with the Orange Team. Other teams, Foundation staff, and volunteers should be tapped to assist with this project, as it requires a lot of effort. Sweeps should target all weeds, particularly those listed as ‘zero tolerance’ and any alien grasses. Of particular concern is *R. argutus*, which is difficult to control. Traditional ‘clip & drip’ treatment using Garlon 4 Ultra, 20% dilution is ineffective on *R. argutus*. Instead, staff should experiment with the following: clip & drip with cocktail of 20% Garlon 4 + 1% Milestone + biodiesel; foliar spray of 5% Milestone in water; and manual removal via digging out roots. For the foliar spray treatment, *R. argutus* canes can be clipped and allowed to resprout before spraying to minimize non-target impact.

Once the enclosure is built, weed control actions are scheduled separately for work done inside and outside of the enclosure, see table below. Within the enclosure, quarterly sweeps will be continued, and control of zero tolerance species prioritized. Care should be taken when working around restoration plantings and seed sows to avoid trampling these zones. To minimize non-target impact around restoration sites, Garlon will not be applied foliarly to weeds via sprayers with nozzles; only standard applicator bottles will be used to apply Garlon to basal stems or cut stumps. Staff must take care to avoid non-target impacts when spraying any herbicides for any weed targets, as inconspicuous native seedlings may be present, and restoring native understory is critical in creating *A. mustelina* habitat. Weed cover should remain below 10%. Outside of the enclosure, weed sweeps should be conducted twice a year, and should focus on keeping zero tolerance weeds levels low and promoting native cover to improve abiotic conditions. Grasses and other weeds should be removed from the area of the crossover to minimize the potential for staff to disperse them within the enclosure. A brush will be installed outside the enclosure near the cross-over so that staff can clean boots prior to entering the enclosure and prevent accidental transport of weeds into the enclosure. In addition, trees need to be removed or trimmed at least six feet away from the enclosure wall to ensure they do not present a jump risk for rats and Jackson’s chameleons.

Weed Control Actions:

| Action ID | Field Team | Category Code | WCA Code | Location | Team Action Comments | Update |
|---|---|---|---|---|---|---|
| 7673 | Foundation | W/ Weed Control | West Makaleha-02 | 3 Points Snail Jail | Snail Enclosure: clear site of weeds in preparation for construction of snail enclosure. Treat understory herbs, spray alien grasses and ferns. Focus in particular on RubArg. | Clearing complete. Conduct follow-up till enclosure pau. |
| 7674 | Foundation | W/ Weed Control | West Makaleha-02 | 3 Points Snail Jail | Snail Enclosure: Maintain weeds within snail enclosure. Sweep entire enclosure quarterly to twice a year; treat all weeds. Focus on RubArg, vines, woody weed keiki, and ferns. Zero tolerance inside enclosure for alien ferns and RubArg. | Enclosure scheduled for completion in September. |
| 7831 | Foundation | W/ Weed Control | West Makaleha-02 | 3 Points Snail Jail | Snail Enclosure: Control grasses within snail enclosure, quarterly, or as needed. Zero tolerance for alien grasses inside enclosure. | |
| 6270 | Orange | W/ Weed Control | West Makaleha-02 | Outside 3 Points Snail Jail | Upper fence, around snail jail, and from ridge to top of Cyagri cliffs: sweep this area every 6 months/year. Target all weeds, esp. Budasi, Rubarg, Clihir, Psicat. Assist Outreach with gradual removal of Psicat. | Enclosure scheduled for completion in September. |
| 4941 | Orange | W/ Weed Control | West Makaleha-02 | Outside 3 Points Snail Jail | Control weedy grasses across exclosure, focusing on upper half and around snail enclosure, every 3-6 months, as needed. Target Melmin. Exercise care when working around rare taxa. | |

***Re-vegetation*:**

The snail enclosure has significant patches of native canopy, mostly comprised of *Metrosideros polymorpha*. Understory however, post clearing of uluhe and all alien understory, will be rather sparse. Restoration efforts will aim to fill in any canopy light-gaps, and to establish a mid-story and connectivity across all vegetation. Due to the difficulties of searching for *E. rosea*, understory restoration will be conducted as a last step in the restoration process, when there is absolute certainty that the enclosure is *E. rosea* free.

Outplantings of restoration species will begin only after *E. rosea* sweeps are complete, in order to reduce trampling, and after all the alien taxa have been removed to allow more flexibility with use of herbicides. Completion of *E. rosea* and alien plant removal is expected to occur by the end of 2018.

No shrubs or canopy trees will be planted or sowed within 2m inside and outside of the fence enclosure in order to protect the wall from branch falls, and to prevent vegetative predator bridges over the wall. Plants that spill into this buffer zone will be trimmed regularly.

Seed sows are also planned shortly after the first set of reintroductions. The table below summarizes the revegetation actions, species planned for use, and timeline.

Re-vegetation Summary:

| Approximate date | Action | Species | Comments |
|---|---|---|---|
| January 2018 | Outplant | *Coprosma longifolia, Kadua affinis* | These quick-growing, easy to propagate species have worked well to establish shrubby vegetation in open areas in the other snail enclosures. Over time, they are known to connect to canopy vegetation. |
| January-March 2018 | Seed sows | *Pipturus albidus* (fresh seed)<br>*Bidens torta* (stored seed)<br>*Scaevola gaudichaudiana* (fresh seed) | These species are both documented as establishing well from low-effort broadcast sows. |
| March-November 2018 | Outplant | *Antidesma platyphyllum, Ilex anomala, Perrottetia sandwicensis Metrosideros polymopha var. glaberrima, Metrosideros polymorpha var. polymorpha., Metrosideros tremuloides,* | Some of the canopy species listed here are slow-growing, and will be planted in waves as they are ready to leave the greenhouse. Due to the existing canopy, and the moisture at temperature at the elevation of the snail enclosure, it is less of a concern to outplant during the summer months. |

***Trails:***

Trails will be utilized to mitigate trampling of native recruits and outplants. Permanent markers will be used to designate trails.

***Vegetation Monitoring:***

Vegetation monitoring of the enclosure will consist of three approaches, including point-intercept monitoring, photopoints, and UAV imagery. These approaches will track vegetation changes over time, and help guide restoration efforts.

Point-intercept monitoring will be used to measure percent cover of native and non-native taxa. Vegetation will be recorded separately from 0 – 2m AGL and > 2mAGL to document percent cover in the understory and canopy, using approximately 500 point intercepts along non-permanent transects. Monitoring will occur annually for the first 5 years, after which the interval may be extended to every 2 – 3 years.

Photopoints will be used to provide visual representations of sub-canopy vegetation. There will be five photopoints in the enclosure. They will be marked with permanent galvanized pipe, orange flagging, and metal write-on tags with the Pole #. At each pipe, photos are taken in the cardinal directions, using a compass and print-out of previous photopoints to line up each shot. They should be taken quarterly for the first year following clearing, then annually for the next 5+ years.

| Action ID | Field Team | Category Code | WCA Code | Location | Team Action Comments | Update |
|---|---|---|---|---|---|---|
| 7826 | Foundation | W/ Photopoint Monitor | West Makal eha-02 | West Makaleha Snail Jail | Install and take photopoints at West Makaleha Snail Jail. Re-take when clearing complete, then quarterly, then annually. | Installation planned 2018-09 |

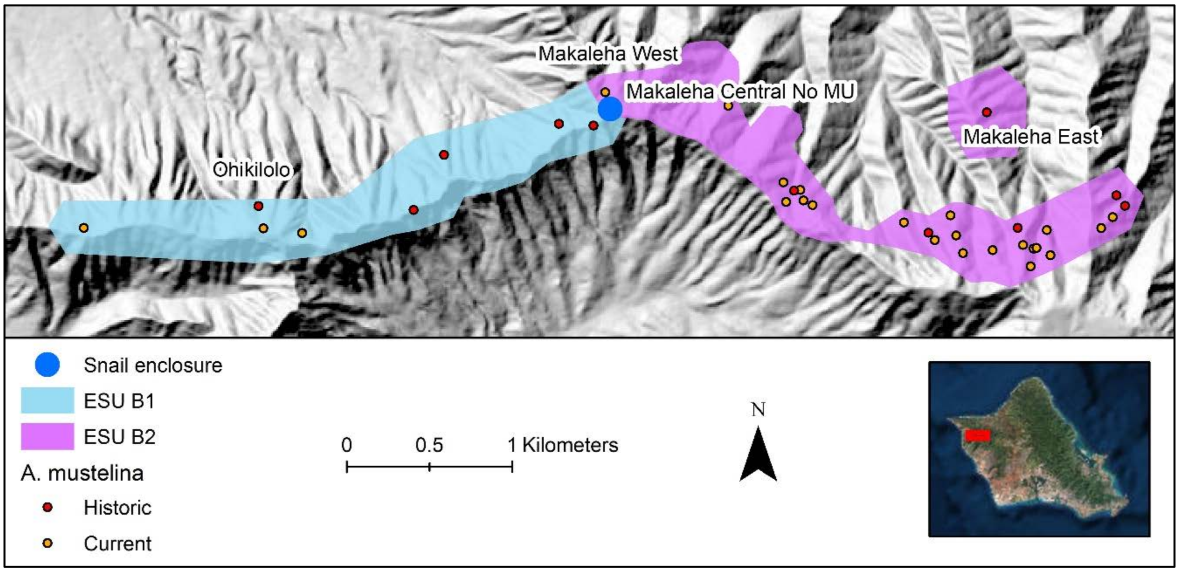
UAV imagery will be used to provide visual representations of upper canopy vegetation and will occur in conjunction with point-intercept monitoring, as possible.

***Vegetation cover goals:***

Preliminary vegetation cover goals were made to guide efforts and may be used to trigger changes in management strategies.

- **Goal for 0 - 2mAGL:** > 50% cover after 2 years and beyond. Given the sparsity of native vegetation in the understory post-clearing, restoration inputs will show up first in this category. An emphasis of tree taxa outplantings in areas that lack canopy will be made initially. Lower cover will trigger more outplanting, seed sows and transplants of understory species. The cover goal may then be maintained with the addition of more understory species.
- **Goal for > 2mAGL:** > 75% by 5 years, and > 90% by 10 years. Given the time required for outplanted trees taxa to grow > 2mAGL, the cover of tree taxa within the 0 – 2 m AGL strata should carefully assessed to ensure that progress towards cover goals for > 2mAGL is made.
- **Goal for total AGL cover:** > 75% by 2 years and beyond. This will give a measure of the overall vegetation cover regardless of vertical stature, and an indication of how much open ground remains, of relevance with respect to snail movement across the enclosure. Lower cover would trigger efforts to plant more and continue to fill in open areas and increase overall planting density.

Snails that are part of ESU-B:




ESU-B stretches approximately 6 kilometers from Ohikilolo Ridge in the west to the Dupont Trail in the east. The snail enclosure at 3 Points lies near the separation line between ESU-B1 and ESU-B2. The tables below show the number of snails known from these different snail populations.

Most of the snails found in ESU-B1 are on Ohikilolo in the Mauka and Makai patches. These were both surveyed recently in May 2018.

| Population Reference Site | Management Designation | Total Snails | Date of Survey | Size Classes | | | | Threat Control | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Large | Medium | Small | Unk | Ungulate | Weed | Rat | Euglandina rosea | Jackson's Chameleon |
| **ESU: B1** **Ohikilolo** | | | | | | | | | | | | |
| **MMR-E** **Ohikilolo Mauka** | Manage for stability | 57 | 2018-05-09 | 37 | 14 | 6 | 0 | Yes | Partial | Yes | No | No |
| **MMR-F** **Ohikilolo Makai** | Manage for stability | 99 | 2018-05-09 | 67 | 17 | 15 | 0 | Yes | Partial | Yes | No | No |
| **MMR-G** **Ohikilolo Alemac Site** | No Management | 0 | 2016-04-20 | 0 | 0 | 0 | 0 | Yes | No | No | No | No |
| **MMR-H** **Ohikilolo Koiahi Prikaa Reintro Site** | No Management | 4 * | 2018-05-08 | 2 | 2 | 0 | 0 | Yes | Partial | Yes | No | No |
| **MMR-I** **Hedpar MMR-B** | No Management | 2 | 2002-06-03 | 2 | 0 | 0 | 0 | Yes | No | No | No | No |
| **MMR-J** **One ridge east of Lower Makua Camp** | No Management | 5 | 2000-11-27 | 0 | 0 | 0 | 5 | Partial | No | No | No | No |
| **MMR-K** **Ctesqu ridge** | No Management | 0 | 2016-08-30 | 0 | 0 | 0 | 0 | Partial | No | No | No | No |
| **MMR-L** **Myrsine along Ohikilolo fence from 3 pts** | No Management | 0 | 2016-08-30 | 0 | 0 | 0 | 0 | Partial | No | No | No | No |
| | **ESU Total:** | 167 | | 108 | 33 | 21 | 5 | | | | | |

*= Snails (past or current) have been Trans-Located to another wild site.

**Size Class Definitions**

| SizeClass | DefSizeClass |
|---|---|
| Large | >18 mm |
| Medium | 8-18 mm |
| Small | < 8 mm |

[shaded] = Threat to Taxon at Population Reference Site

No Shading = Absence of threat to Taxon at Population Reference Site

Yes=Threat is being controlled at PopRefSite

No=Threat is not being controlled at PopRefSite

Partial=Threat is being partially controlled at PopRefSite

Table shows the number of snails, size classes, and threats to the snails in the ESU sites. Yes = threat is being controlled; In some cases the threat may be present but not actively preying on A. mustelina.

The snails in ESU-B2 stretch across the ridges from Central to East Makaleha.
OANRP plan to develop a translocation plan when the 3 Points enclosure is complete (Sept 2018) and propose how many snails to collect from the different populations and mix in the enclosure.

| Population Reference Site | Management Designation | Total Snails | Date of Survey | Size Classes | | | | Threat Control | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Large | Medium | Small | Unk | Ungulate | Weed | Rat | Euglandina rosea | Jackson's Chameleon |
| **ESU: B2 East and Central Makaleha** | | | | | | | | | | | | |
| **AAW-A** Kaawa Gulch | No Management | 20 | 2016-04-06 | 11 | 5 | 4 | 0 | No | No | No | No | No |
| **LEH-A** Central Makaleha (culvert 39) | No Management | 49 * | 2011-05-18 | 29 | 15 | 5 | 0 | No | No | No | No | No |
| **LEH-B** East Makaleha (culvert 45) | No Management | 33 | 2011-04-19 | 11 | 12 | 10 | 0 | No | No | No | No | No |
| **LEH-C** East Branch of East Makaleha (culvert 69) | Manage for stability | 378 | 2016-12-31 | 267 | 99 | 12 | 0 | No | No | Yes | No | No |
| **LEH-D** East Branch of East Makaleha (culvert 73) | Manage for stability | 106 | 2017-12-27 | 76 | 23 | 7 | 0 | No | No | Yes | No | No |
| **LEH-E** East Makaleha (culvert 56-57) | No Management | 31 | 2011-04-20 | 16 | 7 | 8 | 0 | No | No | Yes | No | No |
| **LEH-G** East Makaleha (culvert 59) | No Management | 3 | 2006-04-17 | 3 | 0 | 0 | 0 | No | Partial | No | No | No |
| **LEH-H** East Makaleha (culvert 54) | No Management | 34 | 2000-03-23 | 0 | 0 | 0 | 34 | No | No | No | No | No |
| **LEH-I** East Makaleha (culvert 67) | No Management | 16 | 2000-03-23 | 16 | 0 | 0 | 0 | No | No | No | No | No |
| **LEH-J** East Makaleha (culvert 69 - lower down | No Management | 2 | 2006-11-16 | 2 | 0 | 0 | 0 | No | No | No | No | No |
| **LEH-K** Culvert 43 Ridge | No Management | 0 | 2016-11-09 | 0 | 0 | 0 | 0 | No | No | No | No | No |
| **LEH-L** 3 Points | No Management | 0 | 2018-05-17 | 0 | 0 | 0 | 0 | Yes | Partial | No | No | No |
| | **ESU Total:** | 672 | | 431 | 161 | 46 | 34 | | | | | |

**Size Class Definitions**

| SizeClass | DefSizeClass |
|---|---|
| Large | >18 mm |
| Medium | 8-18 mm |
| Small | < 8 mm |

*= Snails (past or current) have been Trans-Located to another wild site.

[shaded] = Threat to Taxon at Population Reference Site
No Shading = Absence of threat to Taxon at Population Reference Site

Yes=Threat is being controlled at PopRefSite
No=Threat is not being controlled at PopRefSite
Partial=Threat is being partially controlled at PopRefSite

Table shows the number of snails, size classes, and threats to the snails in the ESU sites. Yes = threat is being controlled; In some cases the threat may be present but not actively preying on A. mustelina.

## References

OANRP. 2016. Appendix 3-5 Vegetation monitoring of *Achatinella mustelina* ESU-E enclosure, 2016 pre-clearing results *in* 2016 Status Report for the Makua and Oahu Implementation Plans.

# Hawaiian Hoary Bat

## *Thermal IR and Acoustic Monitoring Project for Removal of Trees at MSTC Obstacle Course and Bldg 1709 Motor Pool, Trimble Road Schofield Barracks on 14 and 15 June 2018 by the Army's Natural Resources Program*

### Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in seven Albizia trees (*Falcataria moluccana*) and three *Eucalyptus robusta* scheduled to be removed at the MSTC Obstacle Course and Motor Pool (Figure 1). If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

### Survey Map

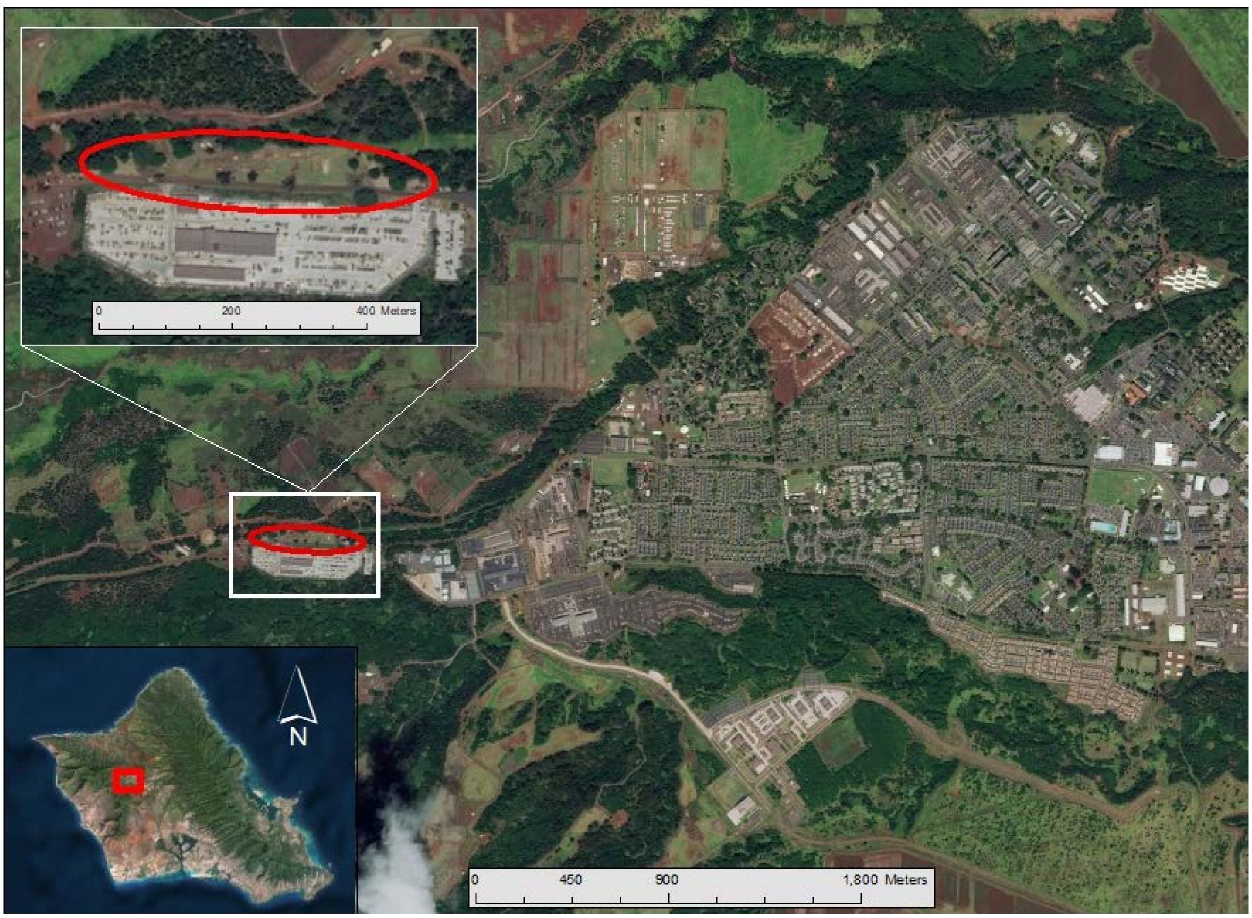



Figure 1. Aerial photo of the MSTC Obstacle Course and Bldg 1709 Motor Pool project site which Hawaiian Hoary bat surveys were conducted. Red oval indicates location of the trees.

## Methods

Visual and acoustic surveys for bats were conducted on 14 and 15 June 2018, the days of the scheduled tree removals. A Fluke Ti400 thermal imager was employed to scan the trees for any roosting bats to confirm no presence. OANRP also employed the hand held Wildlife Acoustics Echo Meter Touch attached to an IPad as a way to scan the area for any possible bats returning to a roost within close proximity. This tool has the ability to listen to bats in real time, GPS tracks and tags all recordings with location information and has full color spectrograms. Scanning commenced from 05:30-06:30 from the ground from different angles and locations.

### Results and Discussion

The visual thermal IR and acoustic surveys detected no bats at all. Multiple species of birds were observed with the thermal IR, with visual confirmation, in and around the area. It was determined that there would be No Effect to bats if the trees were trimmed and the corridor cleared.

### Recommendations

Work with DPW to better monitor the contractors work so that trees that need trimming are not missed prior to the pupping season.

# Hawaiian Hoary Bat

## *Thermal IR and Acoustic Monitoring Project for Removal of Trees at Water Tanks 2300/2301 Trimble Road, Schofield Barracks on 19 and 21 June 2018 by the Army's Natural Resources Program*

### Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in 10 Eucalyptus (*Eucalyptus* spp.) and one Australian Red Cedar (*Toona ciliata*) scheduled to be removed from the area around the water tanks (Figure 1). If bats are present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

### Survey Map

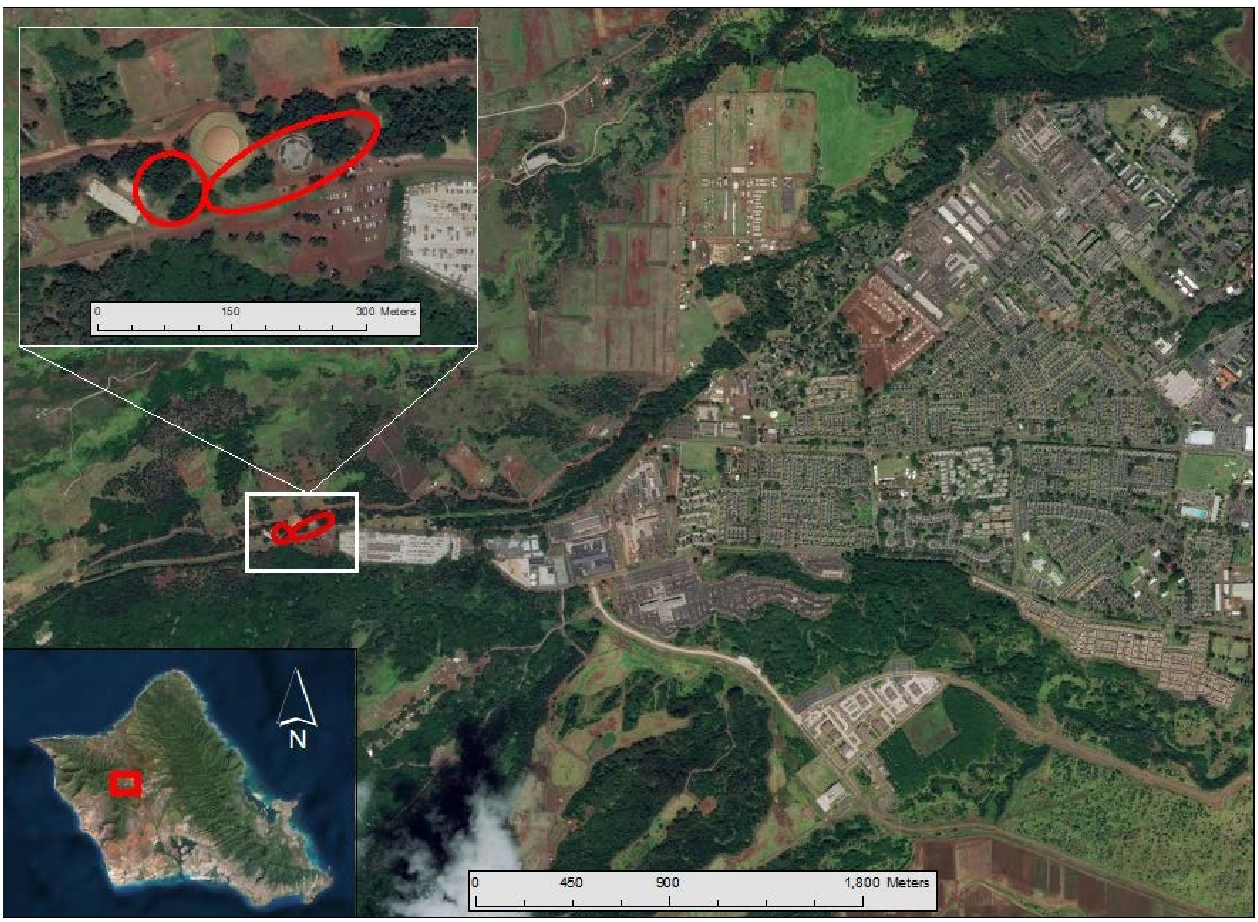



Figure 1. Aerial photo of the Water Tanks 2300 and 2301, project site which Hawaiian Hoary bat surveys were conducted. Red oval indicates location of the trees.

## Methods

Visual and acoustic surveys for bats in the trees were conducted on 19 and 21 June 2018, the day of the scheduled tree removal. A Fluke Ti400 thermal imager was employed to scan the trees for any roosting bats to confirm no presence. OANRP also employed the hand held Wildlife Acoustics Echo Meter Touch attached to an IPad as a way to scan the area for any possible bats returning to a roost within close proximity. This tool has the ability to listen to bats in real time, GPS tracks and tags all recordings with location information and has full color spectrograms. Scanning commenced from 05:00-06:30 from the ground from different angles and locations.

### Results and Discussion

The visual thermal IR and acoustic surveys detected no bats at all. Multiple species of birds were observed with the thermal IR, with visual confirmation, in and around the area. It was determined that there would be No Effect to bats if the trees were removed and the corridor cleared.

### Recommendations

Work with DPW to better monitor the contractors work so that trees that need trimming are not missed prior to the pupping season.

# Hawaiian Hoary Bat

## *Thermal IR and Acoustic Monitoring Project for Trimming of Trees at Bldg 1087, Army Recycle Center, McMahon Road, Schofield Barracks on 21 and 22 June 2018 by the Army's Natural Resources Program*

### Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in one Mountain apple (*Syzygium malaccense*), two Chinese banyon (*Ficus microcarpa*) and one African tulip (*Spathodea campanulata*) scheduled to be removed at the recycle center (Figure 1). If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

### Survey Map

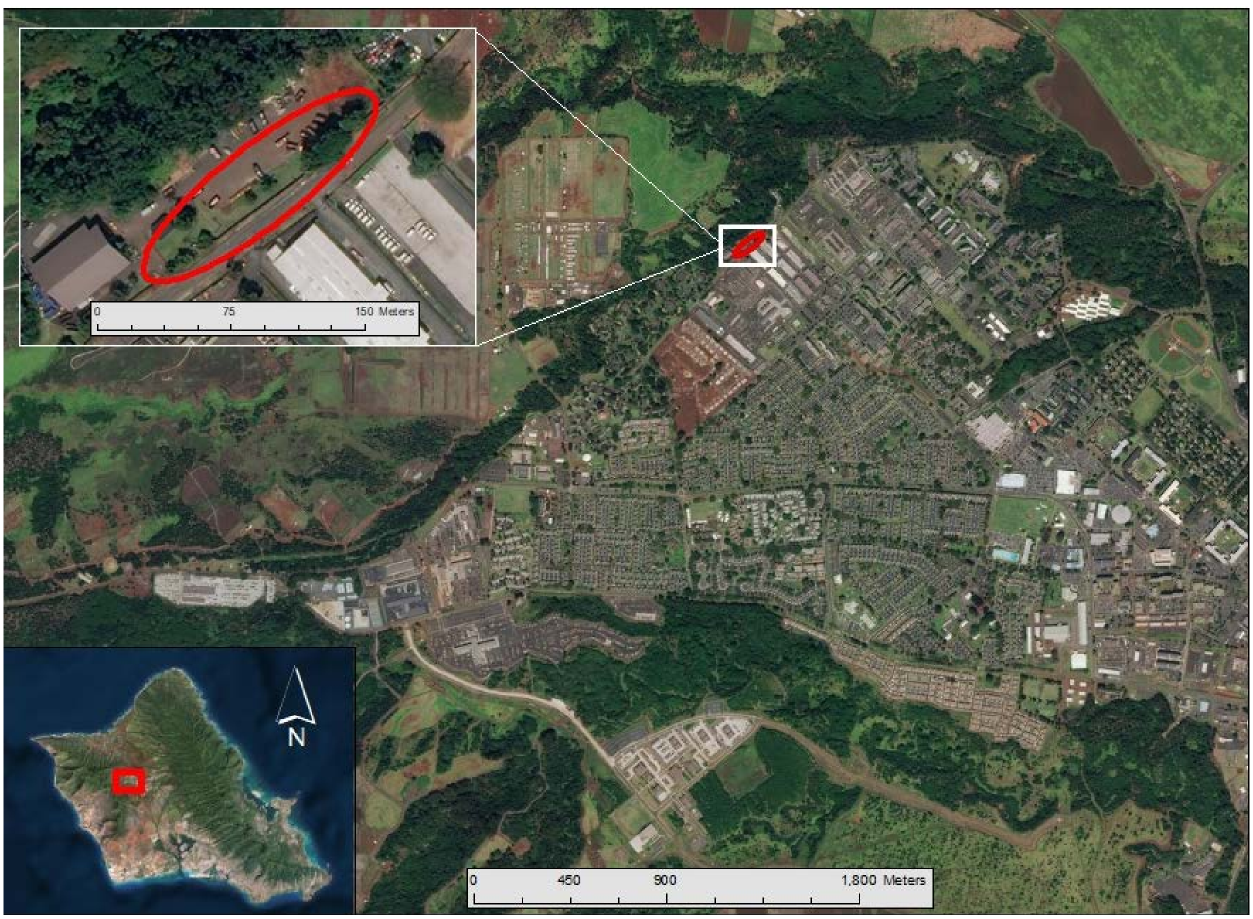



Figure 1. Aerial photo of Bldg 1087 Army Recycle Center, project site which Hawaiian Hoary bat surveys were conducted. Red oval indicate location of the trees.

## Methods

Visual and acoustic surveys for bats in the trees were conducted on 21 and 22 June 2018, the day of the scheduled tree removal. A Fluke Ti400 thermal imager was employed to scan the trees for any roosting bats to confirm no presence. OANRP also employed the hand held Wildlife Acoustics Echo Meter Touch attached to an IPad as a way to scan the area for any possible bats returning to a roost within close proximity. This tool has the ability to listen to bats in real time, GPS tracks and tags all recordings with location information and has full color spectrograms. Scanning commenced from 05:00-06:30 from the ground from different angles and locations.

### Results and Discussion

The visual thermal IR and acoustic surveys detected no bats at all. Multiple species of birds were observed with the thermal IR, with visual confirmation, in and around the area. It was determined that there would be No Effect to bats if the trees were removed and the corridor cleared.

### Recommendations

Work with DPW to better monitor the contractors work so that trees that need trimming are not missed prior to the pupping season.

# Hawaiian Hoary Bat

## *Thermal IR and Acoustic Monitoring Project for Trimming of Trees at Quad B (Bldg 2110 Outdoor Recreation Center Storage) Schofield Barracks on 26 June 2018 by the Army's Natural Resources Program*

### Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in one Golden trumpet (*Tabebuia chrysanta*) and Golden shower (*Cassia fistula*) trees scheduled to be removed at the Bldg. 2110 (Figure 1). If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

### Survey Map

Figure 1. Aerial photo of the Bldg 2110, project site which Hawaiian Hoary bat surveys were conducted. Red oval indicates location of the tree.

## Methods

Visual and acoustic surveys for bats in the trees were conducted on 26 June 2018, the day of the scheduled tree removal. A Fluke Ti400 thermal imager was employed to scan the trees for any roosting bats to confirm no presence. OANRP also employed the hand held Wildlife Acoustics Echo Meter Touch attached to an IPad as a way to scan the area for any possible bats returning to a roost within close proximity. This tool has the ability to listen to bats in real time, GPS tracks and tags all recordings with location information and has full color spectrograms. Scanning commenced from 05:00-06:30 from the ground from different angles and locations.

### Results and Discussion

The visual thermal IR and acoustic surveys detected no bats at all. Multiple species of birds were observed with the thermal IR, with visual confirmation, in and around the area. It was determined that there would be No Effect to bats if the trees were removed and the corridor cleared.

### Recommendations

Work with DPW to better monitor the contractors work so that trees that need trimming are not missed prior to the pupping season.

# Hawaiian Hoary Bat

## *Thermal IR and Acoustic Monitoring Project for Trimming of Trees at Bldg 884, Williston Ave, Schofield Barracks on 27 June 2018 by the Army's Natural Resources Program*

### Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in three Monkey pod trees (*Albizia saman*) scheduled to be trimmed. If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

### Survey Map


Figure 1. Aerial photo of the Bldg. 884, Soldiers Barracks, project site which Hawaiian Hoary bat surveys were conducted. Red dots indicate location of the trees.

## Methods

Visual and acoustic surveys for bats were conducted on 27 June 2018, the day of the scheduled tree trimming. A Fluke Ti400 thermal imager was employed to scan the trees for any roosting bats to confirm no presence. OANRP also employed the hand held Wildlife Acoustics Echo Meter Touch attached to an IPad as a way to scan the area for any possible bats returning to a roost within close proximity. This tool has the ability to listen to bats in real time, GPS tracks and tags all recordings with location information and has full color spectrograms. Scanning commenced from 05:15-06:30 from the ground from different angles and locations.

### Results and Discussion

The visual thermal IR and acoustic surveys detected no bats at all. Multiple species of birds were observed with the thermal IR, with visual confirmation, in and around the area. It was determined that there would be No Effect to bats if the trees were trimmed and the corridor cleared.

### Recommendations

Work with DPW to better monitor the contractors work so that trees that need trimming are not missed prior to the pupping season.

# Hawaiian Hoary Bat

## *Thermal IR and Acoustic Monitoring Project for Removal of Trees along HV Powerline near Red Sentry Booth, Trimble Road Schofield Barracks on 18 and 19 July 2018 by the Army's Natural Resources Program*

### Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in one Albizia (*Falcataria moluccana*) and seven *Eucalyptus robusta* trees scheduled to be removed along the power line on Trimble road (Figure 1). If bats are present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

### Survey Map

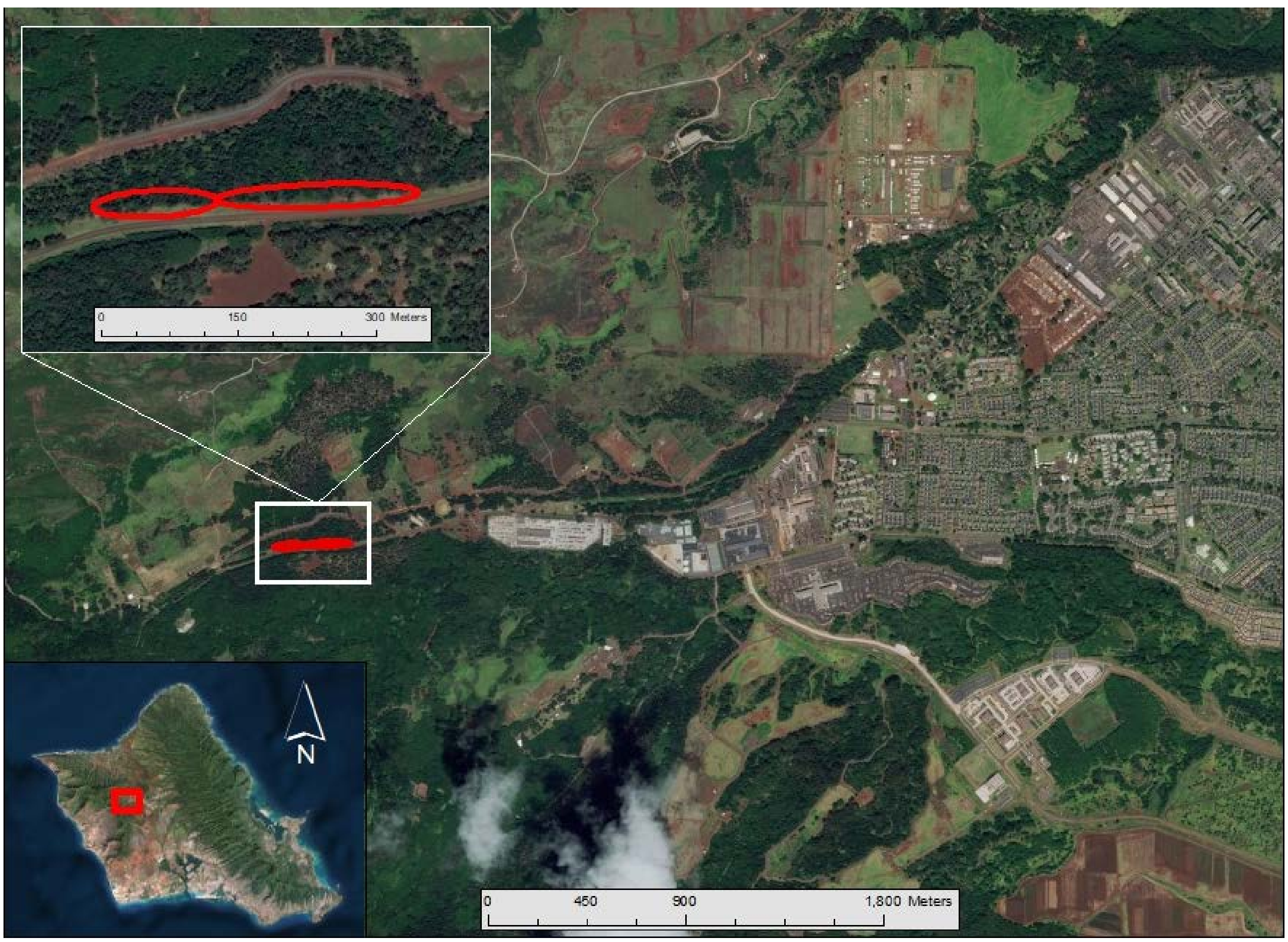



Figure 1. Aerial photo of the HV Power Line tree trimming project along Trimble Road in which Hawaiian Hoary bat surveys were conducted. Red Circle indicate location of the trees.

## Methods

Visual and acoustic surveys for bats were conducted on 18 and 19 July 2018, the days of the scheduled tree removals A Fluke Ti400 thermal imager was employed to scan the trees for any roosting bats to confirm no presence. OANRP also employed the hand held Wildlife Acoustics Echo Meter Touch attached to an IPad as a way to scan the area for any possible bats returning to a roost within close proximity. This tool has the ability to listen to bats in real time, GPS tracks and tags all recordings with location information and has full color spectrograms. Scanning commenced from 05:30-06:30 from the ground from different angles and locations.

### Results and Discussion

The visual thermal IR and acoustic surveys detected no bats at all. Multiple species of birds were observed with the thermal IR, with visual confirmation, in and around the area. It was determined that there would be No Effect to bats if the trees were removed.

### Recommendations

Work with DPW to better monitor the contractors work so that trees that need trimming are not missed prior to the pupping season.

# Hawaiian Hoary Bat

## *Thermal IR and Acoustic Monitoring Project for Trimming of Trees at Cemetery, Lyman Road Schofield Barracks on 10 August 2018 by the Army's Natural Resources Program*

### Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in four Eucalyptus trees scheduled to be removed at the cemetery (Figure 1). If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

### Survey Map

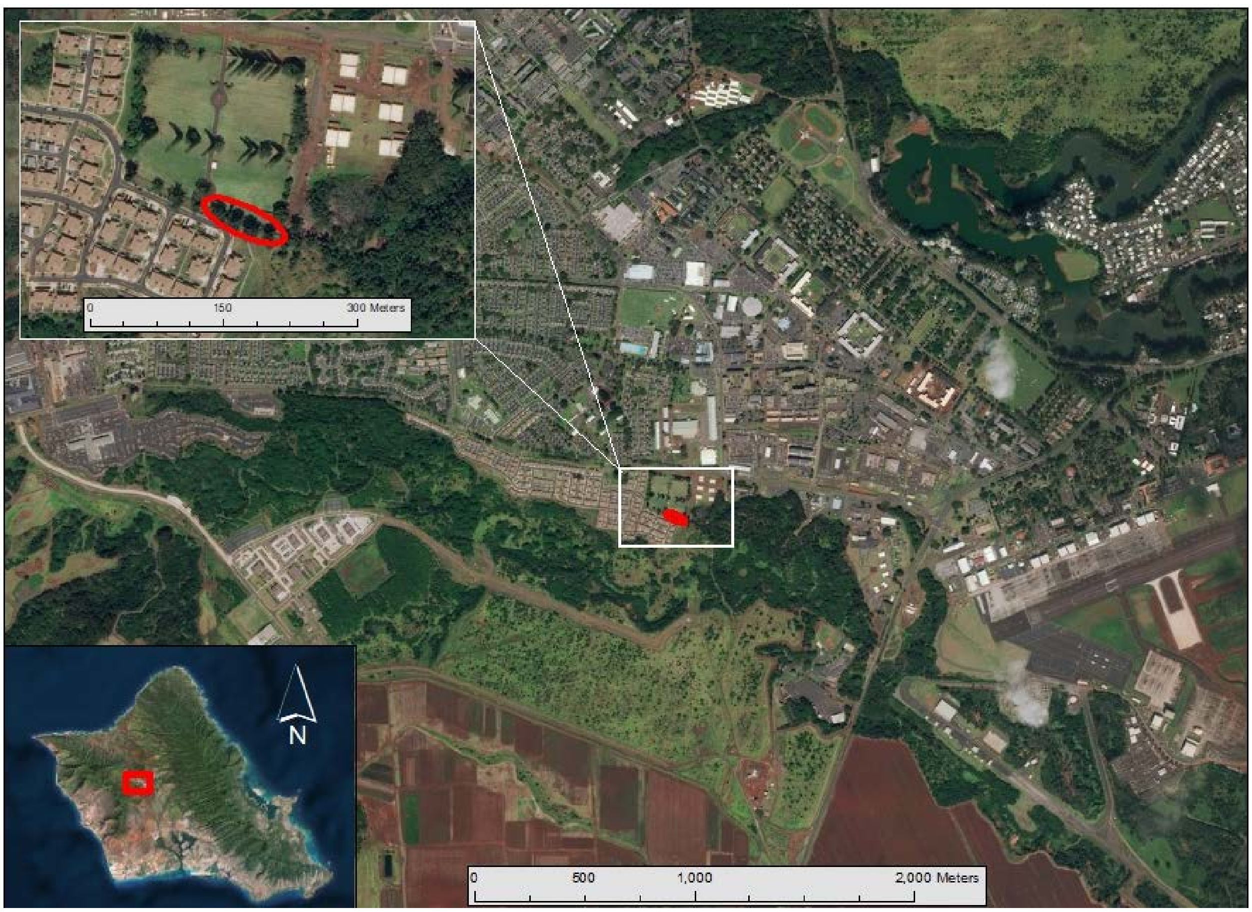



Figure 1. Aerial photo of the Cemetery, Lyman Road, project site which Hawaiian Hoary bat surveys were conducted. Red oval indicates location of the trees.

## Methods

Visual and acoustic surveys for bats in the trees were conducted on 10 August 2018, the day of the scheduled tree removal. A Fluke Ti400 thermal imager was employed to scan the trees for any roosting bats to confirm no presence. OANRP also employed the hand held Wildlife Acoustics Echo Meter Touch attached to an IPad as a way to scan the area for any possible bats returning to a roost within close proximity. This tool has the ability to listen to bats in real time, GPS tracks and tags all recordings with location information and has full color spectrograms. Scanning commenced from 05:00-06:30 from the ground from different angles and locations.

### Results and Discussion

The visual thermal IR and acoustic surveys detected no bats at all. Multiple species of birds were observed with the thermal IR, with visual confirmation, in and around the area. It was determined that there would be No Effect to bats if the trees were removed and the corridor cleared.

### Recommendations

Work with DPW to better monitor the contractors work so that trees that need trimming are not missed prior to the pupping season.

# Hawaiian Hoary Bat

## *Thermal IR and Acoustic Monitoring Project for Trimming of Trees at Quad A (East end of Waianae Ave after Bldg. 131) Schofield Barracks on 11 September 2018 by the Army's Natural Resources Program*

### Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in one Ear pod (*Enterolobium cyclocarpum*)) tree scheduled to be removed at the Quad A (Figure 1). If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

#### Survey Map

Figure 1. Aerial photo of the Quad A, project site which Hawaiian Hoary bat surveys were conducted. Red circle indicates location of the tree.

## Methods

Visual and acoustic surveys for bats in the trees were conducted on 11 September 2018, the day of the scheduled tree removal. A Fluke Ti400 thermal imager was employed to scan the trees for any roosting bats to confirm no presence. OANRP also employed the hand held Wildlife Acoustics Echo Meter Touch attached to an IPad as a way to scan the area for any possible bats returning to a roost within close proximity. This tool has the ability to listen to bats in real time, GPS tracks and tags all recordings with location information and has full color spectrograms. Scanning commenced from 05:00-06:30 from the ground from different angles and locations.

### Results and Discussion

The visual thermal IR and acoustic surveys detected no bats at all. Multiple species of birds were observed with the thermal IR, with visual confirmation, in and around the area. It was determined that there would be No Effect to bats if the trees were removed and the corridor cleared.

### Recommendations

Work with DPW to better monitor the contractors work so that trees that need trimming are not missed prior to the pupping season.

# Hawaiian Hoary Bat

## *Thermal IR Monitoring Project for Tree Removal and Trimming at Fort Shafter Military Reservation, Schofield Barracks Military Reservation, Tripler army Medical Center and Wheeler Army Airfield by Tree Solutions and Environmental Consulting Services during the 2018 Pupping Season*

### Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in any of the trees that are scheduled to be removed or trimmed at multiple project sites. Figures 1 and 2 show the locations of the survey sites at the Fort Shafter Military Reservation, Schofield Barracks Military Reservation, Tripler Army Medical Center and Wheeler Army Airfield. If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

### Survey Map


Figure 1. Aerial photo of project sites where Hawaiian Hoary bat surveys were conducted at Schofield Barracks and Wheeler Army Airfield. Red circles indicates location of the trees.


Figure 2. Aerial photo of project sites where Hawaiian Hoary bat surveys were conducted at Fort Shafter Military Reservation and Tripler Army Medical Center. Red circles indicate location of the trees.

## Methods

Visual surveys for bats were conducted throughout the pupping season on the days of the scheduled tree trimming. A Flir Scout thermal imager was employed to scan the trees for any roosting bats to confirm no presence. Scanning was conducted during the early morning hours prior to the sun heating the vegetation so that there was a higher probability of locating any roosting bats. Scanning was conducted from the ground from different angles and locations.

### Results and Discussion

Table 1 is a list of the different project sites with a breakdown of the date/time of surveys, tree species monitored, observer, equipment used and results. The visual thermal IR surveys detected no bats at all. Multiple species of birds were observed with the thermal IR, with visual confirmation, in and around the area. It was determined that there would be No Effect to bats if the trees were trimmed and the corridor cleared.

Table 1: List of all the surveys that Tree Solutions and Environmental Consulting completed during the 2018 pupping season

| Tree # | Project Name/ Site Map | Date | Time | Observer | Location | Tree Species | Equipment Used | Comments |
|---|---|---|---|---|---|---|---|---|
| 1 | IPC/FSMR | 2018-06-04 | 5:00-6:00 | IN | 1317 Parks Rd. | Ficus microcarpa | FLIR SCOUT/ Binoculars | No birds. no bats. |
| 2 | IPC/FSMR | 2018-06-04 | 5:00-6:00 | IN | 1317 Parks Rd. | Ficus microcarpa | FLIR SCOUT/ Binoculars | 20 birds. no bats. |
| 3 | IPC/FSMR | 2018-06-13 | 5:15-6:00 | IN | 1317 Parks Rd. | Ficus microcarpa | FLIR SCOUT/ Binoculars | 20 birds. no bats. |
| 4 | IPC/FSMR | 2018-06-14 | 5:45-6:20 | IN | 1317 Parks Rd. | Ficus microcarpa | FLIR SCOUT/ Binoculars | 28 birds. no bats. |
| 5 | IPC/FSMR | 2018-06-18 | 5:10-5:35 | IN | 1317 Parks Rd. | Ficus microcarpa | FLIR SCOUT/ Binoculars | 15 birds. no bats. |
| 6 | ARMY/TAMC | 2018-06-18 | 5:45-6:45 | IN | 730 TAMC fitness center | Ficus benjamina | FLIR SCOUT/ Binoculars | Tree#5; 12 birds. no bats. |
| 7 | ARMY/TAMC | 2018-06-18 | 5:45-6:45 | IN | 730 TAMC fitness center | Ficus benjamina | FLIR SCOUT/ Binoculars | Tree#6; 10 birds. no bats. |
| 8 | ARMY/TAMC | 2018-06-18 | 5:45-6:45 | IN | 730 TAMC fitness center | Ficus benjamina | FLIR SCOUT/ Binoculars | Tree#7; 12 birds. no bats. |
| 9 | ARMY/TAMC | 2018-06-18 | 5:45-6:45 | IN | 730 TAMC fitness center | *Albizia saman* | FLIR SCOUT/ Binoculars | Tree#8; 10 birds. no bats. |
| 10 | IPC/WAAF | 2018-06-18 | 5:30-9:00 | DG | 780 Vought Ave. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | Tree#25; bird nest in tree. 5 birds. No bats |
| 11 | IPC/WAAF | 2018-06-18 | 5:30-9:00 | DG | 780 Vought Ave. | *Schefflera actinophylla* | FLIR SCOUT/ Binoculars | Tree#20; 3 birds. No bats |
| 12 | IPC/WAAF | 2018-06-18 | 5:30-9:00 | DG | 780 Vought Ave. | *Schefflera actinophylla* | FLIR SCOUT/ Binoculars | Tree#19; no birds. No bats. |
| 13 | ARMY/TAMC | 2018-06-19 | 5:20-6:00 | IN | 730 TAMC fitness center | *Albizia saman* | FLIR SCOUT/ Binoculars | Tree#1; 5 birds. no bats. |
| 14 | ARMY/TAMC | 2018-06-19 | 5:20-6:00 | IN | 730 TAMC fitness center | *Albizia saman* | FLIR SCOUT/ Binoculars | Tree#2; 4 birds. no bats. |
| 15 | ARMY/TAMC | 2018-06-19 | 5:20-6:00 | IN | 730 TAMC fitness center | *Albizia saman* | FLIR SCOUT/ Binoculars | Tree#3; 5 birds. no bats. |
| 16 | ARMY/TAMC | 2018-06-19 | 5:20-6:00 | IN | 730 TAMC fitness center | *Albizia saman* | FLIR SCOUT/ Binoculars | Tree#4; 3 birds. no bats. |
| 17 | IPC/WAAF | 2018-06-19 | 5:45-8:30 | DG | 780 Vought Ave. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | Tree#21; 8 birds. No bats. |
| 18 | IPC/WAAF | 2018-06-19 | 5:45-8:30 | DG | 780 Vought Ave. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | Tree#22; 1 bird. No bats. |
| 19 | IPC/WAAF | 2018-06-19 | 5:45-8:30 | DG | 780 Vought Ave. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | Tree#23; bird nest in tree. 3 birds. No bats. |
| 20 | IPC/WAAF | 2018-06-20 | 5:45-6:20 | DG | 798 Vought Ave. | *Schefflera actinophylla* | FLIR SCOUT/ Binoculars | Tree#27; 4 birds. No bats. |
| 21 | IPC/WAAF | 2018-06-20 | 5:45-6:20 | DG | 798 Vought Ave. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | Tree#29; 3 birds. No bats |
| 22 | IPC/WAAF | 2018-06-20 | 5:45-6:20 | DG | 798 Vought Ave. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | Tree#21; 1 bird. No bats. |
| 23 | IPC/WAAF | 2018-06-21 | 5:30-6:30 | DG | 798 Vought Ave. | *Mangifera indica* | FLIR SCOUT/ Binoculars | Tree#30; 1 bird. No bats. |
| 24 | IPC/WAAF | 2018-06-21 | 5:30-6:30 | DG | 798 Vought Ave. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | Tree#28; 3 birds. No bats. |
| 25 | IPC/WAAF | 2018-06-21 | 5:30-6:30 | DG | 798 Vought Ave. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | Tree#21; 2 birds. No bats. |
| 26 | ARMY/WAAF | 2018-06-25 | 5:00-6:30 | DG | Santos Dumont Rd. at corner of Bldg. 832 | *Araucaria columnaris* | FLIR SCOUT/ Binoculars | Tree#1; 2 birds. No bats. |
| 27 | ARMY/WAAF | 2018-06-25 | 5:00-6:30 | DG | Santos Dumont Rd. at corner of Bldg. 832 | *Araucaria columnaris* | FLIR SCOUT/ Binoculars | Tree#2; No bats. |
| 28 | ARMY/WAAF | 2018-06-25 | 5:00-6:30 | DG | Santos Dumont Rd. at corner of Bldg. 832 | *Araucaria columnaris* | FLIR SCOUT/ Binoculars | Tree#3; No bats. |
| 29 | ARMY/WAAF | 2018-06-25 | 5:00-6:30 | DG | Santos Dumont Rd. at corner of Bldg. 832 | *Araucaria columnaris* | FLIR SCOUT/ Binoculars | Tree#4; No bats. |
| 30 | ARMY/WAAF | 2018-06-25 | 5:00-6:30 | DG | Santos Dumont Rd. at corner of Bldg. 832 | *Araucaria columnaris* | FLIR SCOUT/ Binoculars | Tree#5: multi-trunk. No bats. |
| 31 | ARMY/WAAF | 2018-06-25 | 5:00-6:30 | DG | Santos Dumont Rd. at corner of Bldg. 832 | *Araucaria columnaris* | FLIR SCOUT/ Binoculars | Tree#6; 3 birds. No bats |
| 32 | IPC/WAAF | 2018-06-28 | 5:15-6:00 | DG | 798 Vought Ave. | *Ficus Elastica* | FLIR SCOUT/ Binoculars | Tree#26; 5 birds. No bats. |
| 33 | IPC/WAAF | 2018-06-29 | 5:30-6:30 | DG | 824 Vought Ave. | *Persea americana* | FLIR SCOUT/ Binoculars | Tree#33; 3 birds. No bats. |

| Tree # | Project Name/ Site Map | Date | Time | Observer | Location | Tree Species | Equipment Used | Comments |
|---|---|---|---|---|---|---|---|---|
| 34 | IPC/WAAF | 2018-07-02 | 5:30-6:30 | DG | 156-102 Sargent St. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | 3 birds. No bats. |
| 35 | IPC/WAAF | 2018-07-02 | 5:30-6:30 | DG | 779 Vought Ave. | *Schefflera actinophylla* | FLIR SCOUT/ Binoculars | Tree#52; no birds. No bats. |
| 36 | IPC/WAAF | 2018-07-02 | 5:30-6:30 | DG | 779 Vought Ave. | *Spathodea campanulata* | FLIR SCOUT/ Binoculars | Tree#53; Flock of white eye birds. No bats. |
| 37 | ARMY/TAMC | 2018-07-11 | 5:30-6:00 | IN | Tripler, building 40 | *Albizia saman* | FLIR SCOUT/ Binoculars | Tree #1; 4 birds |
| 38 | ARMY/TAMC | 2018-07-11 | 5:30-6:00 | IN | Tripler, building 40 | Ficus microcarpa | FLIR SCOUT/ Binoculars | Tree #1; 3 birds, 1 bird nest |
| 39 | ARMY/TAMC | 2018-07-21 | 5:30-6:45 | DG/IN | Tripler, Upper Parking Lot SO#4 | *Albizia saman* | FLIR SCOUT/ Binoculars | tree #24, 3 birds |
| 40 | ARMY/TAMC | 2018-07-21 | 5:30-6:45 | DG/IN | Tripler, Upper Parking Lot SO#4 | *Albizia saman* | FLIR SCOUT/ Binoculars | tree #24, 2 birds |
| 41 | ARMY/TAMC | 2018-07-21 | 5:30-6:45 | DG/IN | Tripler, Upper Parking Lot SO#4 | *Albizia saman* | FLIR SCOUT/ Binoculars | tree #24, no animals |
| 42 | ARMY/TAMC | 2018-07-21 | 5:30-6:45 | DG/IN | Tripler, Upper Parking Lot SO#4 | *Albizia saman* | FLIR SCOUT/ Binoculars | tree #36, 2 birds |
| 43 | ARMY/TAMC | 2018-07-21 | 5:30-6:45 | DG/IN | Tripler, Upper Parking Lot SO#4 | *Albizia saman* | FLIR SCOUT/ Binoculars | tree #24, 2 birds |
| 44 | ARMY/TAMC | 2018-07-21 | 5:30-6:45 | DG/IN | Tripler, Upper Parking Lot SO#4 | *Albizia saman* | FLIR SCOUT/ Binoculars | tree #24, 2 birds |
| 45 | ARMY/TAMC | 2018-07-21 | 5:30-6:45 | DG/IN | Tripler, Upper Parking Lot SO#4 | *Ficus macrophylla* | FLIR SCOUT/ Binoculars | tree #60, no birds |
| 46 | IPC/WAAF | 2018-07-26 | 5:30-6:15 | DG | 243 Fernander Ave | *Casuarina equisetifolia* | FLIR SCOUT/ Binoculars | 2 birds, no bats |
| 47 | ARMY/SBMR | 2018-07-27 | 6:00-7:00 | DG | Schofield Inn | *Enterolobium cyclocarpum* | FLIR SCOUT/ Binoculars | 4 birds, no bat |
| 48 | ARMY/SBMR | 2018-07-27 | 6:00-7:00 | DG | Schofield Inn | *Enterolobium cyclocarpum* | FLIR SCOUT/ Binoculars | 4 birds, no bats |
| 49 | ARMY/SBMR | 2018-07-27 | 6:00-7:00 | DG | Schofield Inn | *Mangifera indica* | FLIR SCOUT/ Binoculars | 1 bird nest, no bats |
| 50 | IPC/SBMR | 2018-07-29 | 5:45-6:00 | IN | Loko I'A lane | *Juniperus* spp. | FLIR SCOUT/ Binoculars | 1 bird, no bats |
| 51 | IPC/WAAF | 2018-07-30 | 5:30-6:15 | DG | 345 Fernander Ave | *Ficus Benjamina* | FLIR SCOUT/ Binoculars | 5 birds, 1 bird nest in the neighboring fan palm tree. no bats |
| 52 | ARMY/SBMR | 2018-08-01 | 5:30-6:30 | DG | Schofield Inn | *Enterolobium cyclocarpum* | FLIR SCOUT/ Binoculars | 1 bird, no bat |
| 53 | ARMY/SBMR | 2018-08-01 | 5:30-6:30 | DG | Schofield Inn | *Enterolobium cyclocarpum* | FLIR SCOUT/ Binoculars | 2 birds, no bats |
| 54 | ARMY/SBMR | 2018-08-01 | 5:30-6:30 | DG | Schofield Inn | *Mangifera indica* | FLIR SCOUT/ Binoculars | 6 birds, no bats |
| 55 | ARMY/SBMR | 2018-08-09 | 5:30-7:00 | DG | Building 786 Bachelor Officers Quarters | *Albizia saman* | FLIR SCOUT/ Binoculars | 3 birds no bats |
| 56 | ARMY/SBMR | 2018-08-09 | 5:30-7:00 | DG | Building 786 Bachelor Officers Quarters | *Albizia* spp. | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 57 | ARMY/SBMR | 2018-08-09 | 5:30-7:00 | DG | Building 786 Bachelor Officers Quarters | *Albizia* spp. | FLIR SCOUT/ Binoculars | no bats |
| 58 | ARMY/SBMR | 2018-08-09 | 5:30-7:00 | DG | Building 786 Bachelor Officers Quarters | *Albizia* spp. | FLIR SCOUT/ Binoculars | no bats |
| 59 | ARMY/SBMR | 2018-08-09 | 5:30-7:00 | DG | Building 786 Bachelor Officers Quarters | *Ficus microcarpa* | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 60 | ARMY/SBMR | 2018-08-09 | 5:30-7:00 | DG | Building 786 Bachelor Officers Quarters | *Albizia saman* | FLIR SCOUT/ Binoculars | 9 birds bo bats |
| 61 | ARMY/SBMR | 2018-08-10 | 5:30-7:00 | DG | Building 788 Bachelor Officers Quarters | *Pterocarpus indicus* | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 62 | ARMY/SBMR | 2018-08-10 | 5:30-7:00 | DG | Building 788 Bachelor Officers Quarters | *Pterocarpus indicus* | FLIR SCOUT/ Binoculars | 4 birds no bats |
| 63 | ARMY/SBMR | 2018-08-10 | 5:30-7:00 | DG | Building 788 Bachelor Officers Quarters | *Pterocarpus indicus* | FLIR SCOUT/ Binoculars | No bats |
| 64 | ARMY/SBMR | 2018-08-10 | 5:30-7:00 | DG | Building 788 Bachelor Officers Quarters | *Pterocarpus indicus* | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 65 | ARMY/SBMR | 2018-08-10 | 5:30-7:00 | DG | Building 788 Bachelor Officers Quarters | *Albizia* spp. | FLIR SCOUT/ Binoculars | 1 bird no bats |
| 66 | ARMY/SBMR | 2018-08-10 | 5:30-7:00 | DG | Building 788 Bachelor Officers Quarters | *Albizia* spp. | FLIR SCOUT/ Binoculars | no bats |
| 67 | ARMY/SBMR | 2018-08-14 | 6:00-7:30 | IN | Building 788 Bachelor Officers Quarters | *Albizia* spp. | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 68 | ARMY/SBMR | 2018-08-14 | 6:00-7:30 | IN | Building 788 Bachelor Officers Quarters | *Albizia* spp. | FLIR SCOUT/ Binoculars | 1 bird no bats |

| Tree # | Project Name/ Site Map | Date | Time | Observer | Location | Tree Species | Equipment Used | Comments |
|---|---|---|---|---|---|---|---|---|
| 69 | ARMY/SBMR | 2018-08-14 | 6:00-7:30 | IN | Building 788 Bachelor Officers Quarters | *Albizia* spp. | FLIR SCOUT/ Binoculars | no bats |
| 70 | ARMY/SBMR | 2018-08-14 | 6:00-7:30 | IN | Building 788 Bachelor Officers Quarters | *Pterocarpus indicus* | FLIR SCOUT/ Binoculars | 4 birds no bats |
| 71 | ARMY/SBMR | 2018-08-14 | 6:00-7:30 | IN | Building 788 Bachelor Officers Quarters | *Pterocarpus indicus* | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 72 | ARMY/SBMR | 2018-08-14 | 6:00-7:30 | IN | Building 788 Bachelor Officers Quarters | *Pterocarpus indicus* | FLIR SCOUT/ Binoculars | 6 birds no bats |
| 73 | ARMY/SBMR | 2018-08-14 | 6:00-7:30 | IN | Building 788 Bachelor Officers Quarters | *Pterocarpus indicus* | FLIR SCOUT/ Binoculars | 1 bird no bats |
| 74 | ARMY/SBMR | 2018-08-21 | 5:45-6:45 | DG | Building 784 Bachelor Officers Quarters | *Albizia saman* | FLIR SCOUT/ Binoculars | 1 bird no bats |
| 75 | ARMY/SBMR | 2018-08-21 | 5:45-6:45 | DG | Building 784 Bachelor Officers Quarters | *Albizia saman* | FLIR SCOUT/ Binoculars | no bats |
| 76 | ARMY/SBMR | 2018-08-21 | 5:45-6:45 | DG | Building 784 Bachelor Officers Quarters | *Albizia saman* | FLIR SCOUT/ Binoculars | 2 bird no bats |
| 77 | IPC/FSMR | 2018-08-23 | 5:15-6:00 | DG | 2029 Simpson St. | *Albizia saman* | FLIR SCOUT/ Binoculars | No bats. tree at park |
| 78 | ARMY/WAAF | 2018-09-08 | 5:15-6:30 | SN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | no bats |
| 79 | ARMY/WAAF | 2018-09-08 | 5:15-6:30 | SN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | no bats |
| 80 | ARMY/WAAF | 2018-09-08 | 5:15-6:30 | SN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 1 bird no bats |
| 81 | ARMY/WAAF | 2018-09-08 | 5:15-6:30 | SN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 4 birds no bats |
| 82 | ARMY/WAAF | 2018-09-08 | 5:15-6:30 | SN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 83 | ARMY/WAAF | 2018-09-08 | 5:15-6:30 | SN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 84 | ARMY/WAAF | 2018-09-08 | 5:15-6:30 | SN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | no bats |
| 85 | ARMY/WAAF | 2018-09-08 | 5:15-6:30 | SN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | no bats |
| 86 | ARMY/WAAF | 2018-09-08 | 5:15-6:30 | SN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 87 | ARMY/WAAF | 2018-09-15 | 5:00-6:30 | IN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 1 bird no bats |
| 88 | ARMY/WAAF | 2018-09-15 | 5:00-6:30 | IN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | no bats |
| 89 | ARMY/WAAF | 2018-09-15 | 5:00-6:30 | IN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 90 | ARMY/WAAF | 2018-09-15 | 5:00-6:30 | IN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 3 birds no bats |
| 91 | ARMY/WAAF | 2018-09-15 | 5:00-6:30 | IN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | no bats |
| 92 | ARMY/WAAF | 2018-09-15 | 5:00-6:30 | IN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 2 birds no bats |
| 93 | ARMY/WAAF | 2018-09-15 | 5:00-6:30 | IN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | no birds |
| 94 | ARMY/WAAF | 2018-09-15 | 5:00-6:30 | IN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 4 birds no bats |
| 95 | ARMY/WAAF | 2018-09-15 | 5:00-6:30 | IN | Wright ave | *Albizia saman* | FLIR SCOUT/ Binoculars | 1 bird no bats |

## Recommendations

Work with DPW to better monitor the contractors work so that trees that need trimming are not missed prior to the pupping season.

Supplemental Environmental Assessment and
Finding of No Significant Impact

# Protecting Endangered O‘ahu ‘Elepaio Using Rodenticide within Schofield Barracks Military Reservation O‘ahu, Hawai‘i

**September 2017**

Prepared by:
**Directorate of Public Works**
**U.S. Army Garrison, Hawai‘i**

# Finding of No Significant Impact
# for Protecting Endangered O‘ahu ‘Elepaio Using Rodenticide within Schofield Barracks Military Reservation, Hawai‘i

AUTHORITY: Pursuant to the National Environmental Policy Act of 1969, as amended (42 USC 4321 *et seq.*) (NEPA), the Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR parts 1500-1508), and the Final Rule on Environmental Analysis of Army Actions (32 CFR Part 651), the United States Army Garrison, Hawai‘i (USAG-HI) has prepared a Supplemental Environmental Assessment (SEA) to consider the environmental effects of protecting the endangered O‘ahu ‘elepaio through the use of rodenticide within the footprint of Schofield Barracks, O‘ahu, Hawai‘i. This document supplements the 2010 O‘ahu Implementation Plan Programmatic Environmental Assessment (OIP PEA) with more specific, current information about the proposed action. The SEA is incorporated by reference in this Finding of No Significant Impact (FNSI).

PROPOSED ACTION: USAG-HI proposes to conduct the broadscale distribution of rodenticide in the Lihue Management Unit (MU) as part of an integrated management program to control rat populations that heavily predate and threaten the survival of O‘ahu ‘elepaio and other endangered native Hawaiian plants and animals.

The rodenticide application would consist of a helicopter, using a specialized suspended bucket, flying along predetermined Global Positioning System (GPS)-plotted transects within the treatment area. The rodenticide bait would be broadcast by the rotary spreader bucket as the helicopter flies along these transects. The 430 hectare (ha) treatment area is contained within a fenced enclosure located in the 714 ha Lihue MU. The rodenticide to be used would be Diphacinone-50: Pelleted Rodenticide Bait for Conservation Purposes (EPA Reg. No. 56228-35) containing the anticoagulant rodenticide diphacinone (0.005% active ingredient). Diphacinone-50 (D-50) has been approved for aerial distribution by the U.S. Environmental Protection Agency (EPA) and the Hawai‘i Department of Agriculture (HDOA). An EPA registered and state licensed diphacinone product comparable to D-50 may be used as a supplement or in the alternative.

ALTERNATIVES CONSIDERED: The Proposed Action and No Action alternatives were evaluated in the SEA. The Proposed Action was first included as a requirement in the 2003 U.S. Fish and Wildlife Service (USFWS) Biological Opinion on Routine Military Training and Transformation of the 2nd Brigade 25th Infantry Division (Light) for installations on O‘ahu, Hawai‘i. The Proposed Action was more specifically described in the 2010 OIP PEA.

An alternative that would solely use hand-broadcasting of rodenticide within Lihue MU was eliminated from consideration because it would not effectively meet the need to control rat populations on a broad enough scale to sufficiently aid O‘ahu ‘elepaio populations. No additional effective means of meeting the project objectives are known at this time. Therefore, only the “Proposed Action” and “No Action” alternative were considered in the SEA.

SUMMARY OF FINDINGS: The attached SEA incorporates by reference and supplements the 2010 OIP PEA. The SEA evaluated the potential environmental effects of the proposed rodenticide application project. No significant impacts are anticipated as a result of either the No Action Alternative or the Proposed Action. Table 2 of the SEA provides a summary of anticipated impacts to each resource area analyzed. Impacts are largely anticipated to be minimized through avoidance and through the implementation of best management practices (BMPs) and procedures. Avoidance results from selecting a treatment area already closed to entry and enclosed by ungulate-proof fencing, and by maintaining an application buffer around surface waters. BMPs would include scheduling the application to avoid heavy precipitation events, closely monitoring the application rate, and using licensed applicators with close manager oversight. Army Natural Resources Program and U.S. Department of Agriculture National Wildlife Research Center managers will monitor the bait application rate, the bate availability period, bait condition, water quality, impacts to nontarget species, and the effectiveness of the Proposed Action.

Potential temporary and less than significant negative impacts may include: short-term localized impacts to air quality and the noise environment associated with helicopter operations; and a potential for short-term localized impacts to treatment area soils and surface water from the rodenticide product. Although unintended, there is potential for insignificant impacts to individual nontarget birds within Lihue MU.

The Proposed Action is the only alternative that can satisfy the purpose and need. All possible adverse impacts would be less than significant, and the project would result in substantial beneficial impact for endangered Oʻahu ʻelepaio populations in Lihue MU as well as for other endangered native and endemic species within the management unit.

Consultations with appropriate local and federal agencies have been and will continue to be conducted. Pursuant to Section 7 of the Endangered Species Act (ESA) (16 USC 1531-1544), USAG-HI has consulted with the USFWS regarding the Proposed Action. The USFWS concurred with the USAG-HI determination that the Proposed Action may affect, but is not likely to adversely affect ESA listed species or species proposed for listing. Prior to implementation, USAG-HI will obtain applicable State of Hawaiʻi and U.S. Army authorizations.

PUBLIC REVIEW: The SEA and draft Finding of No Significant Impact (FNSI) were made available for public review and comment on August 8, 2017 when a Notice of Availability was published in the Honolulu Star-Advertiser. USAG-HI issued a Media Release on August 8th as well. The Proposed Action was featured in several television and radio news broadcasts and also received online news coverage. An electronic copy of the draft FNSI and SEA was made available for download at http://www.garrison.hawaii.army.mil/NEPA/NEPA.htm and copies were also made available for public review at the following public libraries: Hawaii State Library, Waialua Public Library, Waianae Public Library, and Wahiawa Public Library.

Twenty-five (25) written comments on the draft FNSI were received within the public comment period. Nineteen (19) comments supported the Proposed Action and three were opposed; three were neutral. The comments are summarized in the Appendix to this FNSI. No substantive issues beyond those already considered in the SEA were identified through public comment. One comment opposed to the Proposed Action expressed concern about "spraying" rodenticide; another included concern with drift. The proposed rodenticide consists of solid pellets and will not be sprayed. It will be broadcast according to label instructions in winds less than 35 mph to avoid drift. One comment suggested updating the SEA reference to Executive Order (EO) 13112 on invasive species. EO 13751 replaced EO 13112 in December 2016. The updated EO includes activities described in EO 13112, albeit with slightly different wording.

CONCLUSION: Based on a careful review of the relevant portions of the 2010 OIP PEA, the Supplemental EA, to include comments received from the public, I have concluded that the Proposed Action to apply diphacinone rodenticide within Lihue Management Unit, Schofield Barracks, O‘ahu, Hawai‘i would not result in significant impacts to either the man-made or natural environment. Therefore, an environmental impact statement is not required and will not be prepared.

Approved By:

Stephen Dawson

STEPHEN E. DAWSON
Colonel, U.S. Army Garrison, Hawai‘i
Commanding

9/14/17
Date

## FNSI APPENDIX

# USAG-HI Public Comment Tracker - Protecting Elepaio Using Rodenticide SEA / draft FNSI

Standard Response:
"This email confirms receipt of your comments on the proposed project to protect endangered Oʻahu ʻelepaio on Schofield Barracks. We greatly appreciate you taking time to review the project documents and provide your feedback. We value the community's input and will not make a final decision on the project until after reviewing public comments."

| # | Report | Date of Comment | Commenter Name | Organization | Comment | Response |
|---|---|---|---|---|---|---|
| 1 | draft FNSI | 8-Aug-17 | Marilyn Bernhardt | Self | Emailed to PAO Box -<br>Strongly oppose spray method to control rats. Advocate "slower but safer method of" placing "hundreds of traps manually" [to avoid harm to nontarget species]. | 8/10 - Emailed standard response |
| 2 | draft FNSI | 14-Aug-17 | Lisa "Cali" Crampton | Kauai Forest Bird Recovery Project | Emailed to PAO Box -<br>Expresses concern for declining elepaio populations and "strong support for a broad-scale aerial application of 0.005% diphacinone rodenticide within the fenced management unit..." | 8/14 - Emailed standard response |
| 3 | draft FNSI | 14-Aug-17 | Gary Schwiter | Self | Emailed to PAO Box -<br>It would be nice if...a grant program could supply the public with discounted traps the homeowner would use to help reduce the overall rat population. (neutral) | 8/15 - Emailed standard response |
| 4 | draft FNSI | 15-Aug-17 | Ryan Chang | Oahu Invasive Species Committee (OISC) | Emailed to PAO Box -<br>"I support the army using broad-scale aerial application of .005% diphacinone rodenticide within the fenced management unit on Schofield. Like stated in the media release it will not only help elepaio but help other endangered flora and fauna." | 8/15 - Emailed standard response |
| 5 | draft FNSI | 23-Aug-17 | Dr. Aaron Hebshi | Self | Emailed to PAO Box -<br>"...writing to express my support for the Proposed Action..." | 8/24 - Emailed standard response |
| 6 | draft FNSI | 23-Aug-17 | Kathy Shimata | Self | Emailed to PAO Box -<br>"...I support your plan to use rodenticides to eliminate the rats that prey on the Elepaio. I have confidence that you will take every precaution to minimize collateral damages." | 8/24 - Emailed standard response |

| # | Report | Date of Comment | Commenter Name | Organization | Comment | Response |
|---|---|---|---|---|---|---|
| 7 | draft FNSI | 24-Aug-17 | Chiemi Nagle | Limahuli Preserve Predator Control Coordinator- National Tropical Botanical Garden | Emailed to PAO Box - "I agree that trapping is not as effective in the mountainous areas of Hawaii due to the severe terrain so the next best option would be an aerial broadcast of diphacinone. I look forward to hearing the Army's final decision and to see the results, if/when completed. " | 8/24 - Emailed standard response |
| 8 | draft FNSI | 24-Aug-17 | Seth Judge | Self | Emailed to PAO Box - "I'd like to express my support for rat control on Oahu in an effort to protect the Hawaiian Flycatcher, the Elepaio…" | 8/24 - Emailed standard response |
| 9 | draft FNSI | 25-Aug-17 | J. Aaron Hogan | Self | Emailed to PAO Box - "I ... express my support for the rat population control project on O'ahu. As a biologist...I can testify to the detrimental effects that invasive species can have on local fauna and flora. ...this project seems well researched, warranted and implementable." | 8/25 - Emailed standard response |
| 10 | draft FNSI | 25-Aug-17 | Katherine McClure | Self | Emailed to PAO Box - "I'm writing...in support for the...rodenticide application on Oahu. The elepaio...represents...native Hawaiian bird diversity that would be terribly sad to lose... The proposed rodenticide seems promising, and I support efforts to increase survival of elepaio using these techniques." | 8/25 - Emailed standard response |
| 11 | draft FNSI | 25-Aug-17 | Creighton M. Litton | UH Manoa - Department of Natural Resources and Environmental Management | Emailed to PAO Box - "I [am] in strong support of the proposed project to protect native, endangered birds at Schofield Barracks with the use of rodenticide...This project has been well planned based on the best available science, and will undoubtedly result in positive benefits to native bird populations with no known negative consequences for the ecosystem." | 8/25 - Emailed standard response |
| 12 | draft FNSI | 27-Aug-17 | James Russell | Self | Emailed to PAO Box - "I am writing a letter in support of this application. I am an international rodent control and eradication on islands expert with 15 years experience…" | 8/28 - Emailed standard response |
| 13 | draft FNSI | 28-Aug-17 | Donald Drake, PhD | UH Manoa - Department of Botany | Emailed to PAO Box - "I am writing to express my support for the proposed initiative to use rodenticide to control non-native rodents on O'ahu to protect native birds, other native wildlife, and native plants." | 8/28 - Emailed standard response |

| # | Report | Date of Comment | Commenter Name | Organization | Comment | Response |
|---|---|---|---|---|---|---|
| 14 | draft FNSI | 23-Aug-17 | Hillary Palmer | Self | Emailed to PAO Box - "I disagree with this proposal...It seems a lot of poison will need to be dropped. How much drift will there be? How will it effect people? You don't know. Please figure out a better way!" (opposed) | 8/24 - Emailed standard response |
| 15 | draft FNSI | 15-Aug-17 | Roland [Chong]? (emailed from "Chong Family" address) | Self | Emailed to PAO Box - Asked how to get a copy of the endangered bird study done for Schofield Barracks. No other feedback or comment. | 15 Aug - Responded with instructions for viewing the documents and offered to mail hardcopy if address supplied. No further contact. |
| 16 | draft FNSI | 29-Aug-17 | Daniel Clark | USFWS Refuge Mgr, Florida Keys National Wildlife Refuges Complex | Emailed to PAO Box - Supportive and applauds Army initiative | 8/29 - Emailed standard response |
| 17 | draft FNSI | 29-Aug-17 | Nicole Galase | Self | Emailed to PAO Box - Supportive of project | 8/29 - Emailed standard response |
| 18 | draft FNSI | 29-Aug-17 | Rachel Moseley | Self | Emailed to PAO Box - "Strongly" Supports project | 8/30 - Emailed standard response |
| 19 | draft FNSI | 29-Aug-17 | Paul Krushelnycky | Self | Emailed to PAO Box - "Strongly" Supports project | 8/30 - Emailed standard response |
| 20 | draft FNSI | 3-Sep-17 | Clare Aslan | Community Ecologist, Northern Arizona University | Emailed to PAO Box - Supportive of project | 9/5 - Emailed standard response |
| 21 | draft FNSI | 4-Sep-17 | Daniel Gruner | University of Maryland Department of Entomology | Emailed to PAO Box - Supportive of project | 9/5 - Emailed standard response |
| 22 | draft FNSI | 6-Sep-17 | James D. Jacobi, PhD | USGS Pacific Island Ecosystems Research Center | Emailed to PAO Box - (On USGS Letterhead) "Fully Support" proposal | 9/6 - Emailed standard response |
| 23 | draft FNSI | 7-Sep-17 | Chris Lowrey | Self | Emailed to PAO Box - "my family and I are very concerned about the impacts of non-native rats on the populations of native wildlife. We understand there is potential for study concerning control of non-native rats, and hope the Army will support these important works as good stewards..." (tallied as neutral since clear support not stated) | 9/7 - Emailed standard response |
| 24 | draft FNSI | 7-Sep-17 | Vince (sirquickwit@aol.com) | Self | Emailed to PAO Box - "We smell corruption…end this cruel dropping of poison!" (opposed) | 9/8 - Emailed standard response. |

| # | Report | Date of Comment | Commenter Name | Organization | Comment | Response |
|---|---|---|---|---|---|---|
| 25 | draft FNSI | 8-Sep-17 | David Smith, DOFAW Administrator | DOFAW - Hawaii DLNR | Emailed to PAO Box (on DOFAW letterhead) - "DOFAW is in support of the efforts described in the proposed action." Offered two suggestions: 1) Update documents to reference EO 13751 (which replaced EO 13112 on invasive species, yet still includes the activities described in EO 13112, albeit with different wording).<br>2) Consider using Bell Labs' DITRAC product which "is also a 50 ppm diphacinone pellet, but utiliizes a new attractant matrix that...has...greater palatability to Pacific rats." | 9/8 - Emailed standard response. Updated EO reference to be addressed in the FNSI. The SEA Proposed Action identifies the rodenticide to be used as D-50, "or a comparable EPA registered and state licensed diphacinone product." FNSI to be made consistent with SEA and include the phrase "or a comparable EPA registered and state licensed diphacinone product." |
| 26 | draft FNSI | 7-Sep-17 | Laura Leialoha Phillips McIntyre, AICP Program Manager, Environmental Planning Office | EPO - Hawaii Department of Health | Emailed on DoH letterhead to PAO Box on 12 Sept. (dated 7 Sept.) - EPO acknowledged receipt of the NEPA documents and provided information on Hawaii environmental laws, including the state requirement to consider health effects. The letter provides information about environmental analysis tools available through state and federal websites. EPO suggests the Army review Clean Water Branch requirements as well. Finally, EPO requests the Army to "utilize all relevant information...to increase sustainable, innovative, inspirational, transparent, and healthy design." | 9/13 - Emailed standard response.<br>USAG-HI DPW is currently working with Hawaii Clean Water Branch. The Army was careful to consider impacts to public health in its analysis, although these effects are not described in a separate section. |

DEPARTMENT OF THE ARMY
U.S. ARMY GARRISON, HAWAIʻI

SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT
for
Protecting Endangered Oʻahu ʻElepaio Using Rodenticide within
Schofield Barracks Military Reservation

Oʻahu, Hawaiʻi

July 2017

PREPARED BY:

18 July 2017

DAVID W. FLUETSCH Date
NEPA Coordinator, Environmental Division
Directorate of Public Works
U.S. Army Garrison, Hawaiʻi

REVIEWED BY:

7/20/17

KENT K. WATASE, PE Date
Director of Public Works, Acting
U.S. Army Garrison, Hawaiʻi

SUBMITTED BY PROPONENT:

18 July 2017

for RHONDA L. SUZUKI Date
Environmental Division Chief
Directorate of Public Works
U.S. Army Garrison, Hawaiʻi

APPROVED BY:

24 Jul 2017

STEPHEN E. DAWSON Date
Colonel, U.S. Army
Commander
U.S. Army Garrison, Hawaiʻi

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Figures



Tables

## ACRONYMS AND ABBREVIATIONS

| | | | |
|---|---|---|---|
| AA | Action Area | $LC_{50}$ | Lethal Concentration to 50% of population |
| a.i. | active ingredient | $LD_{50}$ | Lethal Dose to 50% of population |
| Army | United States Army | LLD | Lowest Lethal Dose |
| BA | Biological Assessment | LOC | Level of Concern |
| BO | Biological Opinion | LOEL | Lowest Observable Effect Level |
| bwt | body weight | MBTA | Migratory Bird Treaty Act |
| CEQ | Council on Environmental Quality | mg | milligram |
| CFR | Code of Federal Regulations | MIP | Mākua Implementation Plan |
| CWA | Clean Water Act | MU | Management Unit |
| CZMA | Coastal Zone Management Act | NAAQS | National Ambient Air Quality Standards |
| D-50 | Diphacinone-50 | NARS | Natural Area Reserves System |
| dBA | decibels on an A-weighted scale | NHPA | National Historic Preservation Act |
| DMR | Dillingham Military Reservation | NOEL | No Observable Effect Level |
| DOFAW | Hawai‘i Division of Forestry and Wildlife | NPDES | National Pollutant Discharge Elimination System |
| DOH | Department of Health | NWRC | National Wildlife Research Center |
| DPW | Directorate of Public Works | OEQC | Hawai‘i Office of Environmental Quality Control |
| EA | Environmental Assessment | OIP | O‘ahu Implementation Plan |
| EIS | Environmental Impact Statement | PEA | Programmatic Environmental Assessment |
| EPA | U.S. Environmental Protection Agency | ppm | parts per million |
| ESA | Endangered Species Act | RQ | dietary risk quotient |
| FGAR | First Generation Anticoagulant Rodenticide | SBER | Schofield Barracks East Range |
| FIFRA | Federal Insecticide, Fungicide, and Rodenticide Act | SBMR | Schofield Barracks Military Reservation |
| FNSI | Finding of No Significant Impact | SEA | Supplemental Environmental Assessment |
| g | gram | SHPD | State Historic Preservation Division |
| GIS | Geographic Information System | SHPO | State Historic Preservation Officer |
| GPS | Global Positioning System | sp. | species |
| ha | hectare | SRAA | South Range Acquisition Area |
| HAR | Hawai‘i Administrative Rules | ssp. | subspecies |
| HDOA | Hawai‘i Department of Agriculture | USAG-HI | U.S. Army Garrison, Hawai‘i |
| kg | kilogram | USC | United States Code |
| KLOA | Kawailoa Training Area | USDA | U.S. Department of Agriculture |
| KTA | Kahuku Training Area | USFWS | U.S. Fish and Wildlife Service |
| L | liter | UXO | Unexploded Ordnance |

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# 1 PROJECT SUMMARY

**Project Name:** Supplemental Environmental Assessment for Protecting the O‘ahu ‘Elepaio Using Rodenticide within Schofield Barracks Military Reservation

**Proposing Agency:** U.S. Army Garrison, Hawai‘i

**Project Location:** Lihue Management Unit, Schofield Barracks West Range, Wai‘anae Mountains, O‘ahu

**Property Owner:** United States of America

**LU Classification**: Conservation, Subzone P (Protective) and R (Resource)

**Anticipated Determination of Supplemental Environmental Assessment:**

A Finding of No Significant Impact (FNSI) is anticipated for the project.

**Agencies Consulted During Supplemental Environmental Assessment Preparation:**

Consulted Parties:

Federal: U.S. Department of Defense - U.S. Army Garrison, Hawai‘i
U.S. Army Garrison, Hawai‘i Directorate of Public Works
U.S. Department of Agriculture, Animal and Plant Health Inspection Service, National Wildlife Research Center
U.S. Fish and Wildlife Service

Figure 1: Failed Nest Due to Rat Predation Credit: © Jack Jeffrey Photography

## 1.1 Introduction

The U.S. Army Garrison, Hawai‘i (USAG-HI) mission is to support military training and readiness. USAG-HI complies with numerous laws and regulations to assess, minimize, and mitigate environmental impacts of its mission. In 2008, the Army completed the Final Implementation Plan for O‘ahu Training Areas or O‘ahu Implementation Plan (OIP) as required by the U.S. Fish and Wildlife Service (USFWS). The OIP identified conservation measures the Army would implement to mitigate for environmental impacts of military training. In 2010, the Army completed a Programmatic Environmental Assessment (PEA) that evaluated potential impacts of the OIP. The 2010 PEA also identified proposed OIP management activities that lacked sufficient information to fully evaluate. One such activity, the broadscale distribution of rodenticide, was described in the OIP as an important tool needed to stabilize certain threatened and endangered species populations including the O‘ahu ‘elepaio, a native forest bird. However, the 2010 PEA concluded more specific project information was needed before the action could be evaluated in the National Environmental Policy Act (NEPA) process.

A specific proposal has now been developed to protect O‘ahu ‘elepaio and other endangered species from invasive rodents within the Lihue Management Unit, Schofield Barracks Military Reservation. Rodenticide would be distributed by helicopter within the Lihue Management Unit (MU) to reduce non-native rat populations that eat native Hawaiian plants and animals. This Supplemental Environmental Assessment (SEA) documents the evaluation of the potential effects of this proposal. It supplements the 2010 OIP PEA and has been prepared in accordance with the National Environmental Policy Act (NEPA).

This supplemental document incorporates information and analyses presented in several other NEPA products developed by the U.S. Army, U.S. Fish and Wildlife Service (USFWS), and Hawai‘i Division of Forestry and Wildlife (DOFAW):

- Programmatic Environmental Assessment for the Final Implementation Plan for O‘ahu Training Areas: Schofield Barracks Military Reservation, Schofield Barracks East Range, Kawailoa Training Area, Kahuku Training Area, and Dillingham Military Reservation. U.S. Army, March 2010 (the 2010 PEA).
- Final Supplemental Environmental Assessment, Lehua Island Ecosystem Restoration Project. USFWS and DOFAW, October 2008.
- Draft Environmental Assessment (EA) for Restoration of Habitat on the Desecheo National Wildlife Refuge through the Eradication of Non-Native Rats. USFWS, December 2015.
- Draft Environmental Assessment for Evaluation of the Field Efficacy of Broadcast Application of Two Rodenticides (diphacinone, chlorophacinone) to Control Mice (*Mus musculus*) in Native Hawaiian Conservation Areas. USFWS, February 2017.

## 1.2 Background

The O‘ahu ‘elepaio is a territorial, non-migratory, monarch flycatcher (Monarchidae) endemic to the island of O‘ahu in the Hawaiian Archipelago (VanderWerf 1998). It is found nowhere else in the world. O‘ahu ‘elepaio were abundant and widespread in forested habitat throughout O‘ahu in the early 20th century, but their numbers have declined steadily. The current geographic range encompasses about 5,187 hectares (ha) and has declined by 75% since 1975 (VanderWerf et al. 2001). ‘Elepaio distribution is fragmented into numerous small populations often isolated by urban and agricultural development (VanderWerf et al. 2001, 2013). In 2012, the total population was estimated to be 1,261 birds, down from 1,974 birds based on surveys in the 1990s (VanderWerf et al. 2013). The O'ahu 'elepaio has been in decline for decades due to low adult survival and low reproductive success resulting mainly from nest predation by rats and introduced, mosquito-borne diseases such as avian pox virus (USFWS 2006, VanderWerf et al. 2006, VanderWerf 2009).

In 2000, U.S. Fish and Wildlife Service (USFWS) granted the O'ahu 'elepaio endangered species status under the federal Endangered Species Act of 1973. USFWS designated critical habitat on O'ahu for the 'elepaio in 2001. Due to the highly negative impact of introduced rats on O'ahu 'elepaio and other natural resources in Lihue Management Unit, the USAG-HI Natural Resources Program has conducted rodent control since 2001 using various techniques including snap traps, automatic traps, and rodenticide bait stations. Ongoing challenges complicate these efforts. Lihue Management Unit is a large area with severe terrain containing unexploded ordnance (UXO). It is located on an active Army training range and is only accessible to natural resource managers 4 to 5 days each month to avoid conflicting with the military training schedule. Army Natural Resources Program managers support isolated populations of rare plants, endangered snails *(Achatinella mustelina)*, and O'ahu 'elepaio *(Chasiempis sandwichensis* ssp. *ibidis)* with a system of small grids of traps and/or bait stations attempting to control rat predation. However, limited access and the intensive nature of servicing these traps and stations means that, in general, they may only be re-baited every 2-6 weeks. This restricted rat control strategy has had limited effect, and rat populations have risen since the program's inception (Kawelo, pers. comm.).

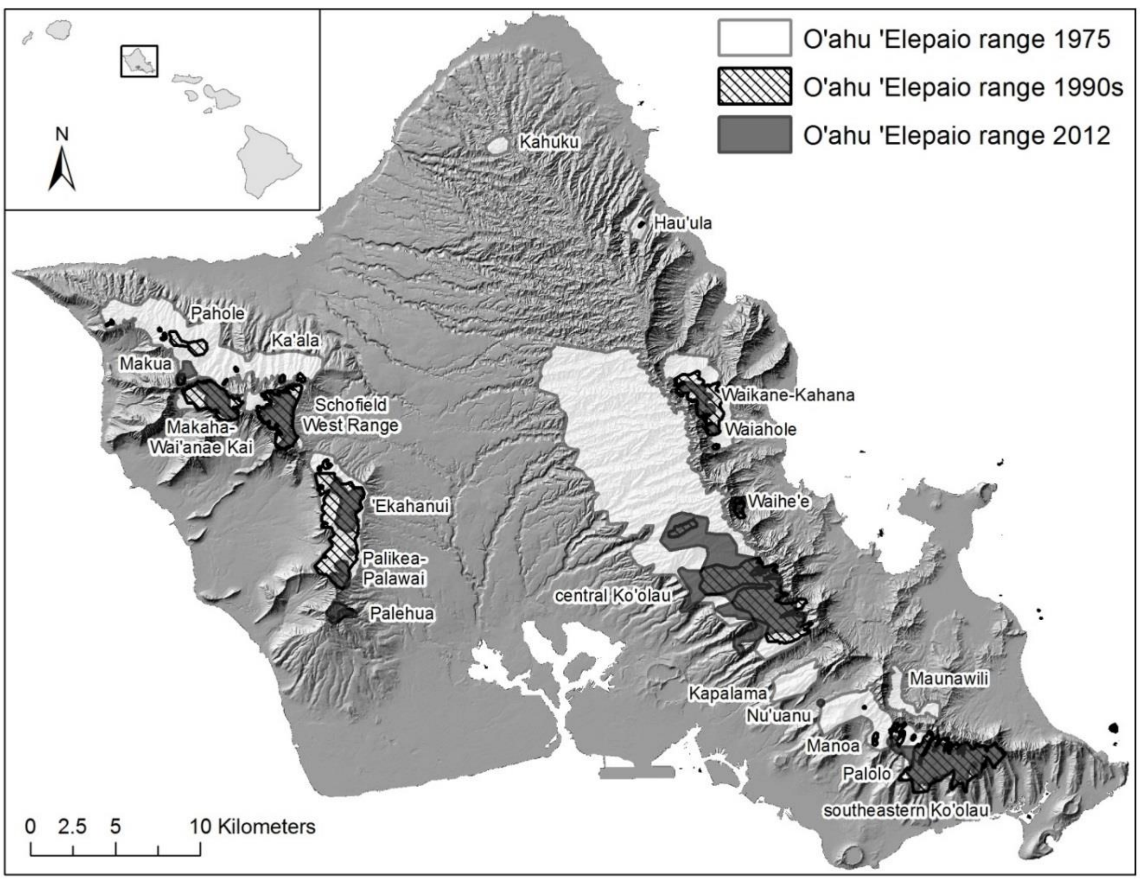


Figure 2: Range of the O'ahu 'Elepaio in 1975, the 1990s, and 2012 (VanderWerf et al. 2013)

In 2003, after the U.S. Army (Army) initiated formal consultation under Section 7 of the Endangered Species Act (ESA; 16 USC 1531 et seq.), the USFWS issued a biological opinion (BO) for the O‘ahu Training Areas, including Dillingham Military Reservation (DMR), Kahuku Training Area (KTA), Kawailoa Training Area (KLOA), Schofield Barracks Military Reservation (SBMR), Schofield Barracks East Range (SBER), and South Range Acquisition Area (SRAA). The 2003 BO concluded that the routine military training and the conservation measures identified by the Army in its O‘ahu Biological Assessment (BA) (Army 2001) would not jeopardize the continued existence of endangered species found within the O‘ahu Action Area (AA), the area of potential impact as defined in the BA. The conclusion of no jeopardy was based on preparation and implementation of both a wildland fire management plan and an O‘ahu Implementation Plan (OIP) for ESA listed species within the O‘ahu training areas.

The 2008 OIP is the result of the 2003 USFWS consultation. The consultation included endangered plant, bird, and tree snail species that may be affected by military training activities on the referenced O‘ahu Army installations. The OIP identified management actions needed beyond those the Army was already implementing to stabilize the endangered target species. OIP goals and geographic scope are described in greater detail in the 2010 OIP PEA.

The 2003 BO also directed the Army to “pursue implementation…and application of a more effective rodenticide including broad scale distribution of rodenticides to improve rat control in remote areas, especially in areas with threatened and endangered species.” Accordingly, the OIP identified aerial broadcast of rodenticide as an important management option to control rat populations and limit predation of endangered O‘ahu ‘elepaio and other endangered species.

The USFWS has been in the process of preparing the Integrated Pest Management Plan (IPM): Programmatic Environmental Impact Statement (PEIS) for the management of invasive rodents and mongoose in Hawai‘i. USFWS intended to complete the PEIS by 2014 and include effects analyses of broadscale rodenticide distribution and the aerial application of rodenticide. Unfortunately, the PEIS has been delayed indefinitely. However, USAG-HI must move forward to achieve the objectives required by the 2003 BO. Consequently, in the absence of a completed IPM PEIS, the evaluation of this Proposed Action is documented with this supplement to the 2010 OIP PEA.

The O‘ahu Implementation Plan outlines the stabilization of numerous endangered species including 23 plant species, one bird species, and 10 snail species. To stabilize these endangered target species, each must be maintained with a sufficient number of separate populations to ensure long-term survival. The OIP also directs that threats to individuals in each population must be controlled, and each species must be adequately represented in *ex situ* (out of the wild) collections.

The 2010 OIP PEA concluded that the long-term benefits of proposed OIP management activities far outweighed the limited short-term negative effects of these management actions. The PEA concluded that implementing the proposed OIP activities would not constitute a federal action that would significantly negatively affect the quality of the environment and a Finding of No Significant Impact (FNSI) was signed. OIP activities included fencing; ungulate control; alien plant, animal, and invertebrate control; alien invertebrate exclosures; collection of endangered snails and plants; reintroductions/augmentations; and erosion control.

The geographic scope of this current analysis is limited mainly to the Lihue Management Unit (MU), an ungulate-proof, fence enclosed unit, located in the northern Wai‘anae Mountains within SBMR. Management units are the focal point for OIP management actions, and typically equate to fenced, ungulate-free areas. Management units were developed to manage designated populations of each target species and appropriate habitat. Most of the rare species involved in the consultation for SBMR in the Wai‘anae Mountains are associated with native-dominated vegetation in mesic (moderately moist) habitats to wet boggy forest at the summit of Ka‘ala. Figure 3 depicts Lihue Management Unit and nearby management units in the Wai‘anae Mountains.

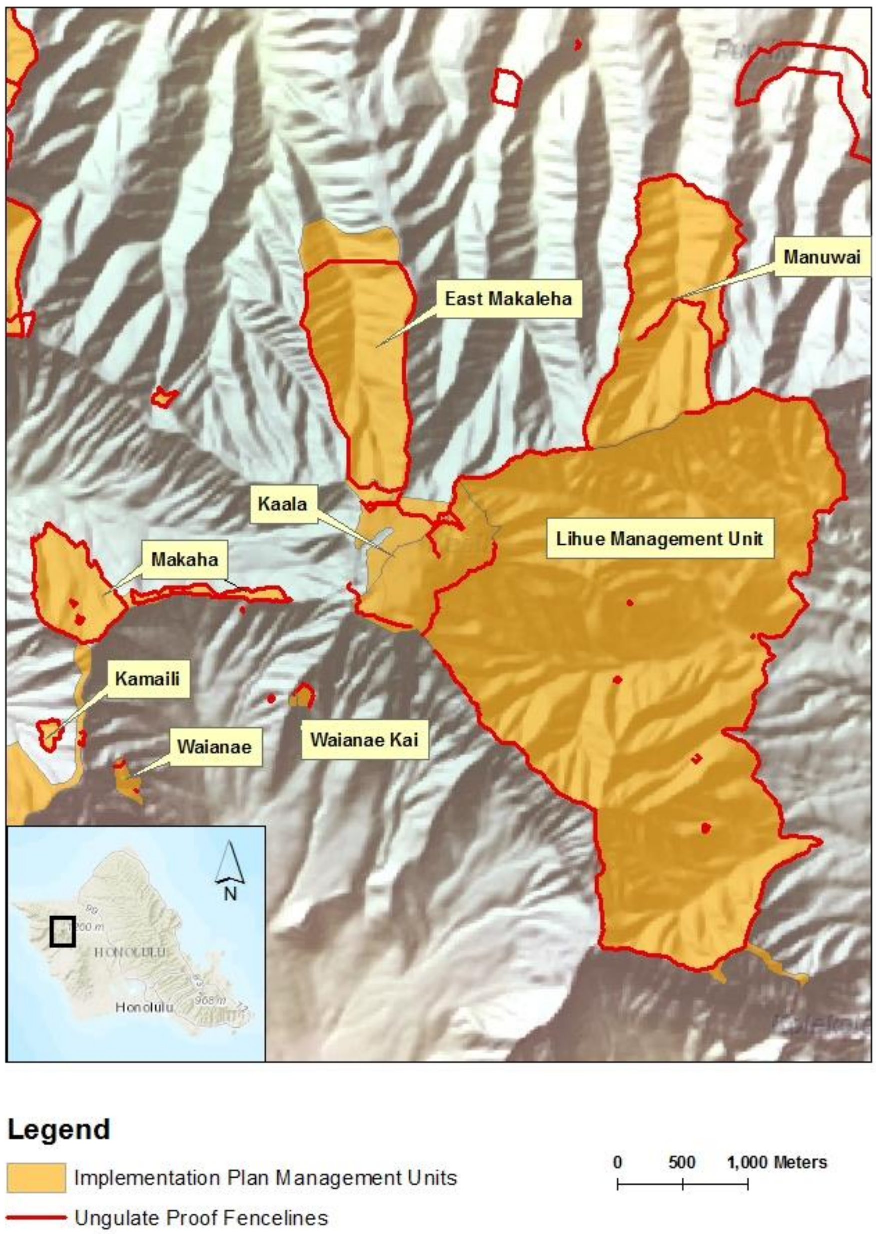


Figure 3: Army Natural Resources Program Management Units in the Northern Wai‘anae Mountains

## 1.3 Public Involvement

The Army provides opportunities for the public to participate in the NEPA process. Persons and organizations having potential interest in the Proposed Action are encouraged to participate in the environmental analysis process. The public may review and provide comments during a 30-day review period for the Supplemental Environmental Assessment (SEA) and draft Finding of No Significant Impact (FNSI). A notice of availability of the SEA and draft FNSI will be published in the State of Hawai‘i Office of Environmental Quality Control’s twice-monthly bulletin, *The Environmental Notice*. A legal notice of availability will also be published in the Honolulu Star-Advertiser. The SEA and draft FNSI will be made available on the USAG-HI website, and provided to local libraries. Copies will be mailed upon request to interested individuals, organizations, and agencies. Comments received during the public comment period will be reviewed by USAG-HI and factored into the Army’s decision-making process.

## 1.4 Decisions to be Made

The Army will use this SEA and other appropriate documents to determine whether:

1. The proposed management actions, as described, might have significant impacts requiring analysis in an Environmental Impact Statement (EIS);
2. No new action should be taken to control rat populations and improve survival of O‘ahu ‘elepaio and other ESA-listed species populations; or
3. The Army should conduct the proposed management actions as described.

This SEA will remain valid, unless either the Proposed Action is so modified and/or new information is available that the effects would be different than those anticipated and documented in this SEA. If the effects would be different, then additional supplemental documentation would need to be prepared.

# 2 PURPOSE OF AND NEED FOR ACTION

## 2.1 Summary of Proposed Action

USAG-HI proposes to conduct the broadscale distribution of rodenticide in the Lihue Management Unit (MU) as part of an integrated management program to control rat *(Rattus rattus, R. norvegicus, and R. exulans)* populations in order to stabilize populations of endangered species as required by Biological Opinions (BOs) issued by the U.S. Fish and Wildlife Service. Army Natural Resources Program managers will continue to employ other rat control measures including deploying snap and automatic traps and hand broadcasting rodenticide within O‘ahu ‘elepaio territories. These activities will complement other population stabilization efforts including: pedestrian and aerial surveying; monitoring; specimen collection; phytosanitation; manual and aerial herbicide application; manual rodenticide and insecticide application; weed control; invasive snail and slug control; invasive reptile/bird control; construction of ungulate exclusion fences (including helicopter drop zones and landing zones) and ungulate control; construction of snail exclosures; construction of cabins, camp sites, water catchments, and weather stations; construction of small radio antennae; and unexploded ordnance (UXO) removal. Detailed descriptions of these management measures are provided in Section 3 of the 2010 PEA.

The rodenticide application would consist of a helicopter, using a specialized suspended bucket, flying along predetermined Global Positioning System (GPS)-plotted transects within the 430 ha treatment area. The rodenticide bait would be broadcast by the rotary spreader bucket as the helicopter flies along these transects. The 430 ha (1063 acre) treatment area is contained within the ungulate-proof fence enclosed 714 ha (1764 acre) Lihue MU. The rodenticide to be used would be Diphacinone-50: Pelleted Rodenticide Bait for Conservation Purposes (EPA Reg. No. 56228-35) containing the anticoagulant rodenticide diphacinone (0.005% active ingredient). Diphacinone-50 has been approved for aerial distribution by the U.S. Environmental Protection Agency (EPA) and the Hawai‘i Department of Agriculture (HDOA).

## 2.2 Purpose and Need

There is a need to ensure the Army is in compliance with ESA and the 2003 BO so it may continue to accomplish its training mission. Specifically, there is a need for the Army to effectively sustain endangered plant and animal populations as stipulated by the 2003 BO. The 2003 BO requires the Army to manage O‘ahu ‘elepaio territories and maintain stable ‘elepaio populations. Fire ignition and introduction of alien and invasive[1] plants and animals are the most important threats to ESA listed plants and animals in the O‘ahu Action Area (CEMML 2003). In particular, introduced rats are primary threats to nesting ‘elepaio (egg and chick predation), endangered snails (direct predation), and rare plant species (fruit and seed predation). The Army needs to control rat predation within O‘ahu ‘elepaio nesting areas to enable higher reproductive success critical to maintaining stable populations.

The Army’s Proposed Action is to conduct broadscale distribution of diphacinone rodenticide in the Lihue Management Unit (MU) to reduce the rat population and predatory pressure on ‘elepaio nesting areas. The aerial broadcast of rodenticide was identified in both the OIP and 2003 BO as the most effective way to limit rat predation on a management unit scale. This activity will complement other ongoing management activities that also help meet OIP objectives.

The purpose of this Proposed Action is to control rat populations on a management unit scale and improve survival rates of O‘ahu ‘elepaio within Lihue MU. Rat predation of O‘ahu ‘elepaio in Lihue MU is preventing the Army from sustaining ‘elepaio population objectives of the 2003 BO. Other means of controlling rat populations have been implemented, including snap traps, automatic traps, bait stations, and limited hand broadcasting of diphacinone rodenticide. These methods are very labor intensive and complicated by the fact that the Lihue MU is only accessible by Army natural resource managers 4-5 days each month during range maintenance week. The lower boundary of Lihue MU borders the upper boundary of the Schofield Barracks West Range ordnance impact area, so at other times, Lihue MU is closed to all entry to prevent conflict with military training activities. Terrain within Lihue MU is severe and difficult to traverse. In addition, the ‘elepaio breeding territories within Lihue MU contain unexploded ordnance (UXO) which severely limits where managers may conduct their activities.

[1] Executive Order 13112 defines an alien species as “any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to [a respective] ecosystem,” and invasive species as “an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.” Therefore, in this SEA, the term “invasive” will be used to mean any nonnative species introduced into an area that causes ecological harm.

## 2.3 Regulatory Overview

A complete discussion of the federal laws and consultations that may be relevant to implementing the Proposed Action appear in Section 2.3 of the 2010 OIP PEA. The Proposed Action would take place solely on federally owned land managed by the Army.

### 2.3.1 National Environmental Policy Act of 1969 (NEPA)

This SEA was prepared by USAG-HI in accordance with NEPA, as implemented by Council on Environmental Quality (CEQ) regulations at 40 CFR 1500-1508 and the U.S. Army's rule governing NEPA, Environmental Effects of Army Actions (32 CFR Part 651). This SEA analyzes the potential impact of the Proposed Action in order to determine whether to sign a FNSI or prepare an EIS.

### 2.3.2 Endangered Species Act of 1973 (ESA)

The ESA, as amended (16 USC 1531 *et seq*.), requires federal agencies to implement programs for conservation of federally listed endangered and threatened plants and animals. Section 7 of the ESA requires federal agencies proposing actions that may affect listed species or critical habitats to first consult with USFWS to ensure they do not jeopardize listed species or destroy critical habitat. The steps taken by USAG-HI to implement the Proposed Action are in accordance with the requirements for federal agency compliance with the ESA.

### 2.3.3 Migratory Bird Treaty Act of 1918 (MBTA)

The MBTA protects over 1000 species of birds, including the species native and not native to Hawai‘i, by implementing U.S. obligations under four treaties within the United States. The MBTA provides that it is unlawful to pursue, hunt, take, capture, kill, possess, sell, purchase, barter, import, export, or transport any migratory bird, or any part, nest, or egg of any such bird, unless authorized under a permit issued by the Secretary of the Interior.

### 2.3.4 National Historic Preservation Act 1966 (NHPA)

The NHPA, as amended (16 USC 470), established both a national policy for preservation of historic properties as well as the National Register of Historic Places. Section 106 of the NHPA requires federal agencies to take into account the effects of federal actions on historic properties, and affords the State Historic Preservation Officer (SHPO) a reasonable opportunity to comment on such undertakings. Hawai‘i implements the NHPA, under the jurisdiction of the Hawai‘i Department of Land and Natural Resources (DLNR), State Historic Preservation Division (SHPD). The SHPD concurred with Section 106 determinations associated with the 2010 OIP PEA. Based on literature reviews and surveys previously conducted, known cultural resources are present within the Lihue MU. However, there is no anticipated potential for impact to these cultural resources from the aerial distribution or broadcast of D-50.

### 2.3.5 Clean Water Act of 1972 (CWA)

The CWA amended the Federal Pollution Control Act of 1948 and is the primary federal law that protects the nation's waters, including lakes, rivers, and coastal areas. The primary objective of the CWA is to restore and maintain the integrity of the nation's waters. The National Pollutant Discharge Elimination System (NPDES) program regulates discharges from pesticide applications consistent with Section 402 of the CWA. The State of Hawai‘i Department of Health (DOH) administers the NPDES program in Hawai‘i.

#### 2.3.6 Coastal Zone Management Act of 1972 (CZMA)

The purpose of the CZMA, as amended (16 USC §1451 *et seq.*), is to encourage coastal states to manage and conserve coastal areas as a unique, irreplaceable resource. The Hawai‘i coastal zone management (CZM) area encompasses the entire state. Federal agency activity that affects land or water use or natural resources of the coastal zone shall be carried out in a manner which is consistent, to the maximum extent practicable, with the policies of approved state management programs. This proposed treatment area is located in central O‘ahu far from the coastline. The Proposed Action is consistent with the CZMA and the Hawai‘i CZM Program to the maximum extent practicable.

#### 2.3.7 Federal Insecticide, Fungicide, and Rodenticide Act of 1947 (FIFRA)

The Proposed Action involves use of the rodenticide diphacinone for controlling invasive rodents. The use of rodenticides and other registered pesticides in the United States is regulated by the U.S. Environmental Protection Agency (EPA) under the FIFRA, as amended in 1972 (7 USC §136). General or specific use of a particular rodenticide formulation must be formally approved by the EPA, with specific use requirements and restrictions identified on the label. Currently, conservation uses in Hawai‘i are allowed under a FIFRA Section 24(c) registration for diphacinone in bait stations (Ramik Mini Bars kills Rats and Mice (SLN No. HI-980005; EPA Reg. No. 61282-26)) and a nationwide label under Section 3 that includes aerial broadcast (Diphacinone-50 (EPA Reg. No. 56228-35)). A Section 24(c) registration and label has been approved and licensed by HDOA for broadcast application of Diphacinone-50 for conservation purposes, such as currently proposed.

#### 2.3.8 Executive Order 13112, Invasive Species

Executive Order 13112 of February 3, 1999, requires federal agencies whose actions may affect the status of invasive species to, subject to the availability of appropriated funds and within Administrative budgetary limits, use relevant programs and authorities to:

- Prevent the introduction of invasive species;
- Detect and respond rapidly to and control populations of such species in a cost-effective and environmentally sound manner;
- Monitor invasive species populations accurately and reliably;
- Provide for restoration of native species and habitat conditions in ecosystems that have been invaded;
- Conduct research on invasive species and develop technologies to prevent introduction of and provide for environmentally sound control of invasive species; and
- Promote public education on invasive species and the means to address them.

The natural resource management actions described within the OIP and this Proposed Action assist the Army in compliance with this Invasive Species Executive Order.

Figure 4: Invasive Rat Eating Bird Eggs Credit: © Jack Jeffrey Photography

# 3 DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

The Proposed Action, as summarized in Section 2.1 and described in detail in Section 3.1, is to conduct the broadscale distribution of Diphacinone-50, or comparably registered and licensed diphacinone product, in Lihue MU of SBMR to control invasive rat populations and thereby limit predation of O‘ahu ‘elepaio eggs and chicks. Reduced predatory pressure during the critical nesting season will improve ‘elepaio reproductive success and support stable ‘elepaio populations within Lihue MU (Figure 5). The Proposed Action is one of a number of management activities already implemented and ongoing to support target species. These other activities are described in Section 3 of the 2010 OIP PEA.

Section 3.2 describes other strategies considered during evaluation of this Proposed Action. The No Action Alternative, in which no new management action would be taken, is considered in this document, and described in Section 3.2.2.1.

## 3.1 Broadscale Use of Rodenticide in Lihue Management Unit (Proposed Action)

The Army is proposing to conduct the broadscale application of rodenticide within the Lihue Management Unit of SBMR. This broadscale application would consist of a helicopter dispersing rodenticide within the treatment area, using a specialized bucket suspended underneath, and flying along predetermined transects. The rodenticide product would be broadcast by the rotary spreader bucket as the helicopter flies along these transects. EPA and the HDOA have approved Diphacinone-50: Pelleted Rodenticide Bait for Conservation Purposes (EPA Reg. No. 56228-35) containing the anticoagulant rodenticide diphacinone (0.005% active ingredient) for this type of conservation use. Diphacinone-50 (hereafter D-50), or a comparable EPA registered and state licensed diphacinone product, would be used in this application. The 430 ha treatment area has been selected to include almost all the ‘elepaio territories contained within an ungulate-proof, fenced enclosure located in the 714 ha Lihue MU.

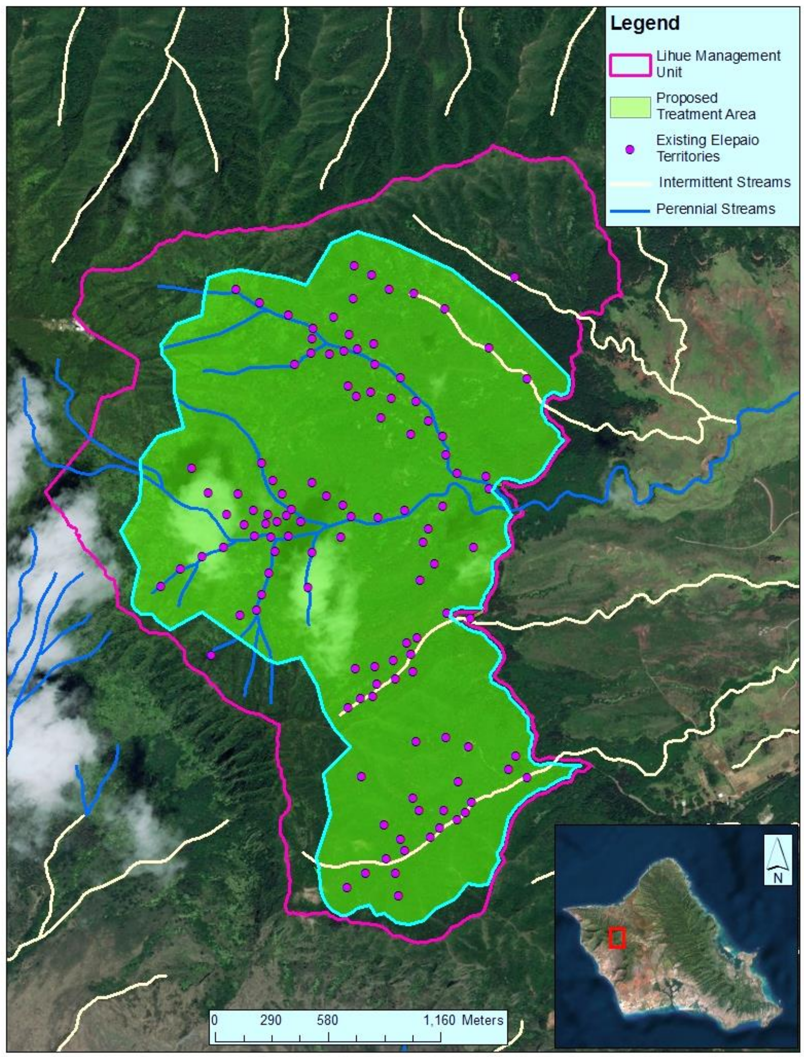


**Figure 5: Proposed Rodenticide Treatment Area – Lihue MU**

USDA APHIS National Wildlife Research Center (NWRC) would purchase and oversee storage and use of the D-50 bait product. The D-50 bait would be applied according to the EPA registered product label. For D-50, a single treatment consists of two applications of rodenticide bait. The applications are typically spaced 5-7 days apart. For aerial distribution or broadcast, rodenticide bait is applied at 11.1-13.8 kg/ha for the first application, and no more than 13.8 kg/ha for the second application, 5-7 days later. In situations where weather or logistics only allow one bait application, a single application may be made at a rate no higher than 22.5 kg/ha. The treatment area consists of 430 ha within ungulate fencing, and completely contained within the 714 ha Lihue MU. The number and duration of flights would be dependent on the size of the bucket available for applying bait. It is anticipated that the entire treatment area would require 2-4 days to complete a single application. Consistent with label direction, the second application would occur 5-7 days after the first application and would follow the same application pattern.

Although not required by label direction, additional measures would be implemented to avoid sensitive areas. Surface waters within Lihue MU will be buffered by 50 feet. For example, flowing streams will be buffered by 50 feet from each bank. All fences will be buffered by 50 feet to ensure that the entire application is contained within the management unit. In some areas of high rodent activity, D-50 may be applied by hand within these buffer areas. Some rats may survive within untreated buffer areas, but it is expected that overall rat populations will be effectively reduced to an acceptable range enabling sustainable 'elepaio territories.

The diphacinone treatment would take place as early as November 2017. The primary weather-related logistical constraints are wind and rain. Rodenticide application will not be conducted in winds higher than 35 mph. For each application day, a forecast of five days and nights without significant rainfall (>13 mm) is preferred (Dunlevy 2007). The treatment would be scheduled for a period with little forecasted rain. If the weather window is too narrow, a single application may be necessary as per label direction. November/December timing coincides with the disappearance of strawberry guava fruit which is one of the major food sources for rats at Lihue (Shiels 2010, Shiels and Drake 2011). Strawberry guava fruiting normally occurs June-October (peaking in September/October), and October/November is generally the beginning of increased rodent activity at other management units as monitored by rat activity tracking tunnels. By late November and December, strawberry guava fruit has disappeared and the lowest seasonal abundance and diversity of alternative foods is available for rats (such as seeds, invertebrates, and vulnerable 'elepaio eggs and chicks). December is also the beginning of 'elepaio breeding season.

Access to Lihue MU must be coordinated with training range managers (Range Control), and the management unit is only accessible via military land. The area is closed to the public and unauthorized entry is not expected. The management

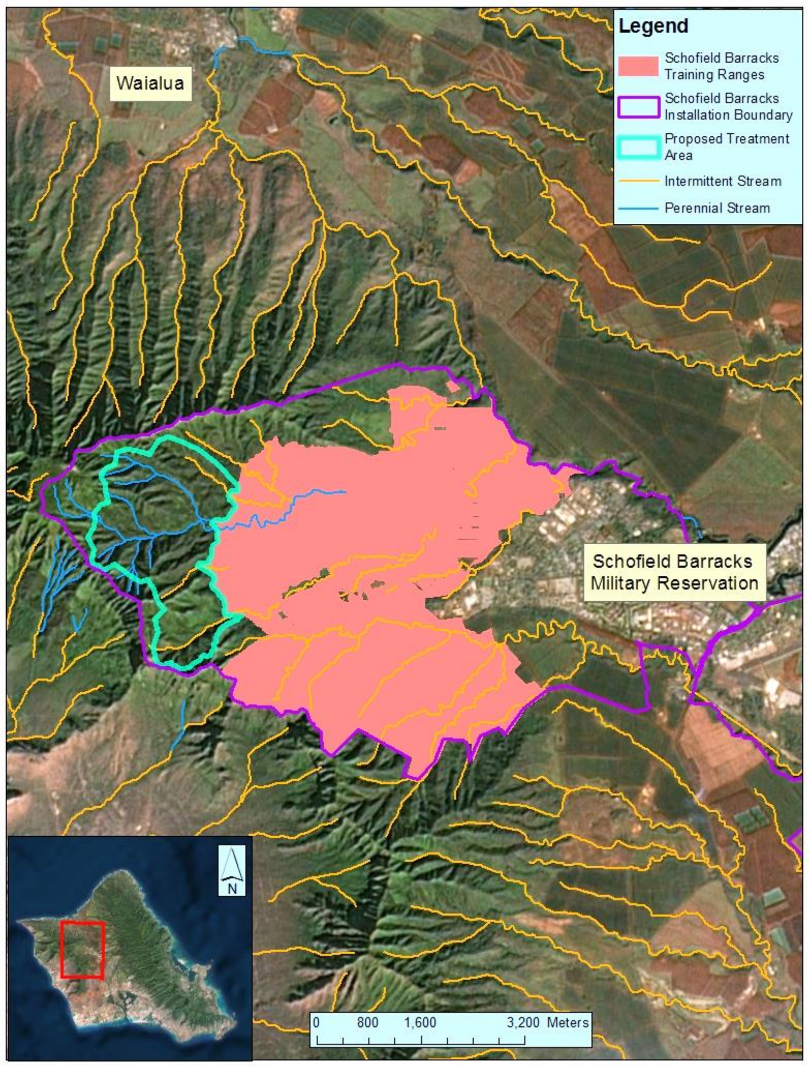


**Figure 6: Proposed Treatment Area and Schofield Training Ranges**

unit is also down range from an active firing range (Figure 6) and authorized access is closely monitored by Range Control. As an added measure to inform authorized personnel, warning signs would be posted along the fence line and on the gates leading to Lihue MU. Signs would include the date of the broadcast and they would remain in place for 2 months following the first bait application.

### 3.1.1 Lihue Management Unit Description[2]

The Proposed Action will take place completely within Lihue MU. Lihue MU is not contiguous with any other management units. Other O’ahu management units are described in the 2010 PEA. Lihue is a large management unit, comprising 714 ha (1,764 acres) at Schofield Barracks West Range within SBMR. The management unit is on the eastern side of the Wai‘anae Range at elevations ranging from 2,000 to 3,500 feet. The majority of the management unit is within the Resource subzone of the Conservation District, with areas in the upper elevations in the Protective subzone (Figure 7). Topography includes ridges and gulches running up to the Ka‘ala summit and northern ridges with moderate to steep slopes on the ridges and gentle to moderate slopes in the gulches. Natural communities include mesic to wet mixed native and introduced forest in the lower elevations, with native wet forest in the higher elevations.

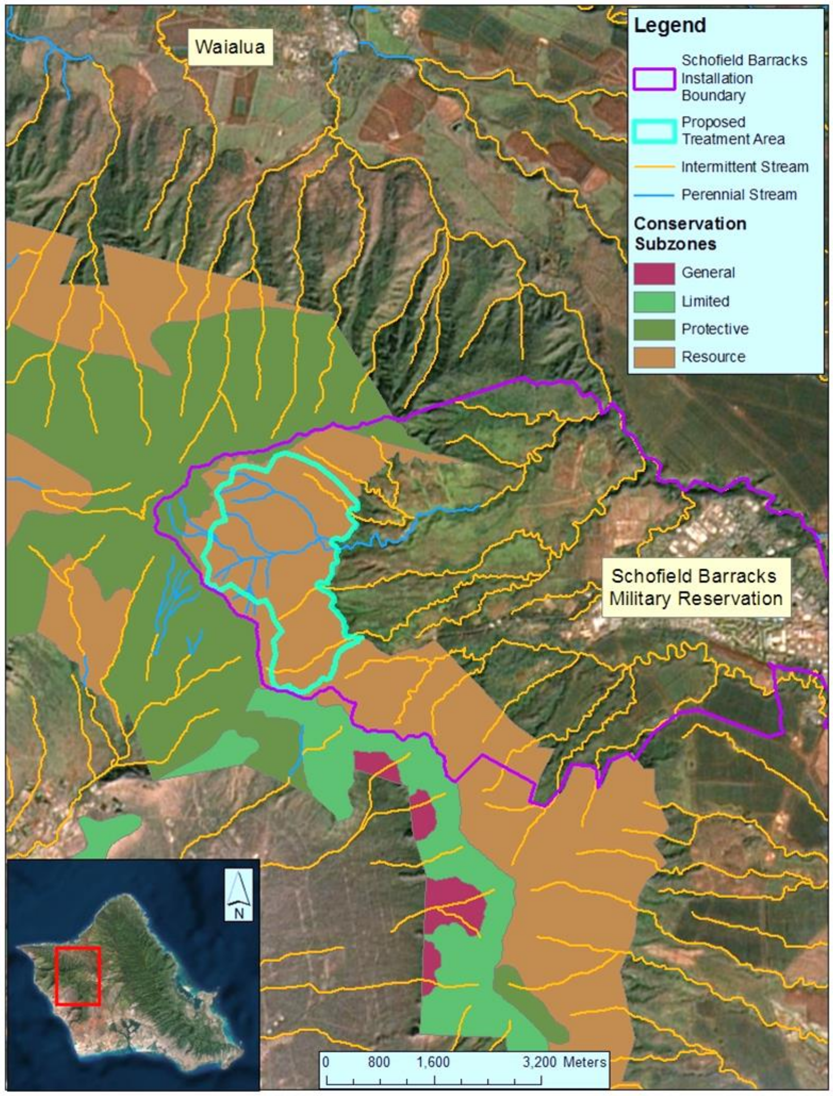


**Figure 7: Conservation District Subzones near Lihue MU**

Lihue MU is surrounded by State of Hawai‘i Forest Reserves to the north and west (Figure 8), the SBMR Military Training Areas to the east (Figure 6), and Lualualei Naval Magazine to the south.

[2] Note that MU acreages in this document do not always correspond exactly to MU acreages listed in the OIP. Since publication of the OIP, additional GPS surveying has been conducted, and MU boundaries have been refined.

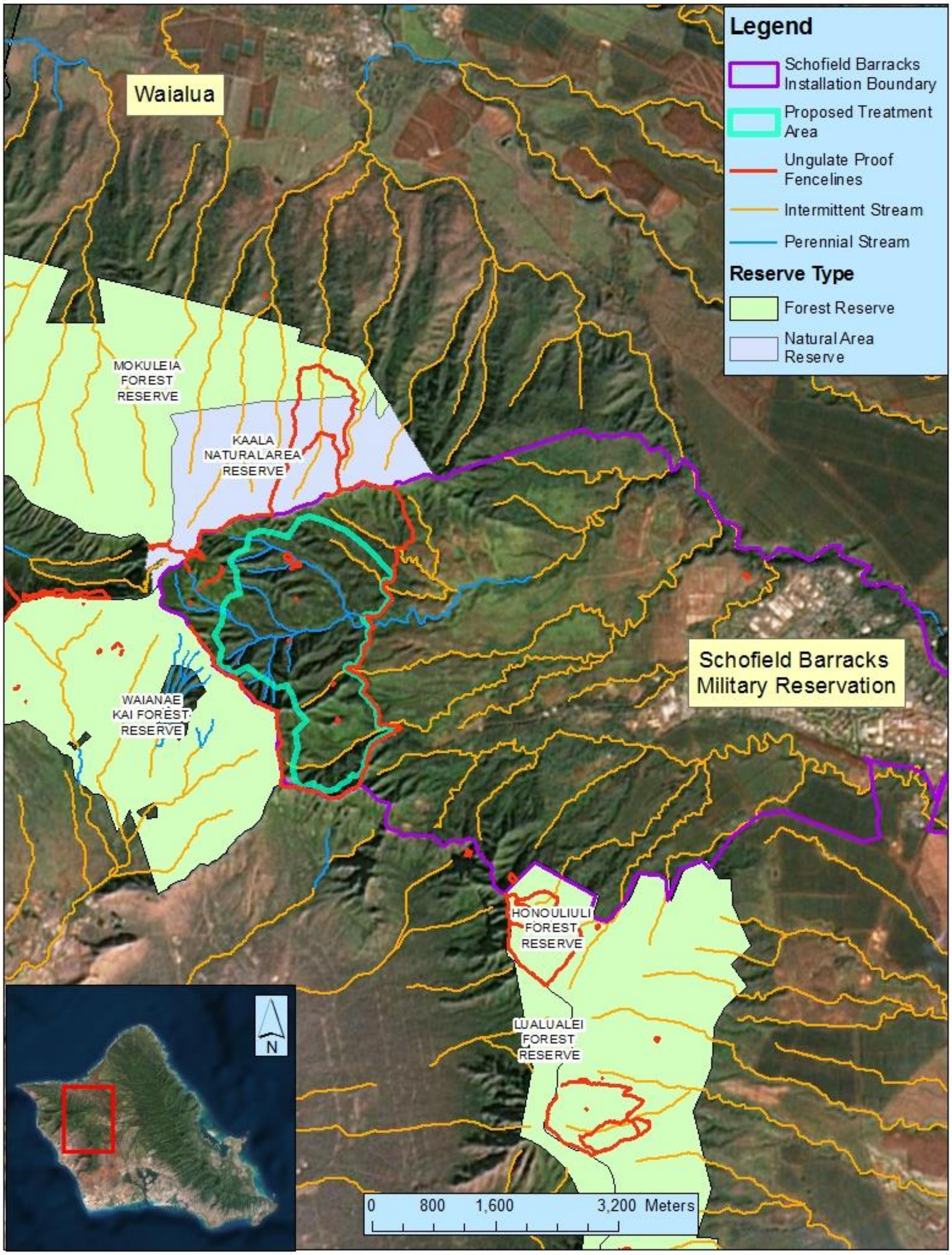


Figure 8: State of Hawai'i Forest Reserves near Lihue MU and Proposed Treatment Area

### 3.1.2 Proposed Management Activities

#### *3.1.2.1 Broadscale Rodenticide Distribution*

Broadscale distribution of rodenticide has been, and continues to be, investigated in Hawai‘i to eradicate rats from remote areas, particularly off-shore islands, where hand distribution of the pelletized rat bait is impossible. The goal of a rodent control operation is not eradication, however. A rodent control operation is intended to reduce rodent populations to acceptably small sizes and to maintain those lower population densities. The purpose of this Proposed Action is to control the rat population within Lihue MU because eradication is not feasible. Rat numbers will again rise as new rats enter from areas bordering the treatment area, but treating a large area like Lihue MU will increase the time rats will take to repopulate the unit from outside. The reduction of overall rat population levels within the management unit will increase trapping effectiveness in managed territories, and rare species should experience substantially longer periods of relief. Without continued treatment, however, rat populations will eventually recover.

A rodenticide treatment would occur when rat reproduction is ramping up (typically winter months). Rat abundance monitoring using tracking tunnels at other sites indicate rat populations are increasing by December due to peak breeding after the fall fruiting season. December is also the beginning of ‘elepaio breeding season when ‘elepaio have vulnerable nesting females, eggs and chicks. Additionally, this preferred treatment period coincides with the lowest seasonal abundance and diversity of alternative foods available for rats, such as seeds and invertebrates. In Lihue MU, aerial rodenticide distribution is the only broadscale means of addressing the spiking rat population threat to nesting ‘elepaio.

A helicopter, using a specialized bucket slung from the base of the aircraft, would fly along predetermined Global Positioning System (GPS)-plotted transects as the bait is distributed in 70 meter-wide swaths. The bait bucket system is comprised of a bait storage compartment, a remotely-triggered adjustable gate to regulate bait flow, and a motor-driven broadcast device that can be turned on (to broadcast bait over a wide swath) or off remotely and independently of the outflow gate. The number and duration of flights would be dependent on bucket capacity and rate of application. The length of time to complete the Lihue MU application within the 430 ha treatment area would depend on how long bucket loading and transect flight operations require, but it is anticipated that it could be completed in two to four days. A second distribution would occur in the same area approximately five to seven days after the first application. If a second distribution is to be made, the entire treatment operation may need to be scheduled when the training range is available for more days than typical months.

Broadscale rodenticide distribution allows for greater bait interaction than bait boxes or mechanical traps (bait boxes deter some individuals from entry; Recht 1988), and thus, potentially, a better control method for suppressing rat populations. In 2012, the USAG-HI Natural Resources Program was forced to halt use of bait boxes because a label change made bait box use unfeasible in Lihue MU. Aerial application of rodenticide may be the most efficient and effective way of adequately controlling the seasonal spike in rat activity within the management unit.

#### *3.1.2.2 Monitoring*

A number of monitoring activities already in place are described in the OIP. Current monitoring relating to the Proposed Action include: (1) assessment of the distribution and status of alien plant and animal species within the management units and in the vicinity of target species population units, (2) assessment of the status and stability of native plant, snail, and bird communities within a management unit, (3) assessment of alien species control methods as related to alien species population levels, (4) bird banding, and (5) snail mark and recapture. Army Natural Resource managers regularly monitor ungulate activity transects to detect feral ungulate ingress and assess the integrity of the ungulate exclosure fence. Monitoring protocols are further described in OIP Chapters 6 (plants) and 9 (snails).

Rat activity is currently monitored at Lihue MU using tracking tunnels. Tracking tunnels consist of ink cards baited and inserted into tunnel boxes. Rodent activity levels are based on foot-tracks in the tracking tunnels. General management objectives for SBMR management units state there should be less than 10% activity levels in rat tracking tunnels. In New Zealand, studies have shown that rat activity levels of 10% are low enough to maintain certain rare bird populations (Innes et al. 1999). A 10% activity level during ‘elepaio breeding season may also be the most achievable level using a broadscale distribution of rodenticide. Under the Proposed Action, rodent monitoring will continue within the proposed treatment area, and also at a control site where no broadscale rodenticide treatment will occur. Comparison of rodent activity at these two sites will help determine the effectiveness of the initial application and subsequent treatments.

### 3.1.3 Diphacinone and Diphacinone-50

Selection of the most appropriate rodenticide for the specific conditions of a project is one of the main decisions for any rodent control project. Rodenticides must be used in the lowest quantity and toxicity which ensures that every rodent is exposed to a lethal dose while minimizing adverse environmental effects, especially impacts to nontarget species. Prudent use is also critical to ensure that regulators will allow effective rodenticides to continue to be made available for future use (Marsh 1985, Cromarty et al. 2002).

Products containing diphacinone, an anticoagulant rodenticide, were first registered for rodent control in 1960 at active ingredient concentrations of 0.005% to 0.01 % (50 to 100 ppm). It is described as a “first generation” rodenticide. Generally “second generation” rodenticides, such as brodifacoum, are both more toxic and more persistent. Diphacinone (0.005% active ingredient) is currently registered for use for conservation purposes in the United States. D-50 rat bait with diphacinone (0.005% active ingredient) has been approved for aerial distribution by the U.S. EPA and the Hawai‘i Department of Agriculture. Diphacinone has been trialed or used with favorable results in a number of landscape-scale rodent control efforts (Dunlevy et al. 2000, Spurr et al. 2003a, Spurr et al. 2003b). Diphacinone is often a preferred rodenticide because of the reduced environmental risk in comparison to other rodenticides such as brodifacoum (Fisher et al. 2003, Eason and Ogilvie 2009). At least 32 successful island rodent eradications have been reported using diphacinone as the primary toxicant (Howald et al. 2007, Island Conservation unpubl. data, cited in USFWS 2015).

The primary advantage of diphacinone as a rodenticide for conservation purposes is the low risk it poses to nontarget organisms in comparison to brodifacoum. Diphacinone has comparatively low persistence in animal tissues; the chemical does not stay very long in the body. This makes toxicity to nontarget species through secondary exposure less likely than for brodifacoum (Fisher 2009).

Diphacinone-50 (D-50) is a cereal bait product, available in 1-2 g pellets, with an added fish flavor. The bait contains 0.005% diphacinone. D-50 pellets are dyed green, which has been shown to make pellets less attractive to some birds and reptiles (Pank 1976, Tershy et al. 1992, Tershy and Breese 1994). D-50 bait product is similar to commercially available Ramik®Green bait products, however D-50 is licensed by the State of Hawai‘i and labeled to allow aerial broadcast for "control of invasive rodents for conservation purposes on islands." (D-50 Product Label, Appendix B.) The label also stipulates that D-50 may only be purchased by USDA APHIS Wildlife Services, USFWS, or NPS and used by Certified Applicators or persons under their direct supervision.

The physiological action of diphacinone is the same as for other anticoagulants such as brodifacoum; diphacinone interferes with the blood's clotting ability and causes profuse bleeding. Although diphacinone can be lethal to some rats when administered in a single, large dose, it is relatively more potent in small doses administered over several days (Buckle and Smith 1994, Timm 1994). Several properties indicate that diphacinone generally takes longer than other anticoagulants to accumulate in a rodent and achieve a lethal dose. $LD_{50}$, or a single dose that is lethal to 50% of the test subjects in a population or study group, is a measure of acute oral toxicity. Single lethal doses of 1.93 - 43.3 mg/kg have been reported for laboratory rats, but doses of < 1 mg/kg over five successive days are more effective (Hone and Mulligan 1982, Jackson and Ashton 1992). Jackson and Ashton (1992) reported $LD_{50}$ values over a five-day period of 0.21 and 0.35 mg/kg/day in domestic and wild Norway rats respectively. Tobin (1992) demonstrated that for mortality to occur, black and Polynesian rats required a mean of 8.6 mg/kg (11.8 - 28.4 g of pellet) and Norway rats required a mean of 10 mg/kg (34.6 g pellet) ingested over an average of six to seven days, with a range of between four and 12 days.

From an operational perspective, diphacinone bait should be available to all rats for 10 - 12 days. This requires that (a) the bait is highly attractive to rats to ensure that rats prefer it above natural food items, (b) that sufficient bait is available daily to ensure rats frequently encounter bait within their environment, and (c) that the consistent bait uptake in the environment through ingestion by rats, other animals, and degradation by invertebrate, microbial and other environmental action does not diminish the amount of bait available below sufficient daily ingestion levels for rats (USFWS 2015).

According to the Extension Toxicology Network[3], diphacinone has a low potential to leach in soil, and is rapidly decomposed in water by sunlight. Diphacinone is slightly toxic to birds. The $LD_{50}$ for diphacinone in mallard ducks is 3,158 mg/kg, and in bobwhite quail is 1,630 mg/kg. Diphacinone is moderately toxic to fish species. The 96-hour lethal concentration for half the exposed subjects ($LC_{50}$) for diphacinone in channel catfish is 2.1 mg/L, in bluegills is 7.6 mg/L, and in rainbow trout is 2.8 mg/L. The 48-hour $LC_{50}$ in Daphnia, a small freshwater crustacean, is 1.8 mg/L. Studies with cattle indicate a high degree of tolerance for the compound. Ramik, the rodenticide most commonly used by natural resource managers, contains 0.005% diphacinone.

From the perspective of nontarget risk, diphacinone is the optimum choice of registered rodenticides for natural areas in Hawai‘i. Laboratory trials have indicated that diphacinone has low toxicity to birds when compared with brodifacoum (Erickson and Urban 2004, Eisemann and Swift 2006). Recent research suggests that the toxicity of diphacinone to some birds may be considerably higher than previously thought (Rattner et al. 2010), yet overall, the toxicity of diphacinone still remains low compared with brodifacoum.

[3] Extension Toxicology Network is a pesticide information project of cooperative extension offices of Cornell University, Oregon State University, the University of Idaho, and the University of California at Davis and the Institute for Environmental Toxicology, Michigan State University funded by USDA. http://extoxnet.orst.edu/pips/diphacin.htm. Accessed October 13, 2009.

Bait palatability is another important aspect important for successful rat control and eradication. In field trials, the products Brodifacoum-25D and Ramik® Green (comparable to D-50) have both been shown to be preferred by most rats over locally available natural food sources (Pitt et al. 2011). While bait product choice is an important component of control efficacy, the most important component is the methodology used for bait delivery. Success is most often a function of how many rats within the target area are exposed to a lethal dose. Aerial broadcast of diphacinone is the most promising methodology for controlling rat populations within Lihue MU due to the large size of the management area, the brief and infrequent access windows for land management personnel, its severe terrain, UXO hazard, and low risk to nontarget species.

Issues and Concerns

- *Impacts to Soil and Water from the presence of the toxicant.*

Impacts to Soil and Water are addressed in the Affected Environment and Environmental Consequences Sections 4 and 5, respectively. Surface waters within the treatment area would be buffered by 50 feet. No rodenticide would be aerially broadcast within the buffered areas.

- *Impacts to the Marine Environment from the presence of the toxicant.*

Impacts to Water Resources are addressed in the Affected Environment and Environmental Consequences Sections 4 and 5, respectively. The Proposed Action would take place on Army owned land far from the ocean, in the Waiʻanae Mountains above Schofield Barracks. Haleʻauʻau Stream flows out of the treatment area through the Schofield Barracks West Range Impact Area and becomes intermittent (dries up) before leaving Schofield Barracks. No impacts associated with the Proposed Action have the potential to affect the marine environment.

- *Impacts to Birds and Reptiles*

Rat control activities would include the use of a toxicant that is lethal to rats. The impact of the toxicant to species other than rats or mongoose (another invasive rodent species approved to control with diphacinone bait in Hawaiʻi), and the persistence of the toxicant in the environment are important environmental issues related to impacts of the action to biological resources because animals other than rodents, including reptiles and birds, could ingest the toxicant either directly or indirectly. D-50 pellets are dyed green, which has been shown to make pellets less attractive to some birds and reptiles (Pank 1976, Tershy et al. 1992, Tershy and Breese 1994). No native reptiles are found in Hawaiʻi and several introduced species, including the Jackson chameleon have adverse impacts to rare endemic species in the Waiʻanae Range near Lihue MU (Chiaverano and Holland 2014). Even so, impacts to invasive reptile species are not expected to be significant due to their relatively low numbers in Lihue MU. The impact to birds is also of concern because many birds are known to be physiologically sensitive to anticoagulant rodenticides (Erickson and Urban 2004). In a recent hand-broadcast diphacinone study conducted in the Waiʻanae Range at Kahanahāiki, several common bird species survived and appeared healthy after some diphacinone ingestion (Shiels 2017). Overall, bird survival would benefit from reduced rodent predation.

Risk of rodenticide poisoning for an animal is based on both the toxicity of the chemical and its exposure to the chemical. Exposure can arise from directly ingesting the rodenticide (i.e., primary exposure) or eating an animal that has ingested the rodenticide (i.e., secondary exposure). Toxicity is taxa specific and is determined by the quantity of active ingredient (a.i.) for a given body weight (bwt) to achieve a certain effect, usually measured as milligrams active ingredient (mg a.i.) / kilogram (kg) bwt. Toxicity is most frequently represented as the $LD_{50}$ and $LC_{50}$. $LD_{50}$ is the chemical dose where 50% of the test animals died and is usually administered as a single dose. $LC_{50}$ is the concentration of the chemical in feed where 50% of the test animals died and the test is usually administered over a multi-day period (e.g., five to 10 days). A third measure of toxicity is the LLD, the lowest lethal dose of a chemical at which a test animal died. The lower the $LD_{50}$, $LC_{50}$, or LLD value, the more toxic the chemical, or more sensitive the species. $LD_{50}$, $LC_{50}$, and LLD measure the lethality of a chemical to the subject species. Toxicants are also evaluated by their sublethal effects on animals. These are represented by metrics, such as NOEL (no observable effect level) and LOEL (lowest observable effect level). NOEL is the highest dose or exposure level of a toxicant that produces no measureable toxic effect on the test group of animals and LOEL is the lowest dose or exposure level of a toxicant that produces a measurable toxic effect on the test group of animals. Sublethal effects observed in the anticoagulant acute oral studies included lethargy, subcutaneous, intramuscular, and internal hemorrhaging, piloerection, diarrhea, bloody diarrhea, and anorexia (Anderson et al. 2011).

Individual species of birds and mammals vary in their relative sensitivity (i.e., the toxicity) to different rodenticides. For mammals, diphacinone is considered "very highly toxic" as measured by acute oral toxicity ($LD_{50}$) and dietary toxicity ($LC_{50}$) (Anderson et al. 2011). For birds, the acute oral and dietary toxicity of diphacinone is considered "slightly toxic" and "moderately toxic," respectively. The Shiels (2017) hand-broadcast diphacinone study observed that some birds gained exposure, but there appears to be very little chance of mortality at these application rates.

- *Impacts to Visitors and Recreation*

Lihue MU is closed to the public. It is within SBMR and it is part of an active Army training range. Access is closely controlled due to potential conflict with training activities and unexploded ordnance hazards.

- *Impacts to Historical and Cultural Resources.*

Based on literature reviews and surveys previously conducted, known cultural resources are present within the Lihue MU. However, there is no potential to impact these cultural, archaeological or historic resources by implementing the Proposed Action.

## 3.2 Alternatives Considered

### 3.2.1 Basis for Considering only the No Action and Proposed Action Alternatives

This Proposed Action was first included as a requirement in the 2003 BO and then more specifically described in the 2008 OIP. The 2003 BO stated "the Army will pursue implementation and funding for the licensing and application of a more effective rodenticide including the broad scale distribution of rodenticides to improve rat control in remote areas, especially in areas with threatened and endangered species." The 2008 OIP resulted from a ten year process of extensive development by both the Mākua and Oʻahu Implementation Teams, with substantial input from participants including the U.S. Army, USFWS, State of Hawaiʻi, Nature Conservancy of Hawaiʻi, University of Hawaiʻi, U.S. Geological Survey, Oʻahu Plant Extinction Prevention Program, and independent botanists and ornithologists. It repeats the need to pursue "implementation of broad scale application of rodenticide in areas with threatened and endangered plants and animals." During OIP development and the subsequent NEPA evaluation, multiple landowners were consulted, including the U.S. Army, State of Hawaiʻi, the City and County of Honolulu, and private landowners. The OIP was grounded in extensive experience with natural resource management actions, in particular threatened and endangered species protection.

The regulations implementing NEPA state that an environmental assessment must include alternative ways of meeting the need only if the project would involve “unresolved conflicts regarding alternative uses of resources of concern” (section 102(2)(E) of NEPA). This Proposed Action would take place in an area designated for conservation and watershed protection; therefore, there are no unresolved conflicts regarding alternative uses of resources of concern. As described below, an alternative that would solely use hand-broadcasting of rodenticide within Lihue MU was eliminated from consideration because it would not effectively meet the need to control rat populations on a broad enough scale to sufficiently aid Oʻahu ʻelepaio populations. No additional effective means of meeting the project objectives are known at this time. Therefore, no additional alternatives except the “No Action” alternative will be considered in this SEA.

### 3.2.2 Alternatives to be Evaluated in this Analysis

The Proposed Action and No Action alternatives will be evaluated in this document. The Proposed Action is described in Section 3.1.2.

#### *3.2.2.1 No Action Alternative*

Under the No Action Alternative, the Army would not implement the Proposed Action. The No Action Alternative represents a baseline activity level in which broadscale distribution of rodenticide would not be conducted. The No Action Alternative serves as a baseline against which to assess the environmental impacts of the Proposed Action. In accordance with CEQ regulations, the No Action Alternative is included to compare its impacts with the action alternatives (40 C.F.R. § 1502.14(d)). The No Action baseline in this analysis means that the Army will compare the environmental impacts of not conducting broadscale distribution of rodenticide with the impacts of applying diphacinone rodenticide from helicopter-borne buckets. Selection of the No Action Alternative would mean that the Army would not proceed with the Proposed Action.

### 3.2.3 Alternatives Eliminated From Further Consideration

#### *3.2.3.1 Hand Broadcast of Rodenticide*

An alternative to applying rodenticide by helicopter would be to apply rodenticide solely by hand which involves field technicians walking a grid of trails while evenly distributing rodenticide bait. At Lihue, bait would be spread 10 meters in all directions from locations spaced every 20 meters along the trails to each territory. This would provide continuous baiting 10 meters from each side of the trail throughout the trail system. The application rate at each “broadcast location” would be 13.8 kg/ha. Staff would use pre-measured bait containers for each location and broadcast the product by hand uniformly throughout the area. No bait would be cast into water.

UXO are present throughout Lihue MU and limit overland hiking. Due to area logistics, including difficult terrain, UXO safety and application costs, a hand broadcast method would only be applied along UXO cleared trails. This would severely limit the amount of area that could be treated and thus limit its effectiveness in controlling rat populations on a management unit scale. Using this hand-broadcast method, the total area treated would be ~33 ha. The linear treatment patterns would be narrow corridors surrounded by untreated territory. Re-invasion by rats would be very rapid and the temporary suppression achieved would be minimal. At Kahanahāiki Management Unit a hand-broadcast application was conducted over a 20 ha area and rat activity levels registered in the tracking tunnels were higher than pre-broadcast levels just 2 months after treatment. This method would require a re-broadcast interval of every 2-3 months, demanding significantly more staff time and increasing the potential for unsafe contact with UXO. To achieve effective population control for a longer period of time a larger area must be treated.

Hand broadcasting rodenticide to suppress rat population for such a short period would be insufficient to enable Army compliance with the USFWS 2003 BO for the O‘ahu Training Areas. This could force the Army to restrict training options on O‘ahu. O‘ahu ‘elepaio may continue to decline in numbers due to the threats they face, which could ultimately lead to their extinction. For these reasons, USAG-HI has determined the hand broadcast alternative would not meet the need to effectively sustain ‘elepaio populations in accordance with the 2003 BO, and it was eliminated from further consideration.

# 4 AFFECTED ENVIRONMENT

This section describes the environmental resource areas which may be affected by the Proposed Action and No Action Alternative. More information about the existing environment affected by Army training and management activities throughout O‘ahu is included in the 2010 OIP PEA.

## 4.1 Topography and Soils

Elevation ranges and topography are described for each management unit in Section 3.2.1 of the 2010 PEA and management unit locations are shown on Figures 1a – 2b of the 2010 PEA.

### 4.1.1 Wai‘anae Range Management Units

For the management units found in the Wai‘anae Range near SBMR (Lihue, Ka‘ala, Manuwai, and East Makaleha), Tropohumults-Dystrandepts soils are common in the mountainous areas. Areas of the Lihue MU consist of Helemano Silty Clay with 30 to 90% slopes. Soil erosion is locally significant in areas where natural drainage and gulches occur; however, the dry climate and lack of permanent streambeds may reduce the risk of erosion, as well as in areas where soils are not as well developed because of exposed lava.

## 4.2 Water Resources

### 4.2.1 Groundwater Resources

On O‘ahu, there are six groundwater aquifer sectors (Honolulu, Pearl Harbor, Wai‘anae, North, Central, and Windward). Aquifer sectors reflect broad hydrogeological similarities, yet maintain traditional hydrographic, topographic, and historical boundaries. Aquifer systems, subsets of aquifer sectors, are more specifically defined by hydraulic continuity among aquifers in the system (Yuen 1990). The 2010 PEA describes the characteristics of these aquifers in greater detail. All of the aquifer systems overlain by the OIP management units share the characteristics of being fresh water, irreplaceable, and highly vulnerable to contamination. Lihue MU overlays parts of two aquifer systems: Mokulē‘ia (in the North Sector) and Wahiawa (in the Central Sector). The Wahiawa Aquifer is currently used for drinking water.

### 4.2.2 Surface Water Resources

There are many ephemeral drainages and intermittent streams which flow from upper elevations through the management units in the Wai‘anae and Ko‘olau mountains. These streams generally flow during precipitation events and for a short period thereafter. Hale‘au‘au is the sole perennial stream located within the Lihue MU Treatment Area. It flows east from Lihue MU directly through the SBMR Impact Area which contains a wide range of both exploded and unexploded ordnance. Before leaving SBMR, Hale‘au‘au Stream percolates to the water table and becomes an intermittent stream that flows only during substantial precipitation events. Hale‘au‘au sometimes disappears above the firebreak road on the upper side of the SBMR Impact Area. Hale‘au‘au Stream is part of the Kaukonahua Watershed that eventually empties into Kaiaka Bay, Waialua. Figure 8 depicts surface waters related to the Lihue MU.

The State of Hawai‘i DOH Clean Water Branch assigns surface water quality standards based on the CWA requirements. Surface waters, generally ephemeral streams in the uppermost portions of the Wai‘anae and Ko‘olau mountains, are classified as Class 1 (Inland Freshwater) water (HAR 11-54-3). The objective of Class 1 waters is that the waters remain in their natural state as nearly as possible with an absolute minimum of pollution from human-caused sources. Conduct resulting in demonstrable increases in point or nonpoint source contamination is prohibited. Hale‘au‘au Stream and other ephemeral streams in Lihue MU are designated Class 1 waters.

## 4.3 Climate/Air Quality

The State of Hawai‘i DOH Clean Air Branch monitors the ambient air in the state of Hawai‘i for gaseous and particulate air pollutants. The U.S. EPA has set national ambient air quality standards (NAAQS) for six criteria pollutants: carbon monoxide, nitrogen dioxide, sulfur dioxide, lead, ozone, and particulate matter (40 CFR Part 50), and Hawai‘i has established state standards for the criteria pollutants plus hydrogen sulfide (HAR 11-59) which are as stringent or more stringent than the NAAQS. The island of O‘ahu is an attainment area for the NAAQS and state standards. The nearest air monitoring stations on O‘ahu are in industrial areas on the south and southwest coast of the island. The proposed treatment area is within undeveloped, naturally forested mid-slope mountainous terrain; there are no man-made structures or emission sources.

## 4.4 Noise Environment

The State of Hawai‘i DOH Indoor Radiological Health Branch has promulgated Community Noise Control rules (HAR 11-46) which define maximum permissible sound levels for various zoning districts. The Lihue MU is located in a Class A zoning area, which includes lands zoned residential, conservation, preservation, public space, open space, or similar. Maximum permissible sound levels in dBA (decibels on the A-weighted scale) for Class A zoning districts are 55 dBA daytime (0700 to 2200) and 45 dBA nighttime (2200 to 0700), measured at the property line. According to HAR 11-46-4(c), noise levels shall not exceed the maximum permissible sound levels for more than 10% of the time within a twenty minute period, except by permit or variance.

Generally, little ambient noise is produced from within the management units, as they are far removed from residential or agricultural areas, and there are no man-made structures or sensitive noise receptors (such as schools, hospitals, or churches). Management units adjacent to training areas may receive occasional noise from vehicles, aircraft, artillery, and human activity.

## 4.5 Biological Resources

Biological resources (endangered plants, birds, and snails) are described in extensive detail in the OIP. The descriptions of these resources in this document are derived from the OIP. Many non-native species are also found in Lihue MU. The species within Lihue MU that are listed as endangered or threatened under the Endangered Species Act are found in Table 1.

**Table 1. ESA Listed Endangered Plants and Animals Found in Lihue Management Unit**

| Plants | Common Name | Animals | Common Name |
|---|---|---|---|
| Alectryon macrococcus macrococcus | māhoe | Drosophila montgomeryi | picture wing fly |
| Asplenium dielfalcatum | | Drosophila substenoptera | picture wing fly |
| Chrysodracon forbesii | halapepe | Drosophila obatai | picture wing fly |
| Cyanea calycina | haha | Chasiempis ibidis | O'ahu 'elepaio |
| Cyanea grimesiana obatae | haha | Achatinella mustelina | kāhuli (O'ahu tree snail) |
| Delissea waianaeensis | | Lasiurus cinereus semotus | ōpe'ape'a (Hawaiian hoary bat) |
| Flueggea neowawraea | mehamehame | | |
| Gardenia mannii | na'u, nanu | | |
| Hesperomannia oahuensis | | | |
| Labordia cyrtandrae | kamakahala | | |
| Lepidium arbuscula | anaunau | | |
| Nothocestrum latifolium* | aiea | | |
| Phyllostegia mollis | | | |
| Platydesma cornuta var. decurrens | | | |
| Pteralyxia macrocarpa | kaulu | | |
| Schiedea hookeri | | | |
| Schiedea kaalae | | | |
| Sicyos lanceoloidea | anunu | | |
| Stenogyne kanehoana | | | |
| Plantago princeps | laukahi kuahiwi, 'ale | | |
| Tetramolopium filiforme | | | |
| | | | |
| *Threatened | | | |

### 4.5.1 Flora

A variety of native species and habitats exist in the Wai‘anae and Ko‘olau mountains. The Wai‘anae mountains contain a significant portion of the rare plant taxa in the Hawaiian Islands. OIP target plants are ESA listed endangered species endemic to the Hawaiian Islands (see OIP Table 5, p. 45), and the majority of the target species are endemic to O‘ahu alone. Many species are endemic to their respective mountain range and are some of the state’s rarest species. Most of the rare Wai‘anae species are associated with native-dominated vegetation in mesic (moderately moist) habitats to wet boggy forest at the summit of Ka‘ala.

### 4.5.2 Fauna

Target faunal species are listed in OIP Table 6 (OIP, p. 46). Animal life in the upper elevations of the Ko‘olau and Wai‘anae mountains generally consists of a majority of non-native and a few native bird species, and large and small non-native mammals such as feral pigs, feral goats, mongooses, rats, and mice.

#### *4.5.2.1 Birds and Mammals Present in Lihue Management Unit*

Several species of native and non-native birds and mammals present in the Wai‘anae Mountains are protected under the ESA, MBTA, or State of Hawai‘i statutes. The Hawaiian hoary bat (*Lasiurus cinereus semotus*) is one such species. Hoary bats populations are thought to be increasing on O’ahu but no hoary bats have been observed in Lihue MU. Hawaiian hoary bats have been detected along the SBMR Impact Area firebreak road using echolocation bat detectors. It is impossible to determine the number of bats utilizing SBMR with the tools available, thus the Army can only conclude that bats are present within SBMR. Feral pigs are common in the Wai‘anae mountains, however, the Lihue MU ungulate-proof fence keeps feral pigs or goats out of the management unit. Monitoring activities are ongoing to ensure no ungulates enter or remain within the Lihue MU exclosure.

Native bird species such as the ‘amakihi (*Hemignathus flavus*) ‘i‘iwi (*Vestiaria coccinea*) and ‘apapane (*Himatione sanguinea*), members of the honeycreeper family, have been observed at high elevations in the Wai‘anae mountains, and may be present in Lihue MU. The ‘i‘iwi (*Vestiaria coccinea*) is being proposed for ESA listing and is still found in some forested areas on O'ahu, but it is rare. The last time an ‘i‘iwi was observed in Lihue MU was in 1999 (Kawelo, pers. comm.). The O‘ahu ‘elepaio (*Chasiempis ibidis*) is a native forest bird endemic to O‘ahu which has been in decline for decades due to low adult survival and low reproductive success resulting mainly from nest predation by rats and introduced diseases such as avian pox virus. In 2000, USFWS granted the O‘ahu ‘elepaio endangered species status under the federal Endangered Species Act and designated critical habitat on O‘ahu for the ‘elepaio in 2001. This project's purpose is to control rodents threatening O‘ahu ‘elepaio populations in Lihue MU.

*Birds Protected by the MBTA that are not listed under the ESA*

Additional native bird species are protected by the Migratory Bird Treaty Act (MBTA), but not the ESA: Pacific golden plover or kōlea (*Pluvialis fulva*), Hawaiian short-eared owl or pueo (*Asio flammeus sandwichensis)*, ‘amakihi (*Hemignathus virens virens)*, ‘apapane (*Himatione sanguinea)*. Non-native species introduced from mainland U.S. that are also protected by the MBTA include barn owl (*Tyto alba*), house finch (*Carpodacus mexicanus*), and northern cardinal (*Cardinalis cardinalis*).

Lihue MU is heavily forested and kōlea, pueo, and barn owls primarily inhabit open country. Pueo have never been observed in the forested treatment area (Kawelo, pers. comm.). Although individual kōlea and barn owls may at times be found in Lihue MU, they are not expected to be commonly present in Lihue MU.

*Game birds and mammals*

Some game birds, all non-native species, are also present in Lihue MU. Zebra dove *(Geopelia striata)*, spotted dove *(Streptopella chinensis)*, and Erckel's francolin *(Francolinus erckelli)* could be present. These birds are protected under Hawai‘i state game regulations (DOFAW 2002).

*State protected, non-game birds*

Several species of native and non-native birds, which are not game species, are protected by the State of Hawai‘i: O‘ahu ‘elepaio (*Chasiempis sandwichensis ibidis)*, rock dove (*Columba livia*), Japanese bush-warbler (*Cettia diphone*), nutmeg mannikin (*Lonchura punctulata*), and red-billed leiothrix (*Leiothrix lutea*).

*Vertebrates Without Protected Status*

Several species of invasive mammals with no protected status could also be present in Lihue MU: feral cat (*Felis catus*), small Indian mongoose (*Herpestes auropunctatus*), black rat (*Rattus rattus*), house mouse (*Mus musculus*); and one introduced bird with no protected status could also be present: Japanese white-eye (*Zosterops japonicus*).

#### *4.5.2.2 Other Terrestrial Species in Lihue Management Unit*

There are no native reptiles in the Hawaiian Islands. Cannibal snail *(Euglandina rosea)*, giant African snail *(Lissachatina fulica)*, and various non-native reptiles including skinks, lizards, and geckos are present within Lihue MU. Introduced Jackson chameleon could also be present. Non-native invasive species have substantial negative impacts to native flora and fauna.

#### *4.5.2.3 Aquatic Organisms*

A biological survey of O’ahu training area streams was conducted in 1997 and the Hale‘au‘au drainage was included in this aquatic survey. A handful of endemic and introduced aquatic species were observed, but none were considered rare or threatened. No Megalagrion damselflies were observed. The survey report did note the upper reaches of Hale‘au‘au exhibited “relatively high habitat quality, and the stream was rich in Megalagrion species historically.” The report recommended Hale‘au‘au “be considered for trial reintroductions of any of the Megalagrion historically known from the area, which includes currently rare and endangered taxa.”

Subsequent incidental observations during regular site visits to Lihue MU have noted *Megalagrion hawaiiensis, Anax strenuous,* bullfrog *(Rana catesbiana)* and wrinkled frog *(Rana rugose)*.

## 4.6 Cultural, Historic, and Archaeological Resources

Archeological sites and/or cultural resources, including prehistoric and contact period sites as well as historic era features, have primarily been identified at lower-elevation flat lands and stream gulches within military lands on O‘ahu. Historic settlement (as early as AD 100 to 800) typically started along the coastline, with the population relying on the wealth of marine resources for subsistence. As populations and subsistence demands increased, settlements expanded inland to take advantage of upland resources and more reliable water sources. Archaeological resources are diverse and may include heiau (religious structures), ko‘a (small shrines), fishponds, fishing shrines, habitation sites, caves and rock shelters, mounds, burial platforms, stone walls and enclosures, agricultural terraces, canals or ditches, rock art sites, and trails (Tomonari-Tuggle 2002, as cited in Tetra Tech 2004). Historic period archaeological sites may include gun emplacements, concrete structures and bunkers, concrete walls, wooden structural remains, masonry platforms, concrete revetments, bermed depressions, berms and rock piles, tunnels, miscellaneous feature complexes, road beds, railroad remnants, and trash deposits.

## 4.7 Land Use/Recreational Resources

Management activities supporting native plant and animal species are ongoing in much of the Wai‘anae and Ko‘olau mountains. Portions of the Wai‘anae mountains, including some of the management units described in the OIP, are designated reserves of the state Natural Area Reserve System (NARS), and the land is managed primarily to protect and preserve native ecosystems and species. Natural Area Reserve (NAR) managers actively conduct ungulate and weed management, native vegetation restoration, and native species reintroduction.

The Army’s environmental program is engaged in a variety of active management programs in SBMR and other selected areas of the Wai‘anae mountains. Ongoing Army programs for rare plant, snail, ‘elepaio, and insect protection include fencing, ungulate control, weed control, predator control and native vegetation restoration.

State Forest Reserves also occur in both the Wai‘anae and Ko‘olau mountains and provide protective conservation zoning and programs for public hunting. Hiking and hunting are the primary recreational uses within the Forest Reserves. Board of Water Supply lands in the Wai‘anae mountains are designated as protected watershed with limited public access.

No hunting is allowed in Lihue MU. Feral pigs are kept out of the unit by ungulate-proof fencelines, however some areas near Lihue MU are within Public Hunting Areas. Hunting is allowed in a portion of the Mokuleī‘a Forest Reserve and in the Ka‘ala NAR when an entry permit is granted by the O‘ahu NARS manager. Hunters must be accompanied in the Forest Reserve and NAR by a staff member of the Division of Forestry and Wildlife (DOFAW). Game allowed to be taken in the Public Hunting Areas includes feral pigs and feral goats, and birds including ring-neck pheasant, green pheasant, California valley quail, Japanese quail, Gambel's quail, Erckel's francolin, gray francolin, black francolin, chukar partridge, barred dove (small dove), and spotted dove (large dove). Permitted hunting methods include rifles, shotguns, handguns, knives, spears, and bows and arrows. Dogs are permitted but must be kept under physical restraint and control except when actually hunting.

Lihue MU lies within the state Land Use Conservation District. The Conservation District Subzone for most of Lihue MU is "Resource." The Proposed Action treatment area is fully contained in the "Resource" subzone. A portion of Lihue MU has been assigned a Conservation District Subzone of "Protective." The Protective subzone includes the most environmentally sensitive areas. Federal agency activity on federal land shall be carried out in a manner which is consistent, to the extent practicable, with the policies of approved state management programs.

## 4.8 Socioeconomic Environment

Lihue MU is located in an undeveloped portion of SBMR. It is owned by the federal government. Nearby population centers include Schofield Barracks, but no public access or commercial activity is authorized in Lihue MU, as it is part of SBMR West Range.

## 4.9 Visual and Aesthetic Resources

Visual resources are usually defined as the visual quality or character of an area, consisting of both the landscape features and the social environment from which they are viewed. Visual characteristics of the project area and surrounding regions include undeveloped forested land, mountain ridges, military training areas and views of the Pacific Ocean. Views from within the project area can include local unique landforms, sweeping views of mountain ridges, and panoramic coastal views. Scenic vistas and views of the area from public settings include views of the undeveloped mountains.

## 4.10 Environmental Justice and Protection of Children.

Lihue MU is Army owned land located in an undeveloped portion of SBMR. It is completely surrounded by military lands and state forest reserves. Nearby population centers include Schofield Barracks, but no public access or commercial activity is authorized in Lihue MU.

# 5 ENVIRONMENTAL CONSEQUENCES OF THE PROPOSED ACTION AND NO ACTION ALTERNATIVE

This section describes the potential environmental consequences associated with the Proposed Action and the No Action Alternative. The Proposed Action is described in Section 3. This section has been organized by resource area to provide a comparative framework for evaluating the impacts of the Proposed Action and the No Action Alternative. Table 2 summarizes the impacts of the Proposed Action on the relevant resource areas of the affected environment.

## 5.1 Impact Methodology and Significance Criteria

Project actions are evaluated by their potential direct, indirect, and cumulative effects. Direct impacts are those caused by project actions and occur at the same time and place. Indirect effects are those caused by project actions and are later in time or farther removed in distance. Impacts may be short term or long term, depending on how resource areas are affected during the course of the project implementation and operation. Cumulative impacts are addressed in Section 7.

Quantitative and qualitative analyses were used to determine whether, and the extent to which, a significance threshold would be exceeded. Based on the results of these analyses, this SEA identifies whether a particular potential impact would be adverse or beneficial, and to what extent. Context and intensity were taken into consideration in determining a potential impact’s significance, as defined in 40 CFR Part 1508.27. The severity of environmental impacts has been characterized as none, negligible, minor, moderate, significant, or beneficial:

- None – No impacts are expected to occur.
- Negligible – An impact so small, it is not detectable or so small it would be discountable.
- Minor – A minor impact would either be isolated and localized, not measurable on a wider scale, or so insignificant it would be discountable.
- Moderate – A moderate impact would be measurable on a wide scale (e.g., outside the footprint of disturbance or on a landscape level). If it was adverse, it would not exceed limits of applicable local, state, or federal regulations.
- Significant – A significant impact could exceed limits of applicable local, state, or federal regulations or would untenably alter the function or character of the resource. It would be considered significant unless mitigable to a less than significant level.
- Beneficial – This impact would benefit the resource/issue.

Impacts that range from none to moderate are considered less than significant. Examples of potential impacts that would be considered significant would be ones that:

- Cause the “take” of a highly sensitive resource, such as a threatened, endangered, or special status species;
- Damage or degrade wetlands or riparian habitat regulated by the local, state, or federal government, or another sensitive habitat (such as designated critical habitat) identified in local or regional plans, policies, or regulations or by the USFWS;
- Introduce or increase the prevalence of undesirable non-native species;
- Cause long-term loss or impairment of a substantial portion of local habitat (species-dependent);
- Degrade water quality in a manner that would reduce the existing or potential beneficial uses of the water; or
- Cause impacts to human health or safety.

**Table 2. Potential Environmental Impacts of Proposed Action and No Action Alternative**

| | | Broadscale Rodenticide Application (Proposed Action) | No Action Alternative |
|---|---|---|---|
| Resource Areas | Topography and Soils | Minor short-term impact | Moderate long-term impact |
| | Groundwater/Surface water | Minor short-term impact | None – No Impact |
| | Air Quality | Negligible Impact | None – No Impact |
| | Noise Environment | Minor short-term impact | None – No Impact |
| | Biological Resources | Beneficial impact; minor short-term impact | Moderate long-term impact |
| | Cultural/Historical/ Archaeological Resources | None – No Impact | None – No Impact |
| | Land Use/Recreation | Negligible Impact | None – No Impact |
| | Socioeconomic Environment | None – No Impact | None – No Impact |
| | Visual/Aesthetic Resources | None – No Impact | None – No Impact |
| | Environmental Justice | None – No Impact | None – No Impact |

## 5.2 Topography and Soils

The Proposed Action and No Action Alternative were evaluated to determine the significance of change to the topography and soil resources. Factors considered in determining whether the Proposed Action would have a significant impact on topography and soils include the extent to which its implementation would do the following: 1) contaminate the soil; 2) cause a substantial loss of soil, such as through increased erosion; 3) increase the likelihood of slope failure; or 4) alter the function of the landscape, such as altering drainage patterns.

### 5.2.1 Proposed Action

No significant impacts to topography or soils would occur from the Proposed Action. Effects to topography or soils would be minor. The very low concentration of diphacinone in bait pellets would not lead to measurable soil contamination beyond the localized soil beneath an uneaten and decaying bait pellet. D-50 is not persistent in soil. The half-life in soil is 30 to 60 days for diphacinone, depending on the soil type (USFWS and DOFAW 2008). Diphacinone has extremely low solubility in water and binds tightly to organic material in soil where the rodenticide is degraded by soil micro-organisms and exposure to oxygen and sunlight. Microbial degradation is dependent on climatic factors such as temperature and the presence of microbes enabling degradation. Therefore, degradation times will be longer in colder climates and shorter in warmer places like Hawai`i (Eason and Wickstrom 2001, Eisemann and Swift 2006). Hawai‘i forest environments are generally warm and moist and these conditions promote rapid degradation of the chemical. Soil samples collected one week after diphacinone aerial bait application on Lehua Island in Hawai‘i resulted in little to no detectable concentrations of diphacinone (Orazio et al. 2009). On Palmyra Atoll in 2010 two out of 48 samples tested had concentrations of the diphacinone high enough to be quantified (soil collected directly under a pellet), all other samples yielded a zero (undetectable) or ‘trace’ value (Island Conservation 2010a).

### 5.2.2 No Action Alternative

Under the No Action Alternative, high levels of rats would remain within Lihue MU and would continue to burrow in areas with a substantial soil layer. Through comparisons of rat-invaded and rat-free islands, rats have been shown to reduce soil fertility, and the diversity and abundance of soil fauna (Fukami et al. 2006, Towns et al. 2009). Consequently, under the No Action Alternative, soil fertility and invertebrate diversity would remain reduced and less capable of supporting healthy native Hawaiian habitat; such degradation adds to the potential for impacts to spread beyond Lihue MU resulting in moderate, long-term impacts.

## 5.3 Water Resources

The evaluation of potential impacts on water resources is based on the project’s potential to contribute to lower water quality. The Proposed Action and No Action alternatives were considered to have a significant impact on the resource if they were to result in the following: 1) cause a substantial increase in sedimentation; or 2) degrade water quality in a manner that would reduce the existing or potential beneficial uses of the water.

### 5.3.1 Proposed Action

D-50 has been registered by EPA and licensed by the State of Hawai‘i for conservation purposes using aerial and ground broadcast application techniques. Before EPA may register a pesticide under FIFRA, the applicant must show, among other things, that using the pesticide according to specifications "will not generally cause unreasonable adverse effects on the environment" (EPA 2017). Scientific research corroborates the Army’s determination that the Proposed Action would not degrade Lihue MU water quality in a manner that would reduce its existing or potential beneficial use. The broadcast distribution of D-50 would have minor short-term impacts to groundwater or surface water resources.

Surface waters within Lihue MU, will be buffered by 50 feet. Rodenticide will not be aerial broadcast into these buffer areas. In some places D-50 may be hand applied within the stream buffer areas with care taken to avoid water. Diphacinone has extremely low solubility in water and binds tightly to organic matter in soil, where the rodenticide is degraded by soil micro-organisms and exposure to oxygen and sunlight. Upon breakdown of any uneaten bait, most of the chemical is expected to remain in the top soil layers, and its potential to reach ground water is very low. Bait contact with surface water, although unlikely, may occur in less-permeable areas and in areas closer to streams. In the event of reaching surface water, diphacinone would be expected to be partitioned into the suspended and bottom sediments instead of the water column. (USFWS 2016, Eisemann and Swift 2006)

If heavy precipitation events are forecasted, the application would be postponed to prevent potential runoff or floodwater transport of additional bait pellets to surface waters. If the forecast reduces the operational window to eliminate an opportunity for two distributions then a single higher dose may be applied (per label instructions).

Seawater sampling conducted both one day and one week after aerial application of diphacinone pellets to Lehua Island in January 2009 found no diphacinone residues in seawater surrounding Lehua Island (Orazio et al. 2009). Similarly, water sampling conducted after aerial application of diphacinone pellets to Mokapu Island in February 2008 found no diphacinone residues in the seawater samples (Gale et al. 2008). This low water solubility decreases the likelihood of exposure of aquatic organisms to dissolved rodenticides. Furthermore, the Lihue MU is located far from marine resources, whereas both the Lehua Island and Mokapu Island applications treated each entire island including shoreline areas.

### 5.3.2 No Action Alternative

No impacts are expected from the No Action Alternative.

## 5.4 Climate/Air Quality

Potential air quality impacts from the alternatives were assessed by evaluating emissions and dust generated from helicopter and vehicular use. The likelihood of exceeding federal or state ambient air quality standards was considered in determining whether the Proposed Action would have a significant impact on air quality.

### 5.4.1 Proposed Action

No significant impacts to air quality are expected from the Proposed Action. Emissions from the engine exhaust system of a helicopter would be generated during the application operation. Emissions generated by the helicopter would be negligible, over the course of the two applications within the single rodenticide treatment. Each application would span two to four days. The two applications would be separated by 5 to 7 days, and they would not cause an exceedance of either state or federal ambient air quality standards.

Some fugitive dust may be generated by helicopter hovering during bucket loading, however this would be localized for very short periods. Dust emissions would be negligible.

### 5.4.2 No Action Alternative

No significant impacts are anticipated from the No Action Alternative. Potential sources of air quality impacts (helicopter exhaust and fugitive dust from helicopter operations) would not be generated.

## 5.5 Noise Environment

Potential effects of the Proposed Action and No Action Alternative on noise were evaluated by examining the typical noise that would be generated by helicopter operations. Factors considered in determining whether an alternative would have significant impacts include the extent to which its implementation would do the following: 1) generate new sources of substantial noise; 2) increase the intensity or duration of noise levels to sensitive receptors; or 3) expose people to high levels of noise.

### 5.5.1 Proposed Action

No significant impacts to the noise environment are anticipated from the Proposed Action. Noise associated with the Proposed Action would be due to helicopter operations. A single helicopter would be used to conduct the aerial broadcast application. This would result in a minor impact from a localized increase in noise; however, helicopter use would be for two overflights separated by 5 to 7 days. This constitutes a short exposure duration, and operations would be spread out over the entire 714 ha management unit. Helicopter use is common at SBMR and this use would not substantially add to these common types of noises at SBMR. In addition, the Proposed Action would take place away from populated areas.

#### 5.5.2 No Action Alternative

No significant impacts to the noise environment are anticipated from the No Action Alternative. There would be no noise associated with rodenticide application under this alternative.

## 5.6 Biological Resources

Impacts on biological resources were assessed based on whether the activities would be consistent with applicable natural resource statutes, executive orders, permits, and regulations. An action is considered to have a significant impact on a biological resource if it would result in the following: 1) harm, harassment, or destruction of any endangered, threatened, or rare species, its habitat, migration corridor, or breeding area; 2) cause a reduction in the population of a sensitive species; or 3) introduce or increase the prevalence of undesirable nonnative species.

No significant impacts to biological resources are anticipated from the Proposed Action to apply D-50 rodenticide within the Lihue MU ungulate-proof fence area. The broadscale application of rodenticide, including the aerial application of rodenticide, was specifically identified in the 2008 OIP as an important management action needed to stabilize many plant and animal species throughout the O‘ahu AA. The OIP is a result of close coordination between the USFWS and the U.S. Army. The core goal of the OIP is the continued existence and benefit to listed endangered species. Actions planned in the OIP, including this Proposed Action, are expected to result in long-term net benefits to the listed threatened and endangered species within the O‘ahu AA, which would far outweigh potential short-term negative impacts. The Proposed Action would result in the control of the main threats to O‘ahu ‘elepaio in the area, which should benefit ‘elepaio and lead to an increase in the number of individuals of these species and an increase in the quality of their habitat. Other native Hawaiian plant and animals will also benefit from reduced rodent pressure resulting in healthier native habitat conditions. There is the potential for minor, short-term impacts to nontarget species. Negative impacts that could occur will be minimized through implementation measures and best management practices (BMPs) incorporated into the Proposed Action.

#### 5.6.1 Flora

Plants are not known to be susceptible to toxic effects from diphacinone (USFWS 2015).

##### *5.6.1.1 Proposed Action*

D-50 is nontoxic to plants and would have no effect on them, however control of invasive rodents will benefit endangered and other native plants. Invasive rodents eat the fruit of many native plants and facilitate the spread of invasive plants they have eaten. Controlling invasive rodents would improve conditions and be beneficial for individual native plants and benefit native plant populations (USFWS 2003).

##### *5.6.1.2 No Action Alternative*

Impacts to plants from continuing the present rat control practices without broadscale rodenticide application has the potential to be moderate, long-term and negative. Using the present control means, rat populations have not been adequately limited. Endangered and native plant species continue to be negatively impacted by rodent predation (USFWS 2003). As a result, the long-term impacts of continuing the existing management activities under the No Action Alternative would be the continued degeneration of the native forest within Lihue MU. As Lihue MU forest degradation continues the potential for increased degeneration beyond Lihue MU increases.

### 5.6.2 Fauna

Potential impacts may occur from rodenticides on nontarget species (e.g., pigs or birds); either from accidental direct consumption or consuming affected rodents. Both primary (direct consumption) and secondary hazards (consuming a poisoned rodent) can occur from rodenticide use. These impacts would be minor, short term and localized. There is also the potential for some nontarget species individuals to benefit from reduced predatory pressure.

#### *5.6.2.1 Proposed Action*

The proposed treatment area within Lihue MU is enclosed by ungulate-proof fencelines that prevent pigs and goats from entering the area. The Lihue MU ungulate exclusion is formed almost entirely by ungulate-proof fencing and gates. In several locations along the fenceline severe topographic features such as cliffs prevent ungulate passage (and feasible fence construction). Ongoing monitoring, fence maintenance, and control work maintain the ungulate exclusion. The entire treatment area is within the ungulate exclusion area so feral pigs and goats outside the exclusion area will not be exposed to any rodenticide.

Birds that are most at risk from feeding directly on rodenticides are those that are naturally inquisitive, terrestrial ground-feeders, and that have a diet that includes grains and seeds. The risk of secondary poisoning is greatest for predatory and scavenging birds, especially those that feed directly on the target rodent species, such as owls. In order to consume sufficient diphacinone bait to reach a dose equivalent to the $LD_{50}$ for the northern bobwhite (or a single dose that is lethal to 50% of test subjects), a passerine bird would have to eat 0.53 pounds of bait or 5,027 pounds of invertebrates in one day. Neither of these amounts is even physically possible (USFWS and DOFAW 2008).

However, hazard calculations for sublethal exposure show that a 30 g bird, such as a small passerine, would only need to eat 0.07 g (a $100^{th}$ of a bait pellet, or 0.2% of its body weight) or 0.65 g of invertebrates per day for multiple days to ingest a dose that resulted in measurable blood clotting effects in golden eagles. Therefore, small passerine birds could be vulnerable to sublethal or possibly lethal effects through both primary and secondary exposure if they forage on diphacinone bait or contaminated invertebrates over time (Eisemann and Swift 2006).

*Species protected by the Endangered Species Act (ESA)*

O‘ahu ‘elepaio – ‘Elepaio belong to the large family of monarch flycatchers and prefer feeding on insects and spiders. The Proposed Action is not likely to adversely affect ‘elepaio since it is not likely that forest birds will consume enough insects that have come in contact with the diphacinone rodenticide to cause lethal or sublethal effects (USFWS 2014). The USFWS concurs with this determination (See USFWS Concurrence Letter, Appendix C). Managers actively monitor ‘elepaio territories in Lihue MU and regularly maintain traps in an effort to curb rat predation of nests and birds. Diphacinone bait stations have been used in the past to reduce rat predation of ‘elepaio in Lihue MU, however a change in label direction has eliminated this option in Lihue MU. No adverse impacts to ‘elepaio have been observed during long term use of diphacinone bait stations. It has been documented that O‘ahu ‘elepaio reproductive success dramatically improves in rat controlled environments (del Hoyo 2006). O‘ahu ‘elepaio populations will benefit substantially from the Proposed Action to control rodent populations in Lihue MU. Reduced rodent predation on ‘elepaio nests, in particular, will improve ‘elepaio reproductive success and nestling survival rates, thus leading to more sustainable ‘elepaio populations.

Hawaiian hoary bat – The Hawaiian hoary bat has been observed in the vicinity of Lihue MU. Although no hoary bats have been observed within the treatment area, it is assumed they may occur in Lihue MU. Hoary bats are insectivorous and could possibly forage in areas where rodenticide is used, however “the likelihood that bats will ingest sufficient numbers of potentially contaminated insects to accumulate a dose at which effects could occur is extremely low.” (USFWS 2014). Thus, no bats are likely to be affected by the Proposed Action. The USFWS concurs with this determination (See USFWS Concurrence Letter, Appendix C).

O‘ahu tree snail – Primary or secondary poisoning from diphacinone is not likely to occur for the O‘ahu tree snail since it primarily forages on fungus that grows on trees. O‘ahu tree snails primarily forage in trees and it is not likely it will come into contact with the rodenticide on the ground. The USFWS concurs with the determination that any effects are discountable and therefore not likely to adversely affect the O‘ahu tree snail.

Primary or secondary poisoning from diphacinone is not likely to occur for the Hawaiian picture-wing fly since it primarily forages on decaying plant matter. The USFWS concurs with the determination that any effects are discountable and therefore not likely to adversely affect the Hawaiian picture-wing fly.

*Species protected by the Migratory Bird Treaty Act (MBTA)*

‘Apapane and ‘Amakihi – ‘Apapane and ‘amakihi are at extremely low risk of impact from the Proposed Action due to their food habits. They feed on nectar, and foliar insects and spiders, and forage primarily in the mid- to upper strata of the forest canopy. ‘Amakihi are also at relatively low risk due to their diet. They feed mostly on insects, and other arthropods, nectar, fruit, and sap. Some of the invertebrate taxa that ‘amakihi consume could potentially eat rodenticide baits; however, the bird mostly gleans insects from trees, ferns, and shorter plants (USFWS 2014). Therefore no ‘apapane or ‘amakihi would be affected by the Proposed Action.

‘I‘iwi – The ‘i‘iwi was last observed in Lihue MU in 1999. The ‘i‘iwi is proposed for endangered status, but populations are unlikely to be impacted by the proposed rodenticide application. It is a nectar feeder and not likely to encounter rodenticide residues through normal feeding. Because of the rare presence of this bird on the island of O‘ahu and its normal diet of nectar, populations of ‘i‘iwi are not likely to be affected by the proposed action. The USFWS concurs with this determination (See USFWS Concurrence Letter, Appendix C).

Kōlea – Even if Pacific golden plover or kōlea were to pick up diphacinone bait pellets, an individual would have to consume approximately 1,200 g (almost 2.7 pounds) of diphacinone bait to deliver an $LD_{50}$–equivalent dosage (based upon the lower reported acute oral $LD_{50}$ of >400 mg/kg body weight for bobwhites). It would be physically impossible for kōlea to consume that much bait in one or several days. The projected LOEL (extrapolated from the lowest reported LOEL for diphacinone in birds, 0.11 mg/kg/day, Savarie et al. 1979) of diphacinone for a Pacific golden-plover is 0.02 mg/day or about 0.3 gram of bait per day. As long as bait is present in the area, such a level of non-lethal exposure would be possible (USFWS 2014). However, kōlea are not common in the treatment area because they favor open rangeland habitat and they would likely not consume bait based on their preference for insects, worms, crustaceans and spiders.

Northern cardinal – Cardinals eat a wide range of seeds, fruits, and invertebrates (Halkin et al. 1999), indicating they would likely consume the rodenticide baits or the invertebrates feeding on the baits if available. However cardinal numbers are thought to be low in Lihue MU, and they are predominantly canopy dwellers so relatively few cardinals would have the potential to be affected. Population level effects are highly unlikely.

House finch – Incidental impacts to house finches may result from the Proposed Action. House finches are canopy dwellers observed within Lihue MU. House finches primarily eat vegetation, much of their diet consisting of seeds (Badyaev et al. 2012); so they could possibly eat the grain-based bait. A 22 g house finch would need to eat about 25% of a diphacinone pellet per day over multiple days (e.g., 5 days) to ingest a LLD. To receive a sublethal dose, that same bird would need to eat about 4% of a pellet per day over multiple days. These impacts are unlikely to occur, and lead to population level effects.

Owls – Pueo or Hawaiian short-eared owl are not present in the treatment area and typically forage in open country. Therefore, no pueo would be affected by the Proposed Action. Barn owls only capture live prey and therefore would not ingest grain-based pellets or scavenge dead rodents on the ground. Therefore, there is no potential for the barn owl to ingest rodenticide directly. Because barn owls hunt live prey, they could eat live rats carrying rodenticide residues in their tissues prior to dying. The most conservative (worst case) analyses of these situations has been examined using data from the literature. To assess secondary nontarget hazards for the barn owl, the analysis used whole body values with the maximum residue levels documented in rodents (Erickson and Urban 2004). The $LD_{50}$ for an average sized 315 g (0.7 pound) owl is 126 mg of diphacinone. To ingest these amounts of rodenticides secondarily via rodents contaminated to the highest level documented, an owl would need to consume 37 kg (81.6 pounds) of diphacinone-loaded rats. An owl could obtain an LOEL dosage of diphacinone by eating 10 g of these contaminated rodents. Even under these extreme situations, the risk of mortality due to using a diphacinone formulation is essentially zero.

*Game birds and mammals*

Game birds that could be present in Lihue MU include zebra dove *(Geopelia striata)*, spotted dove *(Streptopella chinensis)*, and Erckel's francolin *(Francolinus erckelli)*. Doves tend to utilize open habitat, such as the training lands below the firebreak road (and below the treatment area). As with some MBTA-protected birds, game birds found in the area would be at some risk of being affected by the Proposed Action and that risk will vary with their relative abundance and distribution, in combination with their diet and body size. The diet of these birds is comprised primarily of vegetation (e.g., seeds and fruits) and animal matter (e.g., insects and snails), which puts them at risk of both primary and secondary poisoning. However, bait pellets would be dyed green which has been shown to make pellets less attractive to some birds and reptiles (Pank 1976, Tershy et al. 1992, Tershy and Breese 1994). As with kōlea, it is unlikely that individual game birds would ingest lethal amounts of diphacinone, although there could be some exposure to non-lethal levels. It is also unlikely that affecting a small number of these game birds from the area would cause population level effects.

*Vertebrates Without Protected Status*

Several species of invasive mammals and one introduced bird, with no protected status, could also be present in Lihue MU: feral cat (*Felis catus*), small Indian mongoose (*Herpestes auropunctatus*), black rat (*Rattus rattus*), house mouse (*Mus musculus*), Kalij pheasant *(Lophura leucomelanos)*, and Japanese white-eye (*Zosterops japonicus*). Mammals that consume sufficient quantities of bait could be subject to lethal or sub-lethal effects. It is unlikely the Japanese white-eye would ingest sufficient quantities to experience lethal effects.

*Other Terrestrial Species in Lihue Management Unit*

There are no native reptiles in the Hawaiian Islands. Cannibal snail *(Euglandina rosea)*, giant African snail *(Lissachatina fulica)*, and various non-native reptiles including skinks, lizards, and geckos are present within Lihue MU. Non-native invasive species have substantial negative impacts to native flora and fauna.

*Aquatic Organisms*

Diphacinone has low solubility in water, and studies indicate it is unlikely to be consumed by any aquatic organisms present. Nonetheless, to avoid impacts to water quality, surface waters will be buffered to avoid depositing rodenticide into Lihue MU water bodies. Surface waters in Lihue MU will be buffered by 50 feet and rodenticide will not be aerially broadcast within these buffer areas. Some hand application within stream buffer areas may occur in key areas with care taken to avoid water. It is unlikely that aquatic organisms will be affected by the Proposed Action.

#### *5.6.2.2 No Action Alternative*

Impacts to fauna from continuing the present rat control practices without aerial rodenticide application would be moderate, long-term and negative. Using the present control means, rat populations have not been adequately limited and ‘elepaio populations have not stabilized. Continuation of the existing management activities under the No Action Alternative is anticipated to result in fewer individuals of the target species to be managed. As a result, the long-term impacts would be the continued degeneration and eventual extirpation (i.e., local extinction) of endangered species populations within Lihue MU, and further deterioration of the native forest.

## 5.7 Cultural, Historical, and Archaeological Resources

The evaluation of impacts on historic and archaeological resources were based on identifying cultural resources within Lihue MU and determining the direct and indirect impacts that may affect these resources. Impacts to historical and archaeological resources are considered significant if 1) prehistoric or historic resources that are listed or potentially eligible for listing on the National Register of Historic Places are disturbed or destroyed; 2) Native Hawaiian resources are physically desecrated or destroyed; or 3) access to traditional areas is affected.

### 5.7.1 Proposed Action

Pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended (16 USC 470f) and (36 CFR 800.3(a)(1)), the USAG-HI has determined this project has no potential to cause effects to historic or other cultural resources; therefore, the USAG-HI has determined it has fulfilled its responsibilities under Section 106 of the National Historic Preservation Act.

Based on literature reviews and surveys previously conducted, known cultural resources are present within the Lihue MU. However, there is no potential to impact these cultural, archaeological or historic resources by implementing the Proposed Action. Cultural resources staff will follow the USAG-HI reporting and documentation protocol in the event of any inadvertent discoveries.

### 5.7.2 No Action Alternative

No significant impacts to cultural, archaeological, or historic resources are anticipated from the No Action Alternative.

## 5.8 Land Use and Recreational Resources

Impacts on land use were assessed based on whether or not the proposed activities were consistent with the site-specific and surrounding land uses. The evaluation of potential impacts on land use was based on the project's consistency with the following: 1) existing and planned land uses; and 2) unique characteristics of the geographical area.

### 5.8.1 Proposed Action

Lihue MU is within federally-owned land designated for conservation. Hunting is not permitted within Lihue MU and the unit is closed to all entry. Impacts to land use and recreational resources from the Proposed Action would be negligible. Ungulates are excluded from Lihue MU by ungulate-proof fencelines. It is unlikely that a wild pig would discover a way to enter Lihue MU, consume a quantity of bait equivalent to the worst case observed in lab and field research experiments, and then discover a way to enter a hunting area. Even if this extremely unlikely case were to occur, and the pig was harvested, a 55 kg person would have to eat over half their body weight of pig meat (28.49 kg) in a single day to reach the lowest detectable clotting effects. This exposure is far less than the therapeutic dose administered to people when diphacinone was used as a heart medication. If a 55 kg person ate the same pig meat over multiple days they would have to eat 8.77 kg (over 19 pounds) per day before the toxicants could build up to levels causing measurable effects (Eisemann and Swift 2006). Game birds found in the area would be at some risk of being affected by the Proposed Action and that risk will vary with their relative abundance and distribution, in combination with their diet and body size. The diet of these birds is comprised primarily of vegetation (e.g., seeds and fruits) and animal matter (e.g., insects and snails), which puts them at risk of both primary and secondary poisoning. However, game bird foraging behavior favors open areas. It is unlikely a game bird would forage so intently within the forested treatment area over multiple days to ingest acute levels of diphacinone. Furthermore, it is unlikely that the range of game birds within Lihue MU would extend to areas open to game bird hunting. Additionally, D-50 pellets are dyed green which has been shown to make pellets less attractive to some birds and reptiles (Pank 1976, Tershy et al. 1992, Tershy and Breese 1994). A recent NRWC study in nearby Kahanahāiki reports no game birds were observed consuming the green colored bait (via regular observations or motion cameras), and no game bird liver samples contained measurable residue levels (Shiels 2017).

### 5.8.2 No Action Alternative

No significant impacts to land use are anticipated from the No Action Alternative. Existing land use would not change under the No Action Alternative.

## 5.9 Socioeconomic Environment

Factors considered in determining whether an alternative would have a significant impact on socioeconomics include the extent or degree to which its implementation would change the following: 1) population; 2) employment; 3) demand for housing; or 4) demand on public services.

### 5.9.1 Proposed Action

No significant impacts to socioeconomics are anticipated from the Proposed Action. The Proposed Action is not expected to affect job opportunities, population structure, housing availability, or the use of public facilities. No impacts to the social or economic welfare of nearby communities are anticipated from the Proposed Action.

### 5.9.2 No Action Alternative

No significant impacts to socioeconomics are anticipated from the No Action Alternative. Although training opportunities within O‘ahu Training Areas could be affected if the requirements of the 2003 BO are not met, it is unlikely subsequent adjustments to training or natural resources management practices would affect the socioeconomic environment.

## 5.10 Visual and Aesthetic Resources

Preserving open space and scenic beauty is a priority for projects that may affect mountainous areas. The General Plan for the City and County of Honolulu states that scenic resources and the open space character of the area should be preserved and protected for future generations.

### 5.10.1 Proposed Action

Lihue MU is located in a remote area and potential impacts from the Proposed Action would consist of a helicopter flying over the area for a short period of time. No significant impacts are anticipated to the visual quality or aesthetics of Lihue MU. The operation would likely not be visible from populated areas. The localized visual impact would be very temporary lasting for only small parts of two to four days and would not constitute an impact to visual/aesthetic resources.

### 5.10.2 No Action Alternative

No significant impacts are anticipated. No changes to existing visual resources would occur.

## 5.11 Environmental Justice and Protection of Children

Factors considered in determining whether an alternative would have a significant impact on environmental justice and protection of children included the extent or degree to which its implementation would result in the following: 1) change in any social, economic, physical, environmental, or health conditions so as to disproportionately affect any particular low-income or minority group; or 2) disproportionately endanger children.

### 5.11.1 Proposed Action

No significant impacts to environmental justice are anticipated from the Proposed Action. The activities associated with this Proposed Action would be located away from residential communities. Disproportionately high and adverse human health or environmental impacts on minority and low-income populations and children are not anticipated.

### 5.11.2 No Action Alternative

No significant impacts to environmental justice are anticipated from the No Action Alternative. No changes to social, economic, or health conditions are anticipated and disproportional impacts to low-income or minority groups and children would not occur.

# 6 CONSISTENCY WITH FEDERAL, STATE, AND LOCAL PLANS, POLICIES, AND APPROVALS

The approach of this project is consistent with the objectives of many entities. It is in accord with USFWS policy for the management of natural communities using an “ecosystem approach” and with the Hawai‘i Natural Area Reserve Law, which states a system of reserves be established to “…preserve in perpetuity specific land and water areas which support communities, as unmodified as possible, of the natural flora and fauna…” (Chapter 195D, Hawai‘i Revised Statutes). Protection and enhancement of endangered species is mandated by both federal and state Endangered Species Acts (16 USC 1531-1543, as amended; Chapter 195, Hawai‘i Revised Statues). It is also in alliance with the State of Hawai‘i’s long-term environmental policies, goals and guidelines outlined in Hawai‘i Revised Statutes, Chapter 344. This project is consistent with a designated land use of the “P” subzone: “preserving natural ecosystems of native plants, fish and wildlife, particularly those which are endangered” (HAR, 13-5-11-4).

The Proposed Action is consistent with the CZMA and the Hawai‘i CZM Program to the maximum extent practicable. The treatment area is located in central O‘ahu far from the coastline. The project would have no effect on coastal ecosystems or the marine environment.

The project also strives toward the provisions of the City and County of Honolulu General Plan Objectives and Policies, Chapter III, Objective A, Policies 1-11, by “protect[ing] and preserv[ing] the natural environment (Objective A)” as well as the “plants, birds, and other animals that are unique to the State of Hawai‘i and the Island of O‘ahu (Policy 8).”

# 7 CUMULATIVE IMPACTS

Cumulative impacts were analyzed for each resource category by examining effects of the Proposed Action when added to effects of other past, present, and reasonably foreseeable future actions. Anticipated cumulative impacts of the Proposed Action to the affected environment are discussed below.

## 7.1 Topography and Soils

Implementation of past and reasonably foreseeable future actions include fencing activities for ungulate control in other areas in the Wai‘anae and Ko‘olau Ranges that would occur as part of the OIP, state, county, or private actions. Reasonably foreseeable future actions would also include minor vegetation removal for reintroduction/augmentation of rare plant species as part of the OIP. No aerial application of rodenticide actions are anticipated in other management areas within the vicinity of Lihue MU. The potential impacts of these future actions would resemble those from the Proposed Action, resulting in a net positive effect on the immediate and surrounding habitat within the fences. As a result, the cumulative effects of the Proposed Action would provide a positive impact both alone and in combination with past, present, and reasonably foreseeable future actions.

## 7.2 Water Resources

Reasonably foreseeable future projects such as additional fence lines or endangered species collections work by other agencies may occur in nearby locations. Additionally, the chemical control of alien plants or animals within other management units is not anticipated to be of sufficient volume to have a significant effect on water resources. The USFWS has begun to evaluate broadscale rodenticide applications in a larger programmatic context, but there are no proposals to conduct similar treatments on O‘ahu; there is no information about where future treatments may occur should a proposal be put forward; and it is understood that additional NEPA analyses would have to be conducted on any future broadscale rodenticide proposals once that information became known. As a result, the proposed project would not significantly affect water resources individually, nor would it contribute to the cumulative impacts of other past, present, and reasonably foreseeable future actions.

## 7.3 Climate/Air Quality

Increase in emissions generated during proposed helicopter operations in Lihue MU would be temporary and short in duration. Reasonably foreseeable future projects such as additional fence lines or endangered species collections work for the OIP or by other agencies may occur in nearby locations, however additional impacts to climate or air quality are not anticipated. The proposed project would not significantly affect climate and air quality individually, nor would it contribute to the cumulative impacts of other past, present, and reasonably foreseeable future actions.

## 7.4 Noise Environment

Increase in noise generated during proposed helicopter operations in Lihue MU would be temporary and short in duration. Reasonably foreseeable future projects such as additional fence lines or endangered species collections work for the OIP or by other agencies may occur in nearby locations, however additional impacts to the noise environment are not anticipated. The proposed project would not significantly affect the noise environment individually, nor would it contribute to the cumulative impacts of other past, present, and reasonably foreseeable future actions.

## 7.5 Biological Resources

Potential negative impacts from the Proposed Action to biological resources and specifically endangered species would be minimized by avoiding sensitive areas and implementing BMPs. Significant adverse impacts are not anticipated. Reasonably foreseeable future projects such as additional fencelines or endangered species collections work conducted by other agencies may occur in nearby locations. However, it is expected that future projects would utilize similar mitigation actions. Consequently, the proposed project would not adversely affect ecosystems and biological resources individually, nor would it contribute to the cumulative effects of past, present, or reasonably foreseeable future actions. Instead, the Proposed Action and reasonably foreseeable future actions are expected to provide a net positive effect at the ecosystem and species levels.

The USFWS has begun to evaluate broadscale rodenticide application in a larger programmatic context, but there are no proposals to conduct similar treatments on O‘ahu; there is no information about where future treatments may occur should a proposal be put forward; and it is understood that additional NEPA analysis would have to be conducted once that information became known.

## 7.6 Cultural, Historical, and Archaeological Resources

USAG-HI has determined the Proposed Action has no potential to cause effects to archaeological, historical or other cultural resources. Other management activities are designed to avoid all archaeological sites. The cumulative effects of the Proposed Action would not be significant either alone or in combination with other past, present, or reasonably foreseeable future actions.

## 7.7 Land Use and Recreational Resources

Impacts to land use and recreation resources would be negligible and short in duration. Reasonably foreseeable future projects such as additional fence lines or endangered species collections work for the OIP or by other agencies may occur in nearby locations, however additional impacts to land use and recreational resources are not anticipated. The cumulative effects of the Proposed Action would not be significant either alone or in combination with other past, present, or reasonably foreseeable future actions.

## 7.8 Visual and Aesthetic Resources

Lihue MU is located in a remote area and potential visual impacts within the unit from helicopter overflight would be short in duration. If visible from other vantage points, the impact of air operations would also be short in duration. Other past, present, and reasonably foreseeable actions that could contribute to visual impacts of the Proposed Action include OIP-related construction, and ungulate exclusion fences in the Wai‘anae mountains undertaken by other agencies or landowners. These projects are separated geographically, and are not expected to have significant impacts. The cumulative effects of the Proposed Action to the visual quality or aesthetics of Lihue MU would not be significant either alone or in combination with other past, present, or reasonably foreseeable future actions.

# 8 OTHER REQUIRED NEPA ANALYSES

In addition to the analyses discussed above, NEPA requires additional evaluation of the project’s impacts with regard to the relationship between local short-term uses of the environment and long-term productivity, and any irreversible or irretrievable commitment of resources.

## 8.1 Relationship Between Short-term Uses of the Environment and Long-term Productivity

Short-term impacts to the environment from the Proposed Action would be limited. They include potential impacts to the noise environment and air quality from helicopter operations, and potential short-term impacts to surface water from rodenticide application. No significant impacts were identified. Long-term productivity would be enhanced by improving the quality of native Hawaiian habitat for endangered and threatened species.

## 8.2 Irreversible and Irretrievable Commitment of Resources

NEPA requires an analysis of the extent to which the Proposed Action’s primary and secondary effects would commit nonrenewable resources to uses that would be irretrievable to future generations. Implementation of the Proposed Action would commit nonrenewable energy and material resources in the form of:

- fuel for helicopters and equipment used to transport personnel and materials
- materials used to formulate and dispense rodenticide
- resources needed to monitor results of the Proposed Action such as equipment, supplies, and fuel for vehicles.

# 9 FINDINGS AND REASONS SUPPORTING THE ANTICIPATED DETERMINATION

The objective of the Proposed Action is to reduce rat populations on a management unit scale and improve survival rates for endangered Oʻahu ʻelepaio populations within Lihue MU. Other native plant and animal species will also benefit from reduced rodent predation. Military training opportunities will be sustained by increased protection and enhancement of native Hawaiian ecosystems and the protection and stabilization of native plant and animal species potentially affected by military training in other areas. The Army may implement the Proposed Action after successfully completing the NEPA process, completing agency consultations, and obtaining all necessary permits and approvals.

No significant impacts are anticipated as a result of the No Action Alternative or the Proposed Action proposed in this SEA. Table 2 (p. 28) provides a summary of anticipated impacts to each resource area analyzed. Impacts are largely anticipated to be minimized through avoidance and through the implementation of BMPs and label requirements. Avoidance results from selecting a treatment area already closed to entry and enclosed by ungulate-proof fencing, and by maintaining an application buffer around surface waters. BMPs would include scheduling the application to avoid heavy precipitation events, closely monitoring the application rate, and using licensed applicators with close manager oversight. No new mitigation measures are anticipated to be required. Monitoring efforts will include monitoring the bait application rate, the bate availability period, bait condition, water quality, impacts to nontarget species, and the effectiveness of this rodent control effort.

The Proposed Action is the only alternative that can satisfy the purpose and need. All adverse effects would be less than significant, and the project would result in substantial beneficial effects for endangered Oʻahu ʻelepaio populations in Lihue MU as well as for other native and endemic species within the management unit. The Army will determine whether it is appropriate to proceed with the Proposed Action once the environmental review process is completed. The anticipated Finding of No Significant Impact is based on a thorough evaluation of applicable research reports addressing rodenticide toxicology and environmental fate; the results of similar aerial application of rodenticide actions reported by other agencies; direct manager experience with Oʻahu endangered species population maintenance and recovery; and in particular, the relevant resource issues and concerns of Lihue Management Unit.

The long-term benefits of alien rodent control far outweigh the minor and less than significant short-term negative effects of this management action.

Potential temporary and less than significant negative impacts include: short-term localized impacts to air quality and the noise environment associated with aerial rodenticide application activities; and a potential for short-term impacts to treatment area soils and surface water from the rodenticide product. There is no intention to adversely impact nontarget species within Lihue MU, but there is potential for unintentional insignificant impacts to individual nontarget birds within Lihue MU. There is also the potential that individual nontarget birds could benefit from reduced predatory pressure from rodents.

The possibility for introduction of new weed species as a result of this activity is very low. Attempts have been made to germinate plants from the grain-based diphacinone pellets without success. Prior to initiating the operation all equipment and materials will be inspected to ensure they are clean and free of weed seeds. During ongoing and subsequent rat monitoring activities, natural resource management staff will follow protocols to prevent weed distribution involving their personal gear and movements. This protocol will be strictly enforced.

Based upon the available information, this SEA has concluded that the Proposed Action will not have any unmitigable significant direct, indirect, or cumulative adverse impacts on the natural or human environment. As such, the Proposed Action does not require the completion of an Environmental Impact Statement, as defined by the Council of Environmental Quality regulations (40 CFR 1500-1508) and Army Regulation (32 CFR Part 651). A draft FNSI has been prepared and an opportunity for public comment will be published in both the Honolulu Star-Advertiser newspaper and the State of Hawai‘i Office of Environmental Quality Control (OEQC) Environmental Notice bulletin.

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# 11 REFERENCES

Anderson B., S. Borges, and K. Garber. 2011. Risks of non-compliant rodenticides to nontarget wildlife. U.S. EPA.

Badyaev A.V., V. Belloni, and G.E. Hill. 2012. House Finch (*Haemorhous mexicanus*). In: Rodewald, P.G. (ed). The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Baroch, J. 1994. Field efficacy of rodenticide bait diphacinone-treated grain (0.005%) FLN No. CA890020 used in bait stations to control California ground squirrel (*Spermophilus beecheyi*). California Department of Food and Agriculture, Unpub. Report, Sacramento, CA. In: Erickson, W. and D. Urban. 2004. Potential risks of nine rodenticides to birds and nontarget mammals: A comparative approach. U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances. 153 pp.

Baroch, J. 1996. Field efficacy of rodenticide bait chlorophacinone-treated grain (0.005%) FLN No. CA890023 used in bait stations to control California ground squirrel (*Spermophilus beecheyi*). California Department of Food and Agriculture, Unpub. Report, Sacramento, CA. In: Erickson, W. and D. Urban. 2004. Potential risks of nine rodenticides to birds and nontarget mammals: A comparative approach. U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances. 153 pp.

Buckle, A. and R. Smith. 1994. Rodent pests and their control. CAB International, Bristol, UK.

Center for Environmental Management of Military Lands (CEMML). April 2003. Programmatic Biological Assessment for Routine Military Training and Transformation of the 2$^{nd}$ Brigade 25$^{th}$ Infantry Division (Light), U.S. Army. O‘ahu, Hawai‘i.

Chiaverano, L.M. and B.S. Holland. 2014. Impact of a predatory invasive lizard on the endangered Hawaiian snail *Achatinella mustelina:* a threat assessment. Endangered Species Research. 24:115-123.

Chimera, C.G., A.C. Medeiros, L.L. Loopel, R.H. Hobody. 2000. Status of Management and Control Efforts for the Invasive Alien Tree *Miconia Calvescens* DC (Melastomataceae) in Hana, East Maui. http://www.botany.hawaii.edu/faculty/duffy/techr/128.pdf. Accessed October 21, 2009.

Choquenot, D. and W. Ruscoe. 1999. Assessing the effect of poisoning programs on the density of non-target fauna: design and interpretation. New Zealand Journal of Ecology 23(2):139-147.

Clout, M.N. and J.C. Russell. 2006. The eradication of mammals from New Zealand Islands. In: Assessment and control of biological invasion risks. F. Koike, M.N. Clout, M. Kawamichi, M. De Poorter, and K. Iwatsuki, Eds. Shoukadoh Book 70 Sellers, Kyoto, Japan and World Conservation Union (IUCN), Gland, Switzerland.

Cory, C. 2000. Scientific research relating to the effects of management of pigs in the native Hawaiian ecosystems. The Nature Conservancy of Hawai‘i, Honolulu, Hawai‘i. Unpublished.

Cox, P.R. and R.H. Smith. 1990. Rodenticide ecotoxicology: Assessing non-target population effects. Functional Ecology 4:315-320.

Cromarty, P.L., K.G. Broome, A. Cox, R.A. Empson, W.M. Hutchison, and I. McFadden. 2002. Eradication planning for invasive alien animal species on islands – the approach developed by the New Zealand Department of Conservation. In: *Turning the Tide: The Eradication of Invasive Species.* C.R. Veitch and M.N. Clout, Eds. IUCN Invasive Species Specialist Group, Gland, Switzerland and Cambridge, UK. p. 85-91.

del Hoyo, J., A. Elliott, and J. Sargatal. 2006. Handbook of the Birds of the World. Vol. 11: Old World Flycatchers to Old World Warblers. Lynx Edicions, Barcelona.

Donlon, C.J., B.R. Tershy, and D.A. Croll. 2002. Islands and introduced herbivores: conservation action as ecosystem experimentation. Journal of Applied Ecology 39:235-246. In: *Environmental Assessment Lehua Island Ecosystem Restoration Project*. September 2005. 117 pp.

Dowding, J.E., E.C. Murphy, and C.R. Veitch. 1999. Brodifacoum residues in target and non-target species following an aerial poisoning operation on Motuihe Island, Hauraki Gulf, New Zealand. New Zealand Journal of Ecology 23(2):207-214.

Dunlevy, P. 2007. Draft Operational Plan to Eradicate Polynesian rats (*Rattus exulans*) from Lehua Island, Hawai‘i. USDA-APHIS-Wildlife Services Hawai‘i/Guam/Pacific Islands.

Dunlevy, P. and L. Scharf. 2008. Alaska Maritime NWR Invasive Rodent Program, 2003-2005 Field Work Report; *Rattus norvegicus*: Initial surveys, feasibility studies and eradication methods development in the Bay of Islands, Adak Island, Alaska. U.S. Fish and Wildlife Service Report, AMNWR 08/06. Homer, AK.

Dunlevy, P. and L. Spitler. 2008. Alaska Maritime NWR invasive rodent program 2003-2005 field work report. U.S. Fish and Wildlife Refuge, Homer, AK.

Dunlevy, P.A. and E.W. Campbell III. 2002. Assessment of hazards to non-native mongooses (*Herpestes auropunctatus*) and feral cats (*Felis catus*) from broadcast application of rodenticide bait in native Hawaiian forests. In: *Proceedings 20th Vertebrate Pest Conference*. R.M. Timm and R.H. Schmidt, Eds. University of California, Davis. p. 277-281.

Dunlevy, P.A., E.W. Campbell III, and G.D. Lindsey. 2000. Broadcast application of a placebo rodenticide bait in a native Hawaiian forest. International Biodeterioration and Biodegradation 45:199-208.Gagne, W.C. and L.W. Cuddihy, 1999. Vegetation. Pp. 45-114 *in* W.H. Wagner, D.R. Herbst, and S.H. Sohmer. Manual of Flowering Plants of Hawai‘i. University of Hawai‘i Press and Bernice P. Bishop Museum Press, Honolulu, Hawai‘i.

Eason, C. and S. Ogilvie. 2009. A re-evaluation of potential rodenticides for aerial control of rodents. Research & Development Series 312, New Zealand Department of Conservation Wellington, NZ.

Eason, C.T. and E. Murphy. 2001. Recognizing and reducing secondary and tertiary poisoning risks associated with brodifacoum. *Pesticides and Wildlife*, Ch. 12. J. Johnston, Ed. American Chemical Society Symposium Series 771. p. 157-163.

Eason, C.T. and E. Spurr. 1995. Review of the toxicity and impacts of brodifacoum on nontarget wildlife in New Zealand. New Zealand Journal of Zoology 22:371-379.

Eason, C.T. and M. Wickstrom. 2001. Vertebrate Pesticide Toxicology Manual (poisons), 2$^{nd}$ ed. New Zealand Department of Conservation Technical Series 23. 122 pp.

Eason, C.T., L. Milne, M. Potts, G. Morriss, G.R.G. Wright and O.R.W. Sutherland. 1999. Secondary and tertiary poisoning risks associated with brodifacoum. New Zealand Journal of Ecology 23(2):219-224.

Eisemann, J. and C. Swift. 2006. Ecological and human health hazards from broadcast application of 0.005% diphacinone baits in native Hawaiian ecosystems. Pages 413-433 *in* R. Timm and J. O’Brien, editors. 22nd Vertebrate Pest Conference. University of California, Davis, Davis, CA.

Erickson, W. and D. Urban. 2004. Potential risks of nine rodenticides to birds and nontarget mammals: a comparative approach. U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, Washington, DC.

Fisher, P. 2005. Review of house mouse (*Mus musculus*) susceptibility to anticoagulant poisons. New Zealand Department of Conservation Internal Science Series No. 198. 18 pp.

Fisher, P. 2009. Residual concentrations and persistence of the anticoagulant rodenticides brodifacoum and diphacinone in fauna. Doctoral dissertation. Lincoln University, Lincoln, NZ.

Fisher, P., C. O'Connor, G. Wright, and C.T. Eason. 2003. Persistence of four anticoagulant rodenticides in the livers of laboratory rats. New Zealand Dept. of Conservation Science Internal Series No. 139. 74 pp. Hawai‘i Department of Health. 2004. Administrative Rules, Title 11, Chapter 54: Water Quality Standards. Honolulu, Hawai‘i.

Fisher, P., C. O'Connor, G. Wright, and C.T. Eason. 2004. Anticoagulant residues in rats and secondary non-target risk. New Zealand Dept. of Conservation Science Internal Series No. 188. 29 pp.

Fukami, T., D. Wardle, P. Bellingham, C. Mulder, D. Towns, G. Yeates, K. Bonner, M. Durrett, M. Grant-Hoffman, and W. Williamson. 2006. Above- and below-ground impacts of introduced predators in seabird-dominated island ecosystems. Ecology Letters 9:1299-1307.

Gale, R.W., M. Tanner, and C.E. Orazio. 2008. Determination of diphacinone in sea water, vertebrates, invertebrates, and bait pellet formulations following aerial broadcast on Mokapu Island, Molokai, Hawai‘i: U.S. Geological Survey Open-File Report 2008–1285, 16 p.

Halkin S.L., S.U. Linville, and G.E. Hill. 1999. Northern Cardinal (*Cardinalis cardinalis*). In: Rodewald, P.G. (ed). The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY.

Hawai‘i Department of Forestry and Wildlife (DOFAW). 2002. Rules regulating game bird hunting, field trials and commercial shooting preserves.

Hawai‘i Department of Health, Office of Environmental Planning. 1997. Water Quality Standards Map of the Island of O‘ahu. October 1997.

Hegdal, P.L. 1985. Primary hazards to game birds associated with the use of Ramik Brown (diphacinone bait) for controlling voles in orchards. Denver Wildlife Research Center Unpubl. Report U02591. U.S. Fish and Wildlife Service.

Hoare, J.M. and K.M. Hare. 2006. The impact of brodifacoum on non-target wildlife: gaps in knowledge. New Zealand Journal of Ecology 30(2):*In press.*

Hone, J. and H. Mulligan. 1982. Vertebrate pesticides. Australia Department of Agriculture, New South Wales.

Howald, G., C. J. Donlan, J.-P. Galvan, J.C. Russell, J. Parkes, A. Samaniego, Y. Wang, D. Veitch, P. Genovesi, M. Pascal, A. Saunders, and B. Tershy. 2007. Invasive rodent eradication on islands. Conservation Biology 21:1258-1268.

Howald, G.R., S. Buckelew, A. Wegmann, J. Sheppard, J. Curl, T. McClelland, E. Pershy, K. Swift, E. Campbell, and B. Flint. 2006. Designing a rat eradication program for the tropics – the Palmyra Atoll experience. Proc. 22nd Vertebrate Pest Conference, Berkeley, CA. *In press.*

Innes, J. and G. Barker. 1999. Ecological consequences of toxin use for mammalian pest control in New Zealand – an overview. New Zealand Journal of Ecology 23(2):111-127.

Innes, J.G., R. Hay, I. Flux, P. Bradfield, H. Speed, and P. Jansen. 1999. Successful recovery of North Island kokako *Callaeas cinerea wilsoni* populations, by adaptive management. *Biological Conservation* 87: 201-224.Kamehameha Schools. July 11, 2003. Final Environmental Assessment for the Helemano Watershed Management Project, O‘ahu, Hawai‘i.

Island Conservation. 2010a. The ecotoxicology and palatability of two rodenticide bait products: field-based assessment at Palmyra Atoll. Prepared by: A. Alifano and A. Wegmann, Santa Cruz, CA.

Jackson, W. and A. Ashton. 1992. A review of available anticoagulants and their use in the United States. Pages 156-160 *in* Proceedings of the Fifteenth Vertebrate Pest Conference. University of California, Davis, University of Nebraska, Lincoln.

Kawelo, H. K. Personal Communication. 13 Feb. 2017.

Lindsey, G.D. and C. Forbes. 2000. Effectiveness of hand broadcast baiting in 0.005% diphacinone bait pellets in reducing rat populations in Hawaiian forests. Unpublished Report. 23 pp.

Mākua Implementation Team (MIT). 2003. Implementation Plan: Mākua Military Reservation, Island of O‘ahu. Prepared for the U.S. Army Garrison, Hawai‘i. Schofield Barracks, Hawai‘i.

Marsh, R.E. 1985. Techniques used in rodent control to safeguard nontarget wildlife. Transactions Western Section of the Wildlife Society Annual Mtg. Monterey, CA. 93 pp.

Murphy, E.C., B.K. Clapperton, P.M.F. Bradfield, H.J. Speed. 1998. Brodifacoum residues in target and non-target animals following large-scale poison operations in New Zealand podocarp-hardwood forests. New Zealand Journal of Zoology 25: 307-314.

New Zealand Department of Conservation. 2001. Brodifacoum (TALON®, PESTOFF®), and Diphacinone (DITRAC®, LIQUATOX®, PESTOFF®. Pesticide Toxicology Manual – Information on Poisons Used in New Zealand as Vertebrate Pesticides, Sections 2.1 and 2.5. 28 pp.

Newton, I., I. Wyllie, and P. Freestone. 1990. Rodenticides in British barn owls. Environmental Pollution 68:101-117.

Orazio, C.E., M.J. Tanner, C. Swenson, J. Herod, P. Dunlevy, and R.W. Gale. 2009. Results of laboratory testing for diphacinone in seawater, fish, invertebrates, and soil following aerial application of rodenticides on Lehua Island, Kauai County, Hawai‘i. U.S. Geological Survey Open-File Report 2009-1142, 15 p. with appendix.

Pank, L. 1976. Effects of seed and background colors on seed acceptance by birds. Journal of Wildlife Management 40:769-774.

Parmar, G., H. Bratt, R. Moore, and P.L. Batten. 1987. Evidence for a common binding site in vivo for the retention of anticoagulants in rat liver. Human Toxicology 6:431-432.

Pitt, W.C., L.C. Driscoll, and R.T. Sugihara. 2011. Efficacy of rodenticide baits for the control of three invasive rodent species in Hawaii. Archives of Environmental Contamination and Toxicology 60:533–542.

Primus, T., G. Wright, and P. Fisher. 2005. Accidental discharge of brodifacoum baits in a tidal marine environment: A case study. Bulletin of Environmental Containment and Toxicology 74:913-919.

Rattner, B., K. Horak, S. Warner, D. Day, and J. Johnston. 2010. Comparative toxicity of diphacinone in northern bobwhite (*Colinus virginianus*) and American kestrels (*Falco* *sparverius*). Pages 146-152 *in* 24th Vertebrate Pest Conference. University of California, Davis, Sacramento, CA.

Recht, M.A. 1988. The biology of domestic rats: telemetry yields insights for pest control. Proceedings for the Vertebrate Pest Conference 13: 98-100.

Savarie, P.J., D.J. Hayes, R.T. McBride and J.D. Roberts. 1979. Efficacy and safety of diphacinone as a predacide. Pages 69-79 in E.E. Kenaga (ed.), Avian and Mammalian Wildlife Toxicology, ASTM STP 693, American Society for Testing and Materials.

Shiels, A.B. 2010. Ecology and impacts of introduced rodents (*Rattus* spp. and *Mus musculus*) in the Hawaiian Islands. Ph.D. Dissertation. University of Hawai‘i at Manoa. 218 pp.

Shiels, A.B. 2017. Assessment of a hand-broadcast rodenticide bait trial to control rats in the Waianae Mountains, Oahu. Final Report QA 2523. USDA, APHIS, WS, NWRC. 75 pp.

Shiels, A.B., and D.R. Drake. 2011. Are introduced rats (*Rattus rattus*) both seed predators and dispersers in Hawai‘i? *Biological Invasions* 13: 883-894.

Shiels, A.B., C.A. Flores, A. Khamsing, P.D. Krushelnycky, S.M. Mosher, and D.R. Drake. 2013. Dietary niche differentiation among three species of invasive rodents (*Rattus rattus*, *R. exulans*, *Mus musculus*). *Biological Invasions* 15: 1037-1048.

Spurr, E., D. Foote, C. Perry, and G. Lindsey. 2003a. Efficacy of aerial broadcast application of baits containing 0.005% diphacinone in reducing rat populations in Hawaiian forests. Unpublished report #QA-02b, U.S. Geological Survey, Pacific Islands Ecosystems Research Center, Hawai‘i National Park, Hawai‘i.

Spurr, E.B., G.D. Lindsey, C.G. Perry, and D. Foote. 2003b. Effectiveness of hand-broadcast application of baits containing 0.005% diphacinone in reducing rat populations in Hawaiian forests. Unpublished report #QA-02a, U.S. Geological Survey, Pacific Islands Ecosystems Research Center, Hawai‘i National Park, Hawai‘i.

Stephenson, B.M., E.O. Minot, and D.P. Armstrong. 1999. Fate of moreporks (*Ninox novaeseelandiae*) during a pest control operation on Mokoia Island, Lake Rotorua, North Island, New Zealand. New Zealand Journal of Ecology 23(2):233-240.

Stephenson, B.M., E.O. Minot, and D.P. Armstrong. 1999. Fate of moreporks (*Ninox novaeseelandiae*) during a pest control operation on Mokoia Island, Lake Rotorua, North Island, New Zealand. New Zealand Journal of Ecology 23(2):233-240.

Stone, C.P., L.W. Cuddihy, and, J.T. Tunison. 1992. Responses to Hawaiian Ecosystems to Removal of Feral Pigs and Goats. *In* Alien Plant Invasions in Native Ecosystems of Hawaii: Management and Research. (C.P. Stone, C.W. Smith, and J.T. Tunison Eds.). University of Hawai‘i at Mānoa, Cooperative Park Resources Studies Unit. pp. 666-704.

Svircev, N. 1992. Ramik® Green commensal rodenticide efficacy data wax block and wax pellet. HACCO Rodenticide Efficacy Facility, Unpublished Report. 14 pp.

Swift, C.E. 1998. Laboratory bioassays with wild-caught black (*Rattus rattus*) and Polynesian (*R. exulans*) rats to determine minimum amounts of Ramik Green (0.005% diphacinone) and exposure times for field broadcast applications in Hawai'i. M.S. Thesis, University of Hawai'i Manoa, Honolulu, HI. 92 pp.

Taylor, R.H. and B.W. Thomas. 1993. Rats eradicated from rugged Breaksea Island (170 ha), Fiordland, New Zealand. Biological Conservation 65:191-198.

Tershy, B. and D. Breese. 1994. Color preference of the island endemic lizard *Uta palmeri* in relation to rat eradication campaigns. The Southwestern Naturalist 39:295-297.

Tershy, B., D. Breese, A. Angeles-P, M. Cervantes-A, M. Mandujano-H, E. Hernandez-N, and A. Cordoba-A. 1992. Natural history and management of Isla San Pedro Mártir, Gulf of California. Report to Conservation International, Conservation International.

Tetra Tech, Inc. 2004. Final Environmental Impact Statement, Transformation of the 2nd Brigade, 25th Infantry Division (L) to a Stryker Brigade Combat Team in Hawai'i.

The Nature Conservancy of Hawai'i. October 1997. Final Environmental Assessment for Honouliuli Nature Preserve.

Timm, R. 1994. Norway rats. Page 16 *in* S. Hygnstrom, R. Timm, and G. Larson, editors. Prevention and control of wildlife damage. University of Nebraska, Lincoln, Lincoln, NE.

Tobin, M. 1992. Rodent damage in Hawaiian macadamia orchards. Pages 277-278 *in* 15th Vertebrate Pest Conference. University of California, Davis, CA.

Tobin, M.E. 1994. Mitigating rat depredation in native Hawaiian habitats. Trans. Western Section of the Wildlife Society 30:15-20.

Tomonari-Tuggle, M.J. 2002. The U.S. Army in Hawai'i: An Historic Context for Cultural Resources on U.S. Army Garrison, Hawai'i Installations. Ms., prepared for CEMML and U.S. Army Garrison, Hawai'i. International Archaeological Research Institute, Inc., Honolulu, Hawai'i. As cited in: Tetra Tech, Inc. 2004. Final Environmental Impact Statement, Transformation of the 2nd Brigade, 25th Infantry Division (L) to a Stryker Brigade Combat Team in Hawai'i.

Towns, D.R., D.A. Wardle, C.P.H. Mulder, G.W. Yeates, B.M. Fitzgerald, G.R. Parrish, P.J. Bellingham, and K.I. Bonner. 2009. Predation of seabirds by invasive rats: multiple indirect consequences for invertebrate communities. Oikos 118:420-430.

Tu, M., C. Hurd, and J.M. Randall. April 2001. Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas. The Nature Conservancy Wildland Invasive Species Team. http://www.invasive.org/gist/handbook.html Accessed November 3, 2009.

Tyrrell, C.L., A. Cree, D.R. Towns. 2000. Variation in reproduction and condition of northern tuatara (*Sphenodon punctatus punctatus*) in the presence and absence of kiori. Science for Conservation Vol. 153. 42 pp.

U.S. Army Garrison, Hawai‘i. June 1997. Biological Surveys at Selected Streams of Kahuku, Schofield Barracks, and Kawailoa Training Areas, Island of O‘ahu, Hawai‘i. Prepared by: The Hawai‘i Natural Heritage Program, The Nature Conservancy of Hawai‘i.

U.S. Army Garrison, Hawai‘i. 2001. Oahu Biological Assessment.

U.S. Army Hawai‘i. 2001. Integrated Natural Resources Management Plan and Environmental Assessment/Finding of No Significant Impact 2002-2006, Oahu.

U.S. Army Hawai‘i. 2006. Final Programmatic Environmental Assessment for the Mākua Implementation Plan, O‘ahu, Hawai‘i.

U.S. Army Hawai‘i. 2010. Programmatic Environmental Assessment for the Final Implementation Plan for O‘ahu Training Areas: Schofield Barracks Military Reservation, Schofield Barracks East Range, Kawailoa Training Area, Kahuku Training Area, and Dillingham Military Reservation.

U.S. Environmental Protection Agency (EPA). 1998. Reregistration Eligibility Decision (RED): Rodenticide Cluster. EPA 738-R-98-007. 319 pp.

U.S. Environmental Protection Agency (EPA). 2017. Summary of the Federal Insecticide, Fungicide, and Rodenticide Act; [accessed 30 June 2017]. https://www.epa.gov/laws-regulations/summary-federal-insecticide-fungicide-and-rodenticide-act.

U.S. Fish and Wildlife Service (USFWS). 1999. Biological Opinion of the U.S. Fish and Wildlife Service for Routine Military Training at Mākua Military Reservation. Honolulu, Hawai‘i. 41pp+ attachments.

U.S. Fish and Wildlife Service (USFWS). 2003. Biological Opinion of the U.S. Fish and Wildlife Service for Routine Military Training and Transformation of the 2nd Brigade 25th Infantry Division (Light) U.S. Army Installations Island of O’ahu. Honolulu, Hawai‘i. 351pp.

U.S. Fish and Wildlife Service (USFWS). 2006. Final Revised Recovery Plan for Hawaiian Forest Birds. U.S. Fish and Wildlife Service, Portland, Oregon. 508 pp.

U.S. Fish and Wildlife Service (USFWS). 2007. Reinitiation of the 1999 Biological Opinion of the U.S. Fish and Wildlife Service for U.S. Military Training at Mākua Military Reservation. Honolulu, Hawai‘i. 639pp+ attachments.

U.S. Fish and Wildlife Service (USFWS). 2011. Desecheo National Wildlife Refuge Rat Eradication to Promote Ecosystem Restoration. Final Environmental Assessment. 255 pages. Boqueron, Puerto Rico.

U.S. Fish and Wildlife Service (USFWS). 2014. Informal consultation for the renewals of EPA Special Local Needs registrations for use of Ramik Mini Bars & Mouse Killer, and Rozol Mini Blocks and Pellets, Hawai‘i.

U.S. Fish and Wildlife Service (USFWS). 2015. Draft Environmental Assessment for Restoration of Habitat on the Desecheo National Wildlife Refuge through the Eradication of Non-Native Rats.

U.S. Fish and Wildlife Service (USFWS). 2017. Draft Environmental Assessment for Evaluation of the Field Efficacy of Broadcast Application of Two Rodenticides (diphacinone, chlorophacinone) to Control Mice (*Mus musculus*) in Native Hawaiian Conservation Areas.

U.S. Fish and Wildlife Service (USFWS) and Hawai‘i Division of Forestry and Wildlife (DOFAW). 2008. Final Supplemental Environmental Assessment, Lehua Island Ecosystem Restoration Project.

United States Soil Conservation Service. 1972. Soil Survey of the Islands of Kauai, O‘ahu, Maui, Molokai, and Lanai, State of Hawai‘i. Washington DC.

VanderWerf, E. A. 1998. Elepaio (*Chasiempis sandwichensis*). No. 344 *in* A. Poole, and F. Gill, editors. The Birds of North America. The Birds of North America, Inc., Philadelphia, Pennsylvania, USA.

VanderWerf, E.A., M.D. Burt, J.L. Rohrer, and S.M. Mosher. 2006. Distribution and prevalence of mosquito-borne diseases in O‘ahu Elepaio. Condor 108:770-777.

VanderWerf E. A. 2009. Importance of nest predation by alien rodents and avian poxvirus in conservation of O‘ahu Elepaio. Journal of Wildlife Management 73:737-746.

VanderWerf, E.A., M.T. Lohr, A.J. Titmus, P.E. Taylor, and M.D. Burt. 2013. Current distribution and abundance of the Oahu Elepaio (*Chasiempis ibidis*). Wilson Journal of Ornithology 125:600-608.

VanderWerf, E.A., J.L. Rohrer, D.G. Smith, and M.D. Burt. 2001. Current distribution and abundance of the O‘ahu ‘Elepaio. Wilson Bulletin 113:10–16.

Yuen, G.A.L. and Associates. 1990. Commission on Water Resources Management, Department of Land and Natural Resources, State of Hawai‘i. Water Resources Protection Plan Volumes 1&2. (http://www.state.hi.us/dlnr/cwrm/planning/wrpp1990.pdf) Accessed August 31, 2009.

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# APPENDIX A
# Introduction to Rodenticides and Rodenticide Hazard Analysis, with Special Reference to Birds

(adapted from "Final Supplemental Environmental Assessment Lehua Island Ecosystem Restoration Project," October 2008)

Diphacinone is a chronic rodenticide, meaning that the onset of symptoms only begins sometime after the lethal dosage has been ingested. If a rat does not experience symptoms until long after ingesting a lethal dose of the rodenticide, it cannot associate the symptoms with the new food item, causing the rats to continue eating the bait until or even long after a lethal dose has been ingested.

Diphacinone is an anticoagulant which acts by disrupting the normal blood-clotting mechanisms of vertebrates by competing with vitamin-K, a chemical necessary for clotting of blood, for receptor sites in the liver. Death in animals receiving a lethal dose of an anticoagulant rodenticide typically occurs from shock due to excessive blood loss through internal and sometimes external hemorrhaging eventually causing severe anemia. Prior to dying, between the time of ingestion and actual death (latent period), poisoned animals may exhibit increasing weakness and behavioral changes such as acting sluggish, changes in activity time, and reduced predator avoidance ability. This behavior can make target rodents more susceptible to predation (Cox and Smith 1990, Newton et al. 1990, Innes and Barker 1999, as cited in USFWS and DOFAW 2008).

Anticoagulant rodenticides are divided into two chemical groups, the indandiones, such as diphacinone and the coumarins; which includes brodifacoum. More informally, anticoagulant rodenticides are also described either as "first generation" or "second generation" rodenticides, simply referring to the time period during which they were developed. Diphacinone is a first generation and brodifacoum a second generation rodenticide. Second generation compounds were specifically designed to overcome resistance to warfarin (an early "first generation" compound) and are therefore generally more toxic than the first generation rodenticides. The coumarins in general, but especially brodifacoum, are characterized by an increased potential for accumulation and persistence in body tissues. This is due primarily to their greater affinity to bind to receptors in the liver and the long latent period during which rodents continue to feed on the toxicant (Eason and Wickstrom 2001, Fisher et al. 2003).

### Diphacinone Characteristics

Diphacinone, because it is less toxic and more rapidly metabolized and excreted, accumulates in body tissues less readily and in lower concentrations, than second generation rodenticides, such as brodifacoum (Erickson and Urban 2004).

Products containing diphacinone were first registered for rodent control in 1960 at active ingredient concentrations of 0.005% to 0.01 % (50 to 100 ppm). Diphacinone (0.005% active ingredient) is currently registered for use for conservation purposes in the United States.

Many laboratory studies of the $LD_{50}$ for vertebrate species have been conducted on a variety of test species (both target and nontarget species) using a range of methods (Swift 1998, Fisher 2005). In general, the median oral lethal dosage of diphacinone for rats is about 3.0 mg/kg, while for brodifacoum it is roughly 0.3 mg/kg. Brodifacoum is about ten times more toxic on a weight/weight basis to rats than diphacinone. However, as previously mentioned, there is a similar latent period between time of ingestion and death between the two toxicants. Many factors influence this delay, but in general the latent period is about seven days and ranges from three to 14 days for both of these rodenticides (Eason and Wickstrom 2001, Erickson and Urban 2004).

A rodenticide that is rapidly metabolized and/or excreted from the primary consumer (the animal directly ingesting the rodenticide) poses fewer hazards to secondary consumers than one that is readily retained in tissues and therefore accumulates in the bodies of animals over time. Sublethal exposure to anticoagulants can produce significant blood clotting abnormalities and internal and external hemorrhaging. Such chronic hemorrhaging might be especially detrimental if combined with other factors such as adverse weather, food shortages, pregnancy or predation stressors, and could predispose an animal to death from other sources, such as bruising, food stress, and reduced potential for recovery from wounds and accidents.

Most rodents will continue eating for several days or more after ingesting a lethal dose of an anticoagulant rodenticide. A laboratory study found that rats ate over twelve $LD_{50}$ doses of a diphacinone bait formulation resulting in liver residues of 4.7 mg/g. For comparison, D-50 is 0.005% a.i. or 5 mg/g (Fisher et al. 2004). Therefore, the livers of these rats actually contained slightly less than the active ingredient concentration of the actual bait formulation.

Generally, repeated exposures to small doses of anticoagulants over several days pose a greater hazard than larger single doses. Anticoagulants bind to receptors in the liver and other tissues, including the kidneys, pancreas, lungs, brain, fat and muscles and are eliminated from the liver last. The length of time a rodenticide is retained in tissues or how quickly it is eliminated (half-life) greatly influences accumulation of rodenticides in tissues and, therefore, nontarget hazards.

Elimination of anticoagulant rodenticides from tissues is biphasic, with a proportion of the toxicant excreted within a shorter time and the remainder bound in the tissues and excreted over a much longer period of time (Parmer et al. 1987, cited in Fisher et al. 2003). During the first phase of diphacinone excretion from tissues, 70% of a single dose may be excreted in about 8 days. In a laboratory test, , 0.8 mg/kg of diphacinone was administered to rats, resulting in mean liver residue concentrations of 0.08 mg/kg at one week and below the detectable limit at six weeks. Further trials of diphacinone resulted in the estimated liver elimination half-life 3 days (Fisher et al. 2003). In addition, the range of whole carcass residues reported by the EPA in primary consumers was 0.48 to 3.4 ppm for diphacinone.

### Efficacy Studies of Brodifacoum and Diphacinone

The following information is compiled from Erickson and Urban (2004) and the New Zealand Pesticide Toxicology Manual (New Zealand Department of Conservation 2001).

Brodifacoum has been used for most rat eradication projects worldwide because its far greater toxicity is perceived to impart a greater probability of success. However, it is important to remember that toxicity and efficacy are not synonymous terms. Efficacy is a complex interaction of many factors, including bait acceptance, application rate, application method, toxicity, and timing of application when rodent populations, reproduction and alternate foods are lowest to ensure eradication. The eradication of rodents on islands has been successfully implemented using the generally less toxic anticoagulant rodenticides warfarin, pindone, diphacinone and bromadiolone (Witmer et al. 2001, Donlan et al. 2002, Dunlevy and Scharf 2008) and some eradication efforts have failed during operations using brodifacoum (Tyrrell et al. 2000, Clout and Russell 2006, Howald et al. 2006).

An increasing number of experts in island rodent eradication and control have recommended using less toxic rodenticides such as diphacinone, and decreasing the use of more persistent and toxic rodenticides such as brodifacoum on future projects because of the greater risk to nontarget species associated with brodifacoum, including both primary hazards (when nontarget species feed directly on the bait) and secondary hazards (when nontarget species feed on rodenticide-exposed animals with rodenticide residues in their tissues) (Tobin 1994, Eason et al. 1999, Fisher et al. 2003). Fisher et al. (2004) recommend conducting additional field studies using diphacinone to further determine efficacy and validate estimates of lower risk for secondary poisoning of nontarget species.

A number of laboratory and field studies in the United States have evaluated the effectiveness of various application methods and the efficacy of diphacinone for control of rat populations, especially in Hawai‘i:

- Laboratory trials using Sprague-Dawley strain laboratory rats found that 100% of 20 laboratory-bred brown rats died after consuming an average of 42 grams of bait (0.21 g of the a.i. diphacinone), 7 g per day per animal over an average of six days (Svircev 1992).
- Laboratory trials found that 100% of 20 Hawaiian wild-caught Polynesian rats died over two to ten days after consuming an average of 19.7 grams of bait (0.099 g of 0.005% diphacinone) per animal and 95% of 20 wild-caught black rats died over four to 17 days after consuming an average of 21.2 grams of bait (0.106 g of diphacinone) per animal. These trials indicated that a minimum average exposure time of 7 days with 37.5 g of bait is needed for effective control of black rats, and 6 days and 30 g are needed for effective control of Polynesian rats (Swift 1998).
- A broadcast application rate study using a nontoxic formulation of Ramik® Green and a biomarker determined the optimal application rate, 22.5 kg/ha or 20 lb/ac, which exposed 100% of Polynesian rats and 94.4% of black rats over a 14-day period (Dunlevy et al. 2000), even though immigration could not be eliminated. Bait disappearance was most rapid at the 22.5 kg/ha application rate with 50% of the bait disappearing by day 6 and 80% disappearing by day 12.
- An exposure using remote cameras found that 98.98% of vertebrates photographed at broadcast rodenticide pellets were the target species, rats and mice (Dunlevy and Campbell 2002).
- A broadcast trial, also using Ramik® Green bait containing 0.005% (50 ppm) diphacinone, resulted in 100% control of radio-collared Polynesian, black, and brown rats in two 4-ha study areas in Hawai‘i (Lindsey and Forbes 2000). Follow-up broadcasts in the same study areas were also highly effective in controlling subsequent rat immigration.
- A trial of Ramik® Green broadcast into a 45.5 ha forested area in Hawai‘i also achieved 100% mortality of 21 radio-collared rats within one week of application. Three weeks after bait application, based on trapping and chew blocks, rat abundance was still reduced by 99% relative to reference areas (Spurr et al. 2003a and 2003b) despite the immigration issues of this main island study site.
- In the Bay of Islands, Adak, Alaska, a three-year study evaluated Ramik® Green and various application methods on several small islands (Dunlevy and Scharf 2008).

These successful laboratory trials and field studies strongly suggest that well planned rat eradication projects utilizing diphacinone have a very high probability of eradicating rats on islands if used appropriately.

**Rodenticide Hazard Analysis**

The U.S. Environmental Protection Agency (EPA) evaluates the hazards associated with the use of rodenticides. Standard evaluation tests of hazard include a toxicity assessment of rodenticides from a single ingestion (acute toxicity) as well as with repeat ingestion over time (chronic toxicity), mortality of nontarget species, retention time of rodenticide residues in primary consumers (animals that eat the bait directly) and indirect exposure of predators and scavengers that eat exposed primary consumers. Because of these concerns, EPA requires standardized studies for determining the toxicity of compounds and their impacts on fish, birds and mammals prior to registration of a particular rodenticide formulation under FIFRA. EPA has two recent documents outlining study methodologies, overall results of studies, and resultant hazards of various rodenticides, including brodifacoum and diphacinone (Reregistration Eligibility Decision (EPA 1998) and Potential Risks of Nine Rodenticides to Birds and Nontarget Mammals: A Comparative Approach (Erickson and Urban 2004)). The following summary of study approaches and terms is primarily from Erickson and Urban (2004), which summarizes the findings of studies regarding diphacinone and brodifacoum, as well as other rodenticides.

The EPA limits their definition of nontarget hazard to a product of toxicity and exposure. The level of exposure is determined by the amount of active ingredient (a.i.) ingested.

Hazard can be characterized and assessed by many measures, including:

- Acute oral toxicity or $LD_{50}$– A single dose that is lethal to 50% of the test subjects in the population or study group under consideration, expressed as milligram(s) of active ingredient per kilogram of test subject body weight;
- Dietary toxicity or $LC_{50}$– The concentration of rodenticide in the diet (multiple feedings) that is lethal to 50% of test subjects in the population or study group under consideration, expressed as parts per million of the daily diet.
- Lowest observed effects level or LOEL– The lowest dosage at which measurable effects, such as increased blood-clotting times, are documented. This is not a mortality threshold and no negative impacts are necessarily derived at this hazard level. Diphacinone has LOELs calculated; brodifacoum does not because of its substantially higher toxicity.
- The dietary risk quotient (RQ) was developed by the EPA to compare hazards among different rodenticides. The ratio of the concentration of any rodenticide (ppm of active ingredient) to the dietary toxicity ($LC_{50}$) of the rodenticide provides a relative index of hazard. This allows for the comparison of the hazards among various rodenticides. The Level of Concern (LOC) is an RQ threshold used by the EPA to determine if unacceptable risk exists for a particular species. The index allows for comparisons among risks for different species. Risk is presumed for non-endangered species if the RQ is $\geq$0.5 and for an endangered species if the RQ >0.1.
- Half life - The length of time that rodenticide residues persist in tissues is calculated in terms of the time that half the original concentration of residue still persists in tissue or blood.

- Total daily food intake for a particular species compared to the animals weight can be used to gauge the possibility that an animal is physically capable of eating the amount of rodenticide (at any particular concentration of the active ingredient) required to deliver an $LD_{50}$ dosage.

To describe the range of potential hazard to nontarget species from rodenticide application, this analysis discusses the acute oral toxicity of both diphacinone and brodifacoum for the species of concern. From the $LD_{50}$ we can determine the amounts of bait and/or rodenticide residue in tissues of prey that an individual of a nontarget species would be required to eat to obtain this dosage. Using this information we can assess the potential for this level of exposure based on knowledge of the biology of the nontarget species, such as behavior and daily food intake. Another very useful way of evaluating the potential hazards associated with rodenticide use is to describe the lowest dosage which results in any measurable effect and assess the potential for this level of exposure. Using laboratory and field data accepted by the EPA, quantitative characterizations of rodenticide nontarget hazards can be made and assessed in conjunction with the known biology of the species of concern.

Standardized laboratory studies are used to determine the acute oral and dietary toxicity of vertebrate pesticides for some standard test subjects, such as brown rats, and sometimes for other species. These studies produce a range of values, sometimes with considerable variation. The details and assessments by the EPA of these studies are discussed in the Reregistration Eligibility Decision (EPA 1998) and Erickson and Urban (2004).

The determinations of the EPA in these documents are utilized in the analyses presented here. For untested mammals, a theoretical $LD_{50}$ can be calculated, based on the weight of the animal, using the laboratory documented $LD_{50}$, accepted by the EPA, for a brown rat for any particular compound. For a brown rat, the $LD_{50}$ of diphacinone is 2.3 mg/kg; for brodifacoum it is 0.4 mg/kg, indicating the substantially greater relative toxicity for brodifacoum. A 100 kg mammal would, therefore, require 230 mg of diphacinone, or 40 mg of brodifacoum to ingest the projected $LD_{50}$ dosage.

EPA calculates hazards for nontarget bird species the same way, using a known laboratory-derived $LD_{50}$ from representative birds: the northern bobwhite quail (*Colinus virginianus*) and mallard duck (*Anas platyrhynchos*). Some studies have also documented, in the laboratory, $LD_{50}$ and $LC_{50}$ values for some other species besides the standard species consistently used by EPA in toxicity studies.

**Methodology Used in This Document to Analyze Rodenticide Impacts to Birds**

The analyses of the direct and indirect impacts of diphacinone and brodifacoum on nontarget birds are based on the known laboratory $LD_{50}$ and $LC_{50}$ information documented by the U.S. Environmental Protection Agency (EPA 1998, Erickson and Urban 2004).

Broadcast applications of diphacinone bait at the maximum rate of 22.5 kg/ha (20 lb/ac); result in approximately one 2.25-gram pellet distributed about every square meter. The maximum broadcast rate of brodifacoum bait is 18 kg/ha (16 pounds bait/acre), resulting in a density of approximately one 2-gram pellet per square meter (see Section 2.1.3 for label requirements).

The analyses of the primary hazards of brodifacoum and diphacinone use a computed $LD_{50}$-equivalent dose. This is based on laboratory studies in species such as the rat, a surrogate for other mammals, and bobwhite or mallard for other avian species. The average weight of an adult female animal of concern and the established $LD_{50}$ of the surrogate species studied are used to calculate the amount of each rodenticide that would need to be ingested to reach the $LD_{50}$-equivalent dosage. This is compared to the area over which that amount would be distributed during an aerial application and the likelihood of an animal eating every bait pellet within that area. If it is highly unlikely that the animal would directly eat bait pellets based on its dietary habits, the calculated results are evaluated in that context.

The analyses of the secondary impacts of brodifacoum and diphacinone assume that the adult female animal of average weight feeds exclusively in an area massively contaminated to the extent documented at the spill site in New Zealand and exclusively on the most contaminated samples collected during the monitoring of the incident: mussels and fish liver. One day after the accident, mussels contained brodifacoum residues of 0.41 ppm and a butterfish sampled nine days after the spill had brodifacoum liver residues of 0.04 ppm. This is then used to calculate amounts of these prey items secondary nontarget species would need to eat in order to ingest the computed $LD_{50}$ for the species of concern. This is then compared to either the animal's average daily food intake or body weight to determine if eating such a quantity is probable or even possible.

For the most conservative assessment of secondary hazard, it is assumed that nontarget species of concern would be exposed to prey items that have themselves been exposed to rodenticides and contain residues and that these residues are similar to the maximum residue levels of either potential prey items documented in Primus et al. (2005) during a massive point-source spill of rodenticide, laboratory exposure to a toxicant only, and/or collected from the site of an actual rodenticide operation.

The evaluation and comparison of $LD_{50}$ values and risk quotients provides a good description of the upper end of the hazard spectrum associated with rodenticide use. However, because anticoagulants are far more toxic when administered on multiple days with smaller exposures, to fully characterize the range of possible hazard the lower end of the hazard potential needs to be assessed. To do this we will examine the Lowest Observed Effect Level (LOEL) for all nontarget species that we know are at the highest risk of exposure. Assessing the LOEL will illustrate the minimum amount of exposure necessary to produce a measurable effect, such as increased blood-clotting time. This is not a mortality threshold and no negative impacts are necessarily derived at this hazard level.

In a laboratory study using golden eagles fed diphacinone-laced sheep muscle (2.7 ppm) Savarie et al. (1979) established the LOEL for golden eagles at 0.11 mg/kg/day in a 7-day exposure study. The EPA reports the LOEL of diphacinone for rats in a 14-day subchronic lab study as 0.085 mg/kg/day (EPA 1998).

The LOELs of brodifacoum are not as well documented as those of diphacinone. No LOEL of brodifacoum for birds has been established because effects have been observed for all doses administered in all tests. The EPA reports the LOEL of brodifacoum for rabbits in a developmental lab study as 0.005 mg/kg/day (EPA 1998). Using these available figures to extrapolate the LOELs for each of the species of concern the lower limit of potential hazard can be assessed.

**Effects on Birds from Ingestion of Rodenticides by Eating Bait (Direct Effect)**

Standard EPA studies of the acute oral toxicity of diphacinone and brodifacoum have been conducted for two avian species. For diphacinone, the $LD_{50}$ for the mallard duck is 3,158 mg/kg and for the northern bobwhite 400 mg/kg $< LD_{50} <$ 2000 mg/kg. For brodifacoum, the $LD_{50}$ for the mallard is 0.26 mg/kg (no documentation for the bobwhite) (Erickson and Urban 2004). The dietary (chronic) toxicity studies of diphacinone for mallard (*Anas* platyrhynchos) and bobwhite quail (*Colinus virginianus*) documented $LC_{50}$ values of 906 ppm for the mallard and >5,000 ppm for the bobwhite quail. For brodifacoum, the $LC_{50}$ reported for the mallard is 2.0 ppm and for the northern bobwhite it is 0.8 ppm, many orders of magnitude higher than the $LC_{50}$ for diphacinone (Erickson and Urban 2004).

Primary and secondary hazard calculations of diphacinone acute oral toxicity for nongame birds weighing $\leq$0.22 pounds ($\leq$3.5 ounces) were made for the equivalent of Hawaiian passerine birds. In order to consume sufficient diphacinone bait to reach a dose equivalent to the $LD_{50}$ for the northern bobwhite, a passerine bird would have to eat 0.53 pounds of bait or 5,027 pounds of invertebrates in one day. Neither of these amounts is even physically possible. While to obtain the $LC_{50}$ for diphacinone, the bird would have to consume 0.36 g of bait or 3.59 g of invertebrates per day over several days. However, hazard calculations for sublethal exposure show that a 30 g bird would only need to eat 0.07 g (a 100$^{th}$ of a bait pellet, or 0.2% of its body weight) or 0.65 g of invertebrates per day for multiple day to ingest a dose that resulted in measurable blood clotting effects in golden eagles. Therefore, small passerine birds could be vulnerable to sublethal or possibly lethal effects through both primary and secondary exposure if they forage on diphacinone bait or contaminated invertebrates over time (Eisemann and Swift 2006).

Birds that are most at risk from feeding directly on rodenticides are those that are naturally inquisitive, which are terrestrial ground-feeders, and that have a diet that includes grains and seeds. The risk of secondary poisoning is greatest for predatory and scavenging birds, especially those that feed directly on the target rodent species, such as owls. Brodifacoum has a far greater potential for primary and secondary poisoning of nontarget bird species than diphacinone because of its much higher toxicity, longer retention time in tissues, and higher rate of bioaccumulation (Erickson and Urban 2004, Eason and Wickstrom 2001, Fisher et al. 2003, Fisher et al. 2004). Combined with an extremely long half-life of residues in tissues, the general characteristic of anticoagulants for delayed symptoms and mortality after exposure results in target animals ingesting many lethal doses before death (Erickson and Urban 2004).

Erickson and Urban (2004) provide this useful discussion of potential effects of diphacinone on avian nontarget species found during field operations:

> Hegdal (1985) conducted a field study in Washington to examine the risk to game birds from the broadcast application of 0.005% diphacinone bait applied for vole control in orchards. Most orchards were treated twice, with 20 to 30 days between treatments; at an average rate of 12.9 kg/ha (11.5 pounds/acre). Telemetry was used to monitor the fate of 52 ring-necked pheasants, 18 California quail, and 30 chukar potentially exposed to the bait. About half of the quail and all chukar were pen-raised and had been released into the orchards. Dead game birds and other animals found were necropsied and any available tissue collected for residue analysis. Eight of 30 pheasants, 9 of 15 quail and one of ten chukar collected by the researchers or shot by hunters contained diphacinone residue in the liver but no mortalities were attributed to diphacinone. Bait made up as much as 90% of crop contents of some birds. No residue was detected in four passerines collected 31 to 73 days after treatment. The author concluded that risk to game birds in orchards appeared to be low but emphasized that substantial quantities of bait were eaten and longer-term behavioral and physiological effects, such as susceptibility to predation, need to be

considered along with direct mortality in order to evaluate potential hazards from exposure.

During field studies using diphacinone, searches for nontarget carcasses after baiting found one dove and two roadrunners (*Geococcyx californicus*); however there was no evidence that these birds were exposed to the rodenticide (Baroch 1994 and 1996). No avian nontarget mortality was observed during rodent eradication operations using a diphacinone rodenticide conducted on Buck Island in the Virgin Islands (Witmer et al. 2001) or Canna Island in Scotland (Elizabeth Bell, pers. comm., February 2006). Throughout two years of studies using a diphacinone rodenticide in the Aleutian Islands only one bird carcass was documented, though two ravens shot during this work also contained diphacinone residues and winter wrens, song sparrows and ptarmigan were also documented to eat the bait (Dunlevy and Scharf 2008). Two studies evaluated diphacinone residues in game birds captured from sites in Hawai‘i that had been treated by hand or aerial broadcasting 0.005% diphacinone bait. The first study utilized hand broadcast techniques on a 10-acre treatment area (Spurr et al. 2003a). Five Kalij pheasants (*Lophura leucomelana*) were collected within the treatment area between 2 and 6 weeks after treatment. Of the five, only one contained detectable diphacinone residues. The liver of this bird contained 0.09 ppm diphacinone. The second study was an aerial broadcast trial of Ramik Green (Spurr et al. 2003b). Two Kalij pheasants were collected within the 112 acre treatment area one month after treatment. Diphacinone residues of 0.12 and 0.18 ppm were found in the livers of these birds. Though extensive carcass searches were conducted during both studies no avian mortality due to diphacinone was found.

**Effects on Birds from Rodenticide Ingestion by Eating Prey (Indirect Effect)**

Incident reports submitted to EPA indicate that nontarget birds and mammals are being secondarily exposed to rodenticides, especially brodifacoum, in the field. Brodifacoum is widely used for control of rodents in protective stations around buildings and human habitation; diphacinone products are less used for this purpose. Diphacinone products are also registered for some field uses, such as in the agriculture industry. In 264 reported incidents, 20 animals had diphacinone residues and 244 animals had brodifacoum residues. The birds most commonly exposed to brodifacoum include great horned owls and red-tailed hawks, but multiple incidents are reported for bald and golden eagles, crows, barn owls, screech owls, hawks, falcons, kestrels and vultures.

Three laboratory studies report the secondary toxicity of diphacinone to birds. Test species were barn owls, great horned owls (*Bubo virginianus*), saw-whet owls (*Aegolius acadicus*), golden eagles (*Aquila chrysaetos* and American crows (*Corvus brachyrhynchos*). A total of 34 individuals were exposed to diphacinone-poisoned prey during these studies and three (9%) birds died, including two of three great horned owls and the only saw-whet owl tested. Symptoms of anticoagulant poisoning were noted in 13 (42%) of the survivors, indicating that raptors can recover from sublethal doses. The highest dosage administered to an eagle was 0.23 mg/kg/day for 10 consecutive days and the LOEL was determined to be 0.11 mg/kg/day. If it is assumed that the great horned owls ate equal quantities of treated mice each day, they would have consumed a maximum dose of 0.78 mg/kg/day for 5 days. Using the same methods, it can be calculated that the saw-whet owl consumed a dose of 11.1 mg/kg/day (Erickson and Urban 2004).

Hazard calculations for the short-eared owl (*Asio flammeus*, pueo) from eating contaminated rats were calculated for the secondary effects of diphacinone as there is an extremely low probability that an owl would feed directly on bait pellets. A 0.77 pound bird would have to consume at least 90.5 pounds of rodents containing 3.4 ppm diphacinone (the highest whole-carcass residue found in a rat) in one day to ingest a dose equivalent to the $LD_{50}$ for the northern bobwhite. Hazard calculations for sublethal exposure show that an owl would only need to eat 11 g of rodent tissue containing 3.4 ppm diphacinone per day for multiple days to ingest a LOEL dose. This amount is less than one rodent per day (Eisemann and Swift 2006). The assessments in Eisemann and Swift (2006) are based on very conservative assumptions and are assumed to overestimate the actual hazard of aerial broadcast of diphacinone.

**Conclusion on Rodenticide Toxicity to Birds**

The EPA (1998) states that brodifacoum is "very highly toxic" to both bobwhite quail and mallard duck for both acute and dietary exposure. Diphacinone is "moderately toxic" in acute tests of bobwhite quail, "practically nontoxic" to quail in dietary tests, and "moderately toxic" to mallard in dietary tests. Brodifacoum toxicity in birds is two orders of magnitude more toxic than required for the category "very highly toxic." The EPA declares a potential primary hazard to nontarget birds when their dietary risk quotient equals or exceeds 0.5 for non-endangered species and 0.1 for endangered species. Brodifacoum exceeds this level of concern for non-endangered species by 126-fold using the northern bobwhite $LC_{50}$ and 50-fold using the mallard $LC_{50}$. For endangered species, the level of concern is exceeded by 630 times and 250 times, respectively. Diphacinone does not exceed these levels of concern for either endangered or non-endangered species using the mallard $LC_{50}$. Using the northern bobwhite $LC_{50,}$ diphacinone is considered "practically nontoxic" to birds by the EPA. The LOEL of brodifacoum for birds has not been determined; where efforts to establish this have been made, all dosages administered produced measurable effects; therefore a dosage where no observed effects (NOEL) have been measured has not been documented. A dosage of no observed effects is necessary to establish the lowest observable effects level.

Although individuals of avian nontarget species can die during eradication operations, especially associated with the use of brodifacoum, if the nontarget population is not extirpated and is healthy and viable it usually recovers. However, if the population is an endangered species or a small isolated island population, it may be driven too low to recover or experience negative population-level genetic effects. In most cases the long-term ecosystem benefits probably outweigh the initial nontarget mortality caused by rodenticides during eradication operations (Taylor and Thomas 1993, Eason and Spurr 1995, Dowding et al. 1999). Stephenson et al. (1999) found that passerine populations can recover naturally from a 30% decrease in populations within one to two breeding seasons following a rodenticide operation because passerine species typically have several clutches per year and successfully fledge several young per clutch. Populations of owls, because they live longer and typically fledge less than one chick per year, may recover more slowly, taking two to three seasons (also Murphy et al. 1998). The relative resilience of a species to recover after large population declines depends on the species capacity to compensate for density independent perturbations in abundance, such as the broadscale application of rodenticides. Species with a high intrinsic rate of increase and strong-density dependent links between their demographics and factors that regulate their abundance will typically be more resilient than species without these population dynamics. Species for which there is clear evidence of a high intrinsic capacity for increase and strong density-dependence in their dynamics should be able to sustain higher levels of reduction from poisoning without any undue threat to their long-term viability (Choquenot and Ruscoe 1999).

Erickson and Urban (2004) conclude that potential primary risks are higher for second generation rodenticides, including brodifacoum, than for first generation rodenticides, including diphacinone.

A small bird finding and eating just a small pellet or two of brodifacoum is likely to ingest a lethal dose, and a few small pellets could provide a lethal dose to larger birds. In contrast, it seems highly unlikely that any small bird could eat 100 to 1000 pellets of diphacinone in a single feeding which would be needed to provide an $LD_{50}$ dose from a first-generation anticoagulant. Eason et al. (1999) and Eason and Wickstrom (2001) state: “the recorded mortality of birds after some control operations, coupled with the detection of brodifacoum residues in a range of wildlife including native birds and feral game animals raises serious concerns about the long-term effects of the targeted field use of brodifacoum…where wildlife might encounter poisoned carcasses.” New Zealand is recommending reducing the field use of brodifacoum because of the high risk of poisoning nontarget species, especially secondary poisoning (Eason and Wickstrom 2001, Eason and Murphy 2001, Hoare and Hare 2006).

# APPENDIX B

## Diphacinone-50 Product Label

### ENVIRONMENTAL HAZARDS

This product is toxic to mammals and birds. Predatory and scavenging mammals and birds might be poisoned if they feed upon animals that have eaten bait.

### STORAGE AND DISPOSAL

Do not contaminate water, food or feed by storage or disposal.
**STORAGE:** Store only in original closed container in a cool, dry place inaccessible to children and pets. Store separately from fertilizer and away from products with strong odors which may contaminate the bait and reduce acceptability. Spillage should be carefully swept up and collected for disposal.
**PESTICIDE DISPOSAL:** Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility.
**PLASTIC CONTAINER DISPOSAL:** Nonrefillable container. Do not reuse or refill this container. Triple rinse container (or equivalent) promptly after use. Offer for recycling, if available. Otherwise, puncture and dispose of in a sanitary landfill, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

### DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

**READ THIS LABEL:** Read this entire label and follow all use directions and use precautions.

**IMPORTANT:** Do not expose children or pets to this product. Take all appropriate steps to limit exposure to and impacts on nontarget species, especially those for which special conservation efforts are planned or ongoing. To help to prevent accidents:

1. Store product not in use in a location out of reach of children and pets.
2. Apply bait only as specified on this label and in strict accordance with the "USE **RESTRICTIONS**" and "**APPLICATION DIRECTIONS**". For applications involving bait stations, the bait stations must be tamper-resistant. The bait stations must deny access to bait compartments by children, pets, and other non-target species larger in body size than the type(s) of rats or mice being targeted by the bait program. Lock and secure bait stations, as necessary, to exclude such nontarget species. In locations where captive or feral livestock occur, either remove and exclude such animals from the application site prior to treatment or make sure that the bait stations used are capable of denying them access to bait compartments, and
3. Dispose of product container, and unused, spoiled and unconsumed bait as specified on this label.

**USE RESTRICTIONS:** This product may be used only to control or eradicate Norway rats (Rattus norvegicus), roof rats (Rattus rattus), Polynesian rats (Rattus exulans), house mice (Mus musculus) or other types of invasive rodents for conservation purposes on islands, grounded vessels or vessels in peril of grounding. This product may be applied only using bait stations, burrow baiting, canopy baiting or aerial and ground broadcast application techniques.

This product is to be used for the protection of State or Federally-listed Threatened or Endangered Species or other species determined to require special protection.

Do not apply this product to food or feed.

Treated areas must be posted with warning signs appropriate to the current rodent control project.

(**DIRECTIONS FOR USE** continued on right panel of this label)

STATE OF HAWAII
Department of Agriculture
ACCEPTED
LICENSE NO.
8600.1

### RESTRICTED USE PESTICIDE
### DUE TO HAZARDS TO NON-TARGET SPECIES

For retail sale only to: USDA Animal and Plant Health Inspection Service Wildlife Services, U.S. Fish and Wildlife Service, and the U.S. National Park Service to be used only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicators certification.

### Diphacinone-50: Pelleted Rodenticide Bait for Conservation Purposes

***Fish Flavored, Weather-resistant Rodenticide for Control or Eradication of Invasive Rodents on Islands or Vessels for Conservation Purposes***

**ACTIVE INGREDIENT:**
Diphacinone: (2-Diphenylacetyl-1,3-Indandione)........................................0.005%
**INERT INGREDIENTS:**........................................99.995%
**TOTAL**........................................100.000%

### KEEP OUT OF REACH OF CHILDREN

### CAUTION

**PRECAUTIONARY STATEMENTS**

**HAZARD TO HUMANS AND DOMESTIC ANIMALS**

Caution: Keep away from humans, domestic animals and pets. If swallowed, this material may reduce the clotting ability of the blood and cause bleeding. Wear protective gloves when applying or loading bait. With a detergent and hot water, wash all implements used for applying bait. Do not use these implements for mixing, holding or transferring food or feed.

**FIRST AID**

Have label with you when obtaining treatment advice.

| | |
|---|---|
| **If swallowed** | • Call a poison control center, doctor, or 1-800-222-1222 immediately for treatment advice.<br>• Have person sip a glass of water if able to swallow.<br>• Do not induce vomiting unless told to do so by the poison control center or doctor. |
| **If on skin or clothing** | • Take off contaminated clothing.<br>• Rinse skin immediately with plenty of water for 15-20 minutes.<br>• Call a poison control center, doctor, or 1-800-222-1222 immediately for treatment advice. |

• **Note to Physician**: If ingested, administer Vitamin $K_1$, intramuscularly or orally as indicated in bishydroxycoumarin overdose. Repeat as necessary based on monitoring of prothrombin times.

**For a medical emergency involving this product, call 1-800-222-1222.**

UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
**4700 River Road, Unit 149**
**Riverdale, MD 20737-1237**
**EPA Reg. No 56228-35**
**EPA Est. No. (61282-WI-1) or (056228-GU-1)**

**Net Contents:** ______________

**Batch Code No.:** ______________

### DIRECTIONS FOR USE
**(continued from left panel)**

**APPLICATION DIRECTIONS:**

**Bait Stations:** Tamper-resistant bait stations must be used when applying this product on grounded vessels or vessels in peril of grounding or when used in areas of human habitation. See Item 2) under "**IMPORTANT**:" regarding the performance characteristics needed for tamper-resistant bait stations. To bait rats: Apply 4 to 16 ounces (113 to 454 grams) of bait per placement. Space placements at intervals of 5 to 50 meters. Placements should be made in a grid over the area for which rodent control is desired. To bait mice: Apply 0.25 to 0.5 ounces (7 to 14 grams) of bait per placement. Space placements at intervals of 2 to 4 meters. Placements should be made in a grid over the area for which rodent control is desired. Larger placements (up to 2 ounces) may be needed at points of very high mouse activity. For both rat and mouse baiting: Maintain an uninterrupted supply of fresh bait for at least 15 days or until signs of rodent activity cease. Where a continuous source of infestation is present, permanent bait stations may be established and bait replenished as needed.

**Burrow-baiting:** Place bait in burrows only if this can be done in a way that minimizes potential for ejection of bait and exposure of bait to seed-eating birds and other non-target species. To bait rats: place 3 to 4 ounces (85 to 113 g) of bait inside each burrow entrance. Baits used in burrows may be applied in piles or in cloth or resealable plastic bags. The bags should be knotted or otherwise sealed to avoid spillage and holes should be made in plastic bags to allow the bait odor to escape. To bait mice: place approximately 0.25 ounces (7 grams) of bait in each active burrow. For both rat and mouse baiting: place one such bag or placement in each active burrow opening and push bag into burrow far enough so that its presence can barely be seen. Do not plug burrows. Flag treated burrows and inspect them frequently, daily if possible. Maintain an uninterrupted supply of bait for at least 15 days or until rodent activity ceases. Remove bait from burrows if there is evidence that bags are ejected.

**Canopy Baiting (bait placement in the canopy of trees and shrubs):** In areas where sufficient food and cover are available to harbor populations of rodents in canopies of trees and shrubs, canopy baiting should be included in the baiting strategy. Approximately 4 to 7 ounces (113 g to 200 g) of bait should be placed in a cloth or resealable plastic bag. The bags should be knotted or otherwise sealed to avoid spillage and holes should be made in plastic bags to allow the bait odor to escape. Using long poles (or other devices) or by hand, bait filled bags should be placed in the canopy of trees or shrubs. Baits should be placed in the canopy at intervals of 50 meters or less, depending upon the level of rodent infestation in these habitats. In some vegetation types, bait stations may need to be used to ensure bait will stay in the canopy.

**Aerial and Ground Broadcast:** Broadcast applications are prohibited on vessels or in areas of human habitation. Broadcast bait pellets by helicopter or manually at a rate of 10 to 12.5 lbs. of bait per acre (11.1 to 13.8 kg/ha) per treatment. Make a second broadcast application typically 5 to 7 days after the first application, depending upon local weather conditions, at a rate no higher than 12.5 lbs. (13.8 g/ha) of bait per acre. In situations where weather or logistics only allow one bait application, a single application may be made at a rate no higher than 20.0 lbs. bait per acre (22.5 kg/ha).

Aerial (helicopter) applications may not be made in winds higher than 35 mph (30 knots). Pilot in command has final authority for determining safe flying conditions. However, aerial applications will be terminated when the following conditions are met:

- Windspeed in excess of 25 knots with an evaluation of the terrain and impact of the wind conditions and not to exceed a steady wind velocity of 30 knots.

If rat activity persists after broadcast application, set up and maintain tamper-resistant bait stations or apply bait directly to rodent burrows in areas where rodents remain active. If terrain does not permit use of bait station or burrow baiting, continue with broadcast baiting, limiting such treatments to areas where active signs of rats are seen. Maintain treatments for as long as rodent activity is evident in the area and rodents appear to be accepting bait.

For all methods of baiting, monitor the baited area periodically and, using gloves, collect and dispose of any dead animals and spilled bait properly. Dead animals and spilled bait may be buried on site if the depth of burial makes excavation by nontarget animals extremely unlikely.

USDA APHIS revised 11/23/2009

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# APPENDIX C

## Section 7, Endangered Species Act USFWS Consultation Letter

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122
Honolulu, Hawaii 96850

In Reply Refer To:
01EPIF00-2017-I-0264

Colonel Stephen E. Dawson
Office of the Garrison Commander
U.S. Army Installation Management Command, Pacific Region
Headquarters, United States Army Garrison, Hawaii
745 Wright Avenue, Building 107, Wheeler Army Airfield
Schofield Barracks, Hawaii 96857-5000

Subject: Informal Consultation for the Proposed Use of Aerial Rodenticide at the U.S. Army Schofield Barracks, Oahu

Dear Colonel Dawson:

The U.S. Fish and Wildlife Service (Service) received your letter, dated May 16, 2017, requesting our concurrence with your determination that the proposed pilot aerial application of diphacinone rodenticide within the Lihue Management Unit of the Schofield Barracks, Oahu may affect, but is not likely to adversely affect the following federally listed species: the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*), the endangered Oahu elepaio (*Chasiempis ibidis*), the endangered Oahu tree snail (*Achatinella mustelina*), and the endangered Hawaiian picture-wing fly (*Drosophila obatai*); also included are the following endangered plants: *Alectryon micrococcus*, *Asplenium dielfalcatum*, *Chrysodracon forbessii*, *Cyanea calycina*, *Cyanea grimesiana obatae*, *Delissea waianaeensis*, *Flueggea neowawraea*, *Gardenia mannii*, *Hesperomannia oahuensis*, *Labordia cyrtandrae*, *Lepidium arbuscular*, *Neraudia angulate*, *Nothocestrum latifolium*, *Phyllostegia mollis*, *Platydesma cornuta decurrens*, *Pteralyxia macrocarpa*, *Schiedea hookeri*, *Schiedea kaalae*, and *Sicyos lanceoloidea*. In addition, this consultation serves as a conference on iiwi (*Vestiaria coccinea*), a species currently proposed for listing.

The findings and recommendations in this consultation are based on (1) your letter and enclosure received on May 16, 2017; and (2) other information available to us in our database and records, including data provided by the Hawaii Biodiversity and Mapping Program. A complete administrative record is on file in our office. This response is in accordance with section 7 of the Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 *et seq.*).

*Project Description*

The Army proposes to conduct an aerial application of diphacinone rodenticide within the Lihue Management Unit (MU) on the Schofield Barracks property located on Oahu. The fenced Lihue MU encompasses 1,764 acres (ac) and protects the above mentioned endangered species from pig and goat predation. Many of the above endangered species are also threatened by rat predation. Currently, only mechanical rat control using traditional snap traps and New Zealand automatic traps is conducted in the Lihue MU. Restricted access to the MU due to training activities and limited control options hinders rat control efforts. The aerial application of the rodenticide will provide an additional rat control option for the Lihue MU, which is an extensive area within the fenced management unit. The rat control will provide positive impacts for listed species through reduced predation on animals and plants within the Lihue MU. The rodenticide diphacinone will be applied in November or December 2017 to 1,063 ac of the Lihue MU, all of which is heavily forested. As part of the proposed rodenticide application, the Army will:

- conduct regular visual inspections of the area while monitoring rat tracking tunnels; and
- actively search for carcasses of rats and other species to measure success of the project and determine if non target species are affected by the rodenticide.

*Avoidance and Minimization Measures*

The following measures identified in your letter will be implemented at the project site to avoid and minimize effects to the Hawaiian hoary bat. These avoidance and minimization measures are considered part of the project description.

- Application of rodenticide will be restricted to forested areas; application of rodenticide to grassy areas will be avoided since Hawaiian hoary bats are known to utilize these areas to forage.

*Conclusion*

The proposed project is not likely to affect Hawaiian hoary bats since it is unlikely that bats will consume enough insects that have come in contact with the diphacinone rodenticide to cause lethal or sublethal effects (USFWS 2014). The avoidance of application of the rodenticide in grassy areas minimizes the probability for the bats to ingest insects that have come in contact with the diphacinone. Therefore, the Service has determined that any effects are insignificant and discountable, and therefore not likely to adversely affect the Hawaiian hoary bat.

The proposed project is not likely to adversely affect elepaio since it is not likely that forest birds will consume enough insects that have come in contact with the diphacinone rodenticide to cause lethal or sublethal effects (USFWS 2014). Therefore, the Service has determined that any effects are insignificant and therefore not likely to adversely affect the elepaio.

Primary or secondary poisoning from diphacinone is not likely to occur for the Oahu tree snail since it primarily forages on fungus that grows on trees. Oahu tree snails primarily forage in trees and it is not likely it will come into contact with the rodenticide on the ground. Therefore, the Service has determined that any effects are discountable and therefore not likely to adversely affect the Oahu tree snail.

Primary or secondary poisoning from diphacinone is not likely to occur for the Hawaiian picture-wing fly since it primarily forages on decaying plant matter. Therefore, the Service has determined that any effects are discountable and therefore not likely to adversely affect the Hawaiian picture-wing fly.

Primary or secondary poisoning from diphacinone is not likely to occur for the iiwi since it is a nectar foraging species. Therefore, the Service has determined that any effects are discountable and not likely to adversely affect the iiwi.

The proposed project is unlikely to affect the following listed plants in the vicinity of the project: *Alectryon micrococcus*, *Asplenium dielfalcatum*, *Chrysodracon forbessii*, *Cyanea calycina*, *Cyanea grimesiana obatae*, *Delissea waianaeensis*, *Flueggea neowawraea*, *Gardenia mannii*, *Hesperomannia* *oahuensis*, *Labordia cyrtandrae*, *Lepidium arbuscular*, *Neraudia angulate*, *Nothocestrum latifolium*, *Phyllostegia mollis*, *Platydesma cornuta decurrens*, *Pteralyxia macrocarpa*, *Schiedea hookeri*, *Schiedea kaalae*, and *Sicyos lanceoloidea*. Diphacinone is non-toxic to plants and baiting programs are approved by the Service to ensure potential adverse impacts will be avoided (USFWS 2014). Control of rodents would reduce rodent predation on listed plants and their seeds. Project implementation will be wholly beneficial to listed plants in the Lihue MU.

Based on the above, we concur that the proposed project may affect, but is not likely to adversely affect, the following federally listed species: the Hawaiian hoary bat, the Oahu elepaio, the Oahu tree snail, and the Hawaiian picture-wing fly; also included are the following endangered plants: *Alectryon micrococcus*, *Asplenium dielfalcatum*, *Chrysodracon forbessii*, *Cyanea calycina*, *Cyanea grimesiana obatae*, *Delissea waianaeensis*, *Flueggea neowawraea*, *Gardenia mannii*, *Hesperomannia oahuensis*, *Labordia cyrtandrae*, *Lepidium arbuscular*, *Neraudia angulate*, *Nothocestrum latifolium*, *Phyllostegia mollis*, *Platydesma cornuta decurrens*, *Pteralyxia macrocarpa*, *Schiedea hookeri*, *Schiedea kaalae*, and *Sicyos lanceoloidea*. In addition, the proposed project is not likely to adversely affect the iiwi, a species currently proposed for listing.

Unless the project description changes, or new information reveals that the proposed project may affect listed species in a manner or to an extent not considered, or a new species or critical habitat is designated that may be affected by the proposed action, no further action pursuant to section 7 of the ESA is necessary. If additional information becomes available, or it is determined that the proposed project may affect federally listed species, we recommend you coordinate with our office early in the planning process so that we may further assist you with ESA compliance.

We thank you for your efforts to conserve listed species and native habitats. Please contact Stacey Lowe, Fish and Wildlife Biologist (phone: 808-792-9400, email: stacey_lowe@fws.gov) should you have any questions pertaining to this response or require further guidance. When referring to this project, please include this reference number: 01EPIF00-2017-I-0264.

Sincerely,

Aaron Nadig
Island Team Manager
Oahu, Kauai, Northwestern
Hawaiian Islands, and American Samoa

cc: U.S. Army Garrison Hawaii, Directorate of Public Works, Environmental Division, Natural Resource Section

Colonel Stephen E. Dawson 4

Literature Cited

U.S. Fish and Wildlife Service. Informal consultation for the renewals of EPA special local needs registrations for use of Ramik Mini Bars and mouse killer, and Rozol Mini Blocks and Pellets, Hawaii. Pacific Islands Field Office, Honolulu, HI. 4 April 2014.

# APPENDIX D

## Wai‘anae Mountain Views and Photos of Lihue Management Unit

Typical Viewplane, Wai‘anae Mountains

View of SBMR West Range and Central Plateau, from Mt. Ka‘ala Summit, Wai‘anae Mountains


View toward SBMR West Range Impact Area from Firebreak Road below Lihue MU


Typical Setting, Lihue Management Unit Rodenticide Treatment Area

‘Elepaio molt all their feathers at the end of each breeding season and must manage without a tail before growing back a new one.

UXO, Lihue Management Unit Rodenticide Treatment Area

Rat Tracking Tunnel, Lihue Management Unit Rodenticide Treatment Area

Tracking Tunnel and Ink Card with Rat Tracks


Typical View of Fenceline


Typical View of Ungulate Fenceline

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**Study Title:** Assessment of an aerial-broadcast bait trial to control rats in the Waianae Mountains, Oahu

**NWRC Study Director:** Aaron Shiels

**Approved NWRC Project:** Improving rodenticides and investigating alternative rodent damage control methods

| | SIGNATURE | DATE |
|---|---|---|
| **NWRC Study Director:** | [signature] | 11/1/17 |

Study Director's position (check one):
- ☐ Project Leader
- ☒ Research Scientist (non-project leader)
- ☐ Biologist/Chemist/Technician
- ☐ Student: NWRC Representative/Contact: ______________________
- ☐ Visiting Scientist: NWRC Representative/Contact: ______________________

| | SIGNATURE | DATE |
|---|---|---|
| Concur:<br>**NWRC Research Project Leader:** | Gary Witmer | 11/1/2017 |
| QAU Review and Processing:<br>**NWRC Quality Assurance:** | L Greiner | 11/9/17 |
| Concur: Acting<br>**NWRC Assistant Director:** | [signature] | 11/15/17 |
| Approved: Acting<br>**NWRC Director:** | [signature] | 11/15/17 |

## REGULATORY CONSIDERATIONS

**Analytical Chemistry**
Will chemical analysis be required of the NWRC Chemistry Lab Unit?
☐ No ☒ Yes – **Attach the Analytical Chemistry Appendix**.

Will the services of the NWRC Formulation Scientist be needed?
☒ No ☐ Yes – **Attach the Formulation Support Appendix.**

**Animal Use**
Will the study include the use of animals?
☐ No ☒ Yes – check all that apply below.
- ☐ Live animals will be used at an NWRC facility. **Attach the Animal Use Appendix.**
- ☒ Handling animals or manipulating the behavior of wildlife in the field. **Attach the Animal Use Appendix.**
- ☐ Collaborating institution is responsible for all or part of live animal phase. **Attach the collaborating institution's protocol and IACUC approval.**
- ☐ Study will be conducted using privately owned animals. **Attach "Consent for the Use of Privately Owned Animals" form (SOP AD025).**
- ☐ No manipulation of the behavior of wildlife in the field (observation only). **No appendix needed.**
- ☐ Samples or data opportunistically collected from ongoing operational activities. **No appendix needed.**

**Biological Laboratories (BioLabs) Support**
Do you anticipate you will require space, equipment, or personnel from the NWRC Biological Laboratories Unit?
☒ No ☐ Yes – **Date of consult with Laboratory Specialist:** Click here to enter text

**Microbiological/Biohazardous Materials**
Will any Microbiological/Biohazardous Materials be used?
☒ No ☐ Yes – **Attach the Microbiological/Biohazardous Materials Use Appendix**.

**Intellectual Property (IP) Considerations**
Do any of these situations apply to this study?
- The condition of confidentiality between you and your collaborator would facilitate open discussions and collaboration.
- This research involves the exchange or transfer of material(s) between the NWRC and your collaborators.
- This research includes existing IP and/or could lead to the development of new IP.

☒ No ☐ Yes – Consult the NWRC Technology Transfer Coordinator. **Date of consult:** Click here to enter text

**Federal Environmental Statute Considerations**
Will this activity involve a field component and meets any of the following conditions?
The field component will occur on Federal land, is funded with Federal money, and/or involves Federal personnel.
☐ No ☒ Yes
- Complete and **Attach the Endangered Species Act Appendix (ESA)** and
- Complete and attach the **National Environmental Policy Act Appendix (NEPA)**.

**Regulated Product Registration Considerations**
Does this activity involve the transfer OR testing of any pesticide, vaccine, drug, diagnostic kit, or pest control or medical device, or their components, including products still in the research and development stage?
☒ No ☐ Yes - Consult with the NWRC Registration Manager regarding any regulatory requirements.

As determined during this consultation, check the applicable regulatory standards.
☒ none ☐ EPA GLP ☐ FDA CVM GLP ☐ USDA CVB GLP-like ☐ OECD GLP
☐ other: Click here to enter text

## DESCRIPTION OF ACTIVITIES

**NWRC Collaborators:**

| Name | NWRC Project | Contribution to study |
|---|---|---|
| Gary Witmer | Rodents | Consultation |
| Tyler Cochran | Rodents | Technical assistance |
| Dave Goldade | Chemistry Unit | Residue analysis |
| Celeste Samra | Rodents | Technical assistance |

***Note:*** *To insert additional collaborators, click anywhere in the cell above, and then click the "+" in the bottom right corner and a new row will appear.*

**Non-NWRC Collaborators:**

| Name | Affiliation | Contribution to study |
|---|---|---|
| Tyler Bogardus | Oahu Army Natural Resources | Operational planning, field assistance, providing staff/infrastructure |
| Tim Ohashi | USDA, APHIS, WS Operations | Facilitate bait entry into Hawaii |
| Craig Clark | USDA, APHIS, WS Operations | Facilitate bait entry into Hawaii |

***Note:*** *To insert additional collaborators, click anywhere in the cell above, and then click the "+" in the bottom right corner and a new row will appear.*

**Study location(s):**

| Name | Address | Activities at this location |
|---|---|---|
| West Range, Schofield Barracks, Oahu | Schofield Barracks, Oahu, Hawaii<br>947 Wright Ave., Wheeler Army Airfield Schofield Barracks, HI 96857-5013 | Research facilities & field work |
| NWRC HQ | 4101 LaPorte Ave, Ft Collins, Colorado | Research facilities & chemistry lab work |

***Note:*** *To insert additional locations, click anywhere in the cell above, and then click the "+" in the bottom right corner and a new row will appear.*

**Funding Source:**

| Source of Funds | APHIS Program | Name of Non-APHIS Collaborator | $ Amount |
|---|---|---|---|
| Internal (NWRC) | | | 3,000 |
| External APHIS | | | |
| Oahu Army Natural Resources | | Oahu Army Natural Resources | 66,931 |

***Note:*** *To insert additional locations, click anywhere in the cell above, and then click the "+" in the bottom right corner and a new row will appear.*

**Study Schedule:**

Proposed study start date: November 17, 2017
Proposed study end date: October 31, 2018
Proposed archive date: June 30, 2019

**Background/Justification:**

Rodents (*Rattus* spp. and *Mus musculus*) have been introduced to many ecosystems worldwide and are among the most widespread and problematic invasive animals affecting islands (Towns et al. 2006; Angel et al. 2009; Shiels et al. 2014). Through mostly unintentional introductions by humans, these rodents occupy > 80% of the major islands worldwide (Atkinson 1985; Towns 2009).

Invasive rats, primarily *R. rattus* and to a lesser degree *R. exulans*, have been documented as important predators of native and endangered species in Hawaii, including birds, arthropods, and plants (Shiels 2010; Shiels et al. 2013; Shiels et al. 2014). In 2000, U.S. Fish and Wildlife Service (USFWS) granted the O'ahu 'elepaio *(Chasiempis sandwichensis* ssp. *ibidis)*, a native forest bird endemic to O'ahu, endangered species status under the federal Endangered Species Act of 1973. Due to the elevated rates of rat predation on O'ahu 'elepaio eggs and chicks (VanderWerf 2001; VanderWerf and Smith 2002), as well as on endemic snails and plants (Shiels et al. 2014), Oahu Army Natural Resources Program (OANRP) has been engaged in rodent control since 2001 using various techniques including snap traps, automatic traps, and rodenticide bait stations. The Lihue Management Unit (LMU) is one of these areas where OANRP controls rats for the benefit of 'elepaio nesting success as well as to promote additional native plants and animals that are at risk to rat predation.

The LMU is a large area (>500 ha) with steep terrain, yet the greatest restrictions in managing the natural resources in the LMU are that 1) substantial amounts of unexploded ordnance (UXO) are present, and 2) it is located on an active Army training range that is only accessible to natural resource managers 4 to 5 days each month. Isolated populations of rare plants, rare snails *(Achatinella mustelina)*, and the O'ahu 'elepaio have been supported with a system of small grids of traps and/or bait stations in the attempt to control rat predation on these rich natural resources. However, limited access and the labor intensive nature of servicing these traps and bait stations means that, in general, they may only be re-baited every 2-6 weeks. This restricted rat control strategy has had limited effect, and rat populations have risen since the program's inception (Kawelo, pers. comm.). Thus, aerial treatment (via helicopter) will occur over a large portion of the LMU with a one-time (2 application) of Diphacinone-50 rodenticide bait just prior to the nesting season of O'ahu 'elepaio to determine the efficiency of such a method; information from this study will be used to inform whether future aerial application of this bait at the LMU and other lands managed by OANRP are likely to be effective and efficient for protecting natural resources from rat predation.

The planned aerial application method for reducing the rat population just prior to the nesting season of O'ahu 'elepaio is through a two-application ("one-time") aerial-broadcasting of Diphacinone-50: Conservation according to label (Diphacinone 50: Conservation, EPA Reg. No.: 56228-35, State of Hawaii Lic. No. 8600.1). While OANRP will be conducting the aerial-broadcast with oversight from NWRC, NWRC will be leading on associated monitoring for the project. For objectivity and best practice procedures, the agency leading the operational aspects of the study should be different than those leading in the monitoring (Pitt et al. 2015). The entire project has been through the NEPA process, headed by U.S. Army Garrison NEPA Coordinator David Fluetch, (EA evaluated, public comment period, EA signed by

Commander Dawson; see Supplemental EA Finding of No Significant Impact 2017 in References section). In this NWRC study protocol, the details of the monitoring portion of the study are outlined.

**Research Objective/Hypothesis:**

The overall objectives for this study are to: 1) determine the density and fate of bait from the 2-application aerial-broadcasts of Diphacinone-50, 2) monitor rodent (mouse and rat) activity and fate before, during, and after the rodenticide application, 3) document the non-target effects through trail cameras, carcass searches, and analysis of diphacinone residues throughout the consumer food web, and 4) sample the water from the stream running through the study site and test it for diphacinone residues before, during, and after the rodenticide application. We hypothesize that reductions in invasive rodents will occur using the planned Diphacinone-50 application, and that such reductions in rat populations will be greater than mice given the palatability and efficacy findings from cage-trials with this rodenticide bait formulation in Hawaii (Pitt et al. 2011). We expect that there will be detectable diphacinone residues in some parts of the non-target, consumer food web, particularly invertebrates such as insects and slugs that may be directly consuming the bait. We expect minimal evidence of non-target mortality based on the relatively low amounts of bait, and type of bait, applied (e.g., relative to a much higher rate of application and brodifacoum on Palmyra; Pitt et al. 2015), and results from a similar study using hand-broadcast technique (QA-2523).

An understanding of the effectiveness of a one-time (two application) baiting of Diphacinone-50: Conservation in the planned manner (i.e., according to label) just prior to O'ahu 'elepaio nesting season will help determine if this would be a useful operational method to continue at LMU, and to trial at other sites in Hawaii where rats threaten native and endangered species and habitats.

**Methods, Procedures and Experimental Design:**

Study Site: The Lihue Management Unit (LMU) is located in the northern Wai'anae Mountains, within Schofield Barracks Military Reserve, Oahu, Hawaii. Management units are the focal point for OANRP management actions, and typically equate to fenced, ungulate free areas, such as the LMU. Management units were developed to manage designated populations of each target species and appropriate habitat. The LMU is home to many rare taxa, including O'ahu 'elepaio, plants, and snails. Non-native rodents are ubiquitous at LMU, including black rats (*Rattus rattus*), Pacific rats (*R. exulans*), and house mice (*Mus musculus*); black rats are numerically dominant in the Waianae Mountains (Shiels 2010). Negative impacts of each of these three rodent species in the Waianae Mountains have been reported to span native plants, insects, snails, and birds (Shiels and Drake 2011; Shiels et al. 2013).

Rodenticide Application to reduce rodent abundance: OANRP will be conducting the bait application for this project. Aerial broadcast application of Diphacinone-50 label (EPA Registration No. 56228-35) will involve a contract pilot (probably Calvin Dorn) that has been certified for aerial application of restricted use pesticides in Hawaii. The aerial application will consist of a helicopter, using a specialized suspended bucket, flying along predetermined Global Positioning System (GPS)-plotted transects within the application area (Dunlevy et al. 2000). The rodenticide bait would be broadcast in swaths by the rotary spreader bucket as the helicopter flies along these transects. The 430 hectare (ha) application area is contained within a fenced enclosure located in the 714 ha LMU. Diphacinone-50, Pelleted Rodenticide Bait, containing the anticoagulant rodenticide diphacinone (0.005% active ingredient) has been approved for aerial distribution by the U.S. Environmental Protection Agency (EPA) and the Hawai'i Department of Agriculture (HDOA) (EPA Reg. No.: 56228-35, State of Hawaii Lic.

No. 8600.1). The first application is planned for November 27, 2017, and after 5-7 days a second application at the same rate will follow. The bait rate for each application will be 11.1-13.8 kg/ha, according to Diphacinone-50 label. Further, as stated on the Diphacinone-50 label, a single application of no higher than 22.5 kg/ha may be applied in situations where weather or logistics only allow one bait application.

Monitoring: NWRC will lead in the monitoring of this study. The details of each monitoring component is addressed below, and overall summary of this study's monitoring includes the following:

1) Abidance by the Diphacinone-50 label's application rate. NWRC staff will measure bait densities in established plots throughout LMU to ensure bait was applied to the site at a rate of no greater than 13.8 kg/ha per application.
2) Bait fate will be monitored by revisiting plots at set intervals after each bait application and bait densities will be measured. Motion cameras will also monitor subsets of bait to determine the types of animals consuming or removing bait.
3) Rodent monitoring will occur before, during, and after hand broadcast by use of rodent tracking tunnels (ink cards baited and inserted into tunnels to establish rodent activity based on foot-tracks). Such monitoring will occur within the treatment area, and outside the treatment area (where no rodent control occurs). OANRP staff have already set up and maintained a monitoring grid of tracking tunnels at these sites. These monitoring techniques will help to assess the efficacy of the rodenticide application on the rat population.
4) Rodent carcass searches will be conducted before, during, and after bait application.
5) Non-target effects. As will any project that uses toxicant bait, we expect that there will be some negative effects to non-target organisms (see Pitt et al. 2015). Justification for proceeding with such a control tool that harms some non-target species is that the longer-term effects of a reduced rat population will provide greater benefit to the native species and habitat that goes beyond the number (and types) of non-target mortalities. There are no expected negative impacts to threatened or endangered species as a result of this rodenticide broadcast. Expected non-target impacts may include some species being affected by eating the bait directly or consuming any animal that has consumed the toxicant. Our non-target monitoring at the LMU will include: 1) conducting carcass searches before, during, and after bait application, 2) assessing the levels of diphacinone residue in the food web by sampling (pre- and post-bait application) rodents, mongoose, game birds, lizards, and invertebrates (slugs and insects), and 3) using trail cameras aimed at bait pellets to document the types and frequencies of non-target visits and visitor consumption of bait pellets.

Below are the detailed methods of each of the monitoring components for this study.

Bait application rate monitoring: On the days of bait application, approximately 60 plots (each 1 x 1 m; denoted with pin flags) will be visited throughout the LMU. The locations of the plots will be along transects next to trails, and the beginning plot along a transect will be chosen randomly and the remaining plots on the transect will be systematically distributed each 10 m. Upon visit, the number of bait pellets inside the 1 x 1 m area will be counted. Given the bait application rate of 13.8 kg/ha, and the weight of a single pellet about 1.1 g, there should be (on average) about 1 bait pellet per 1m$^2$.

Bait availability monitoring: A subset (approx. 40 of the 60 plots) of the bait application plots will be used for bait availability monitoring (i.e. persistence and conditional change of bait pellets over 8 days). Beginning on the first day of bait application (following counts in plots for "Bait Application Rate Monitoring"), two bait pellets will be placed within 5 cm of the pin flag in each 1 x 1 m plot. Monitoring the bait will then commence each 1-3 days thereafter for an 8 day period. Upon visitation, the number and condition of the two bait pellets per plot will be recorded. Partial baits will be estimated to the nearest 25%. The condition of the bait will be assessed as using the Craddock Scale (Craddock 2004), which accounts for wet, moldy, damaged, and intact bait pellets. On approximately 20 of the bait fate monitoring plots, Reconyx (Hyperfire model PC900) motion-sensing cameras will monitor the types of animals visiting the baits.

Rodent monitoring: We will use 150 tracking tunnels (120 in treatment area, 30 in control area), which are baited ink cards placed in tunnels so that foot prints of animal visitors can be identified, to determine presence of invasive rodent species. OANRP has the tunnels in place and has been conducting quarterly assessments of rodents at both control and treatment sites over the last year as part of their rodent trapping efforts around 'elepaio monitoring areas. Rodent monitoring will be done on the following schedule at the control and treatment sites simultaneously, using tracking tunnels: 1 day prior to first application, 1 day prior to second application, 4 weeks after 1st application, monthly thereafter for at least 6 months. An acceptable level of rat activity, which promotes stable or increasing native/endangered elepaio populations has not been clearly identified, but New Zealand studies have shown that rat activity levels of 10% are low enough to maintain certain rare bird populations (Innes et al. 1999). A 10% activity level, and at times even a 20% activity level, has not been achievable using large-scale rat trapping in Hawaii, indicating a further need for testing rodenticides in this manner.

Rodent fates: Rodent fates will be assessed via carcass searches before, during, and after bait application. Rodent carcass searches will involve walking trails at LMU and the control site while visually scanning the ground for any rodent and other vertebrate carcasses in approximately a 2 m swath on either side of the trail. Equal trail segments will be walked/scanned during each of the carcass searching events, and the estimated schedule will be the same as outlined in the "Rodent monitoring" section. If any rodent or other vertebrate carcass is found, a gps location will be taken, and the carcass will be placed (with gloved hand) in a ziplock bag, labeled, and taken by NWRC staff for description, freeze-storage, and possible analysis at the NWRC chemistry lab.

Non-target monitoring: Non-target monitoring will include: 1) carcass searches before, during, and after bait application (see above methodology in "Rodent fates" section), and 2) assessment of the levels of diphacinone residue in the food web by sampling (pre- and post-bait application) rodents, mongoose, game birds, lizards, and invertebrates (slugs and insects). As part of their management efforts, OANRP traps invasive mammals (e.g., rodents, mongoose) and other invasive vertebrates (e.g., birds) in areas where they are protecting natural resources, and some of these carcasses will be collected by OANRP and passed to NWRC for chemical analysis. OANRP will provide 3-6 carcasses of rats, mice, mongoose, and birds (Erckel's francolin and/or Kalij pheasant and/or Red-billed Leothrix) both pre- and post-bait application from live-harvest; these relatively low samples sizes are a result of OANRP's limited access to conduct this sampling in a way that will result in non-decomposed carcasses (e.g., their standard management is to set kill-traps and return to re-set them the following month). Each of these vertebrates is non-native to Hawaii, and they were chosen for diphacinone residue analysis because of their likelihood to directly consume the diphacinone bait, or consume diphacinone indirectly by scavenging a carcass that contains diphacinone. For any of the vertebrate carcasses collected by OANRP as part of their management efforts at LMU, a gps location will be taken at the point of trapping, and the carcass will be placed (with gloved hand) in a ziplock bag, labeled, and given to NWRC staff for description, freeze-storage, and analysis at the NWRC chemistry lab. Note that OANRP has been studying the population biology, nesting, nest success, and fledging success for the elepaio in this study area for >10 years, and they will continue to do so after this diphacinone application (thus another indication to measure efficacy of the rodenticide application).

Lizards and invertebrates are not regularly trapped by OANRP and therefore NWRC staff will obtain up to 20 individual lizards (10 pre- and 10 post-application), and 30 individual slugs/snails and 30 individual cockroaches (or other non-native insects) prior to and following bait application (note that invertebrates may have to be bulked for analysis given a 2 g requirement by NWRC chemistry per sample). The numbers of individuals and samples needed to maximize diphacinone residue detection, if such residues are indeed present, are based on sampling constraints and past sampling and residue analysis from a previous, similar study in this mountain range (QA 2523; Shiels 2017). There are no native lizards, cockroaches, or slugs in Hawaii. The targeted lizard species common to the Waianae Mountains, and that will be collected, is the metallic skink (*Lampropholis delicata*). Insect sticky traps (BioQuip) will be used to collect skinks by using approximately 10 sticky traps baited with fruit or peanut butter and placed on the ground in open forest gaps during the daytime. Traps will be checked each 1-6 hours during the daylight hours and each trap will be removed and stored in a bucket with a lid each night. Captured skinks will be euthanized by manually applied blunt force trauma to the head (hammer blow to the head while restrained on the sticky traps; AVMA 2013). Decapitation will not occur because of the need for whole body diphacinone residue analysis. Slugs and cockroaches will be hand-collected by searching under rocks and forest debris (Joe and Daehler 2008). Slugs and cockroaches (or other non-native insects) will be killed as follows: when possible, sedation by isoflurane (administered via moist cottonball placed with invertebrate in a ziplock bag) will precede freezing, otherwise invertebrates will be sealed in ziplock bags and frozen to ensure rapid death and subsequent storage (AVMA 2013). Gloved hands will be used when collecting or handling any of these specimens. All non-target specimens (collected pre- and post-application) will be sent to NWRC chemistry lab where they will be analyzed for diphacinone residue.

Water, collected from the stream running through the study site, will be collected before, during, and after bait application and analyzed for concentrations of the diphacinone compound. Sampling schedule will follow that under Rodent monitoring" section.

**Statistical Analysis:**
Our study is logistically limited to one bait-application site and one control site (i.e. lacks replication); this is due to the experimental nature of the study and cost/labor constraints. LMU and the control site are sufficiently far apart such that they are truly independent.

Bait fate monitoring: Bait density and availability will be summarized using descriptive statistics. A bait availability curve will be produced. The types of animals visiting the baits (i.e. results of monitoring cameras) will be summarized according to time since bait application.

Rodent monitoring: For each of the tracking tunnel monitoring, chi-square analysis and/or logistical regression will be used to determine if rodent activity differed between control and treatment sites for time periods of before, during, and after bait application. An acceptable level of rat activity, which promotes stable or increasing native/endangered elepaio populations is unknown, but a New Zealand study has shown that rat activity levels of 10% are low enough to maintain certain rare bird populations (Innes et al. 1999). A 10% activity level, and at times even a 20% activity level, has not been achievable using large-scale rat trapping in Hawaii, indicating a further need for testing rodenticides in this manner. We will use the 10-20% level of rat activity (or ~80-90% rat tracking reduction) via tracking tunnels as an indicator efficacy of this bait application.

Rodent fates: Rodent carcass searches will be summarized by species using descriptive statistics.

Non-target monitoring: Concentrations of diphacinone residue assays will be reported in summary tables for the pre- and post-bait application periods and tabulated for concentrations found in each animal species and water sample. Given the sampling design and robust results of a similar study in a nearby forest (QA 2523; Shiels 2017), we are confident that our sampling design and numbers of samplings in this current study will produce robust results, especially given our sampling constraints (e.g., very limited access, spatially and temporally, for non-target sampling).

**Human Health and Safety Risk/Hazard Assessment:**
This study is not expected to cause adverse human safety issues. This study should pose little to no risk to workers. Adherence to all applicable SOPs will be mandatory and all personnel will be adequately trained to perform the required tasks. All staff will utilize appropriate PPE.

**Standard Operating Procedures (SOPs)/Analytical Chemistry Methods:**

| SOP/Method No. | Title |
|---|---|
| HS 004.00 | Personal protective equipment |
| HS 008.00 | Hazard communication |
| HS 007.00 | Safe and effective handling of contaminated laboratory items |
| FP 034.00 | Recovery and handling of animals found dead during routine field activities |
| CH 011.00 | Selected avian tissue preparation for chemical residue analysis |
| HS 013.03 | Shipment of biological substances, animal specimens, and environmental test samples |

***Note:*** *To insert additional SOPs or Methods, click anywhere in the cell above, and then click the "+" in the bottom right corner and a new row will appear.*

**Cost Estimate for Each Fiscal Year:**

| | FY-18 | FY-19 | FY-XX | FY-XX |
|---|---|---|---|---|
| A. Salary and Benefits | 6000 | 3,000 | | |
| B. Facilities (in addition to existing facility or space costs) | 0 | 0 | | |
| C. Chemistry | 11,000 | 0 | | |
| D. Supplies - bait | 38,450 | 0 | | |

| | | | | |
|---|---|---|---|---|
| E. Operating Costs (travel, misc. services, etc.) | 5,189 | 0 | | |
| F. APHIS Pooled Job Costs and Overhead | 14,292 | 0 | | |
| | | | | |
| TOTAL | 74,931 | 3,000 | | |

**Archiving:**
The protocol, amendments, raw data, documentation, records, specimens, correspondence and other documents relating to interpretation and evaluation of data, and final reports generated as a result of this study will be retained in the archives of the National Wildlife Research Center at Fort Collins, Colorado.

**Protocol Amendments:**
Any changes in this protocol will be documented prior to the change using the Protocol Amendment form, reviewed by the appropriate personnel, signed and dated. Approved amendments will be distributed to all study participants as appropriate.

**References:**

AVMA. 2013. AVMA guidelines for the euthanasia of animals: 2013 edition. American Veterinary Medicine Association, Schaumburg, IL.

Angel, A., R.M. Wanless, and J. Cooper. 2009. Review of impacts of the introduced house mouse on islands in the Southern Ocean: are mice equivalent to rats? *Biological Invasions* 11: 1743-1754.

Atkinson, I.A.E. 1985. The spread of commensal species of *Rattus* to oceanic islands and their effects on avifaunas. In: Moors PJ (ed) Conservation of island birds, pp. 35-81. ICBP Technical Publication No. 3.

Craddock, P. 2004. Environmental breakdown and soil contamination by Pestoff poison bait (20 ppm brodifacoum) at Tawharanui Regional Park, north of Auckland- Winter 2003 trial. Unpublished report for Northern Regional Parks, ARC.

Drake, D.R., and T.L. Hunt. 2009. Invasive rodents on islands: integrating historical and contemporary ecology. *Biological Invasions* 11: 1483-1487.

Dunlevy, P.A., E.W. Campbell, and G.D. Lindsey. 2000. Broadcast application of a placebo rodenticide bait in a native Hawaiian forest. International Biodeterioration and Biodegradation 199-208.

Innes, J.G., R. Hay, I. Flux, P. Bradfield, H. Speed, and P. Jansen. 1999. Successful recovery of North Island kokako *Callaeas cinerea wilsoni* populations, by adaptive management. *Biological Conservation* 87: 201-224.

Joe, S.M., and C.C. Daehler. 2008. Invasive slugs as underappreciated obstacles to rare plant restoration: evidence from the Hawaiian Island. *Biological Invasions* 10: 245-255.

Pitt, W.C., L. Driscoll, R.T. Sugihara. 2011. Efficacy of rodenticide baits for the control of three invasive rodent species in Hawaii. *Arch. Environ. Contam. Toxicol.* 60: 533-542.

Pitt, W.C., A.R. Berentsen, A.B. Shiels, S.F. Volker, J.D. Eisemann, A. Wegmann, and G. Howald. 2015. Non-target species mortality and the measurement of brodifacoum rodenticide residues after a rat (*Rattus rattus*) eradication on Palmyra Atoll, tropical Pacific. *Biological Conservation* 185: 36-46.

Shiels, A.B. 2010. Ecology and impacts of introduced rodents (*Rattus* spp. and *Mus musculus*) in the Hawaiian Islands. Dissertation. Department of Botany, University of Hawaii at Manoa.

Shiels, A.B., and D.R. Drake. 2011. Are introduced rats (*Rattus rattus*) both seed predators and dispersers in Hawaii? *Biological Invasions* 13: 883-894.

Shiels, A.B., C.A. Flores, A. Khamsing, P.D. Krushelnycky, S.M. Mosher, and D.R. Drake. 2013. Dietary niche differentiation among three species of invasive rodents (*Rattus rattus, R. exulans*, *Mus musculus*). *Biological Invasions* 15: 1037-1048.

Shiels, A.B., W.C. Pitt, R.T. Sugihara, and G.W. Witmer. 2014. Biology and impacts of Pacific island invasive species. 11. *Rattus rattus*, the black rat (Rodentia: Muridae). *Pacific Science* 68: 145-184.

Shiels, A.B., and D.R. Drake. 2015. Barriers to seed and seedling survival of once-common Hawaiian palms: the role of invasive rats and ungulates. *AoB PLANTS* 7: plv057 (1-10).

Shiels, A.B. 2017. Assessment of a hand-broadcast rodenticide bait trial to control rats in the Waianae Mountains, Oahu. Final Report QA 2523. USDA, APHIS, WS, NWRC. 75 pp.

Supplemental EA Finding of No Significant Impact. 2017. Protecting endangered O'ahu 'elepaio using rodenticide within Schofield Barracks Military Reservation, O'ahu, Hawai'i. Prepared by: Directorate of Public Works, U.S. Army Garrison, Hawai'i. September 2017. 92pp.

Towns, D.R., I.A.E. Atkinson, and C.H. Daugherty. 2006. Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions* 8: 863-891.

Towns, D.R. 2009. Rodents. In: Gillespie, R.G., and Clague, D.A. (Eds.), *Encyclopedia of Islands.* University of California Press, Berkeley, pp 792-796.

VanderWerf, E. A. 2001. Rodent control decreases predation on artificial nests in O'ahu 'elepaio habitat. *Journal of Field Ornithology* 72: 448-457.

VanderWerf, E. A., and D. G. Smith. 2002. Effects of alien rodent control on demography of the in O'ahu 'elepaio, an endangered Hawaiian forest bird. *Pacific Conservation Biology* 8: 73-81.

**Other Pertinent Attachments:** (list in order of appearance)

- Animal Use Appendix
- Endangered Species Act (ESA) Appendix
- National Environmental Policy Act (NEPA) Appendix
- Analytical Chemistry

## ANIMAL USE APPENDIX

An "Animal" is defined as any vertebrate. "Use" includes manipulating the behavior of wild animals in their natural habitat, as well as capturing and/or handling animals.

**Note:** A consultation with the NWRC Attending Veterinarian must be performed prior to submitting this appendix to the IACUC for review. Allow a minimum of 2 weeks for the IACUC review process.

### A. Related Protocols:

List by number

QA-1605 A test of the efficacy of two commercial diphacinone baits on roof rats from Egmont Key, Florida (Witmer)

QA-1736 Evaluation of candidate wildlife biomarkers to assess bait acceptance by mice (*Mus musculus*): comparison of biomarker detection and retention, and bait palatability (Pitt)

QA-1754: An assessment of seedling damage by wild house mice and wild deer mice (Witmer).

QA-1875 Palmyra Atoll rainforest restoration project: rat eradication monitoring plan for alternatives B and C (Aerial broadcast of 25W) (Pitt)

QA-1941 An efficacy test of a cholecalciferol plus diphacinone rodent bait for California voles resistant to chlorophacinone baits. (Witmer)

QA-2008: Impacts and management of invasive vertebrates and invertebrates in lowland wet forest, Hawaii (Shiels)

QA-2210: Forest restoration effects on rodent community composition and impacts, Maui (Shiels)

QA-2452: Impacts of non-native predators on pollinators and native plant reproduction in Hawaii (Shiels)

QA-2523: Assessment of a hand-broadcast rodenticide bait trial to control rats in the Waianae Mountains, Oahu

### B. Assurance of Non-duplication of studies

Provide an assurance that activities in this study do not unnecessarily duplicate previous experiments. If there is duplication, provide scientific justification why this study is necessary. List the databases searched, the date of the search, the period covered by the search, and the key words used or provide other procedures used in your determination.

On 3 October 2017, a literature search using Google Scholar was conducted using the following keywords: rat, *Rattus*, aerial broadcast, diphacinone, Hawaii, tracking tunnel, non-target. The only similar studies to ours were a pilot study so the Diphacinone-50 label, applied aerially, could be registered for conservation in Hawaii (Dunlevy et al. 2000). There are a great number of studies that have used rodenticides applied aerial to eradicate, not suppress/control, rats from whole-islands. There are also some studies by Dr. Witmer that used diphacinone in bait stations to rid small islands of invasive rats. Aside from these, there were no similar studies found that have suppressed rats from forests in Hawaii, using aerial application of rodenticide, for conservation purposes, and certainly none from the exact location proposed (i.e., therefore the study is inherently novel).

### C. Staff Qualifications

All study participants will have documentation on file, which verifies their training and qualifications for the work they will perform in this study, including SOP training logs. All SOPs and study specific training logs will be completed and documented in study or personnel records prior to participation in that aspect of the study.
List the study participants that will be working independently with animals and provide their qualifications/certifications (i.e. name, title, and a brief description of training/experience).

All study participants below have documentation (curriculum vitae, training records) on file which verifies their qualifications for the work they will perform in this study.

Aaron Shiels, NWRC Research Biologist, with >10 years of experience conducting these types of trials and working with invasive rodents and their impacts on island ecosystems.

Tyler Bogartus, Small Mammal Specialist, OANRP, has extensive experience trapping vertebrates and working with rodenticides.

Craig Clark, State Director WS Operations, has experience working with rodent and other invasive animal management issues in Hawaii and Guam.

Gary Witmer, NWRC Research Biologist and Rodent project leader, with >10 years ample experience to support this study.

Tyler Cochran, NWRC Biological Technician, with >2 years ample experience to support this study. Currently does not have IACUC training, so his laboratory duties for this study will reflect this.

Celeste Samra, NWRC Biological Technician, with >3 years ample experience to support this study.

Tim Ohashi, WS Operations, he will help in purchasing the bait only so he will not be involved with any direct procedures with animals or field duties.

**D. Training Assurance**

Provide an assurance that participants have read the protocol (especially those who will handle animals), and have completed appropriate training (e.g., CITI or other training – with documentation).

Yes, and all necessary training will be provided as needed by Dr. Shiels

**E. Permits**

Provide information related to any permits current in possession or being applied for, which are required for the use of animals related to this research activity.

OANRP has conducted a Supplemental EA with a Finding of No Significant Impact; specifically: The entire project has been through the NEPA process, headed by U.S. Army Garrison NEPA Coordinator David Fluetch, (EA evaluated, public comment period, EA signed by Commander Dawson; see Supplemental EA Finding of No Significant Impact 2017 in References section). No further permits or permissions are needed. USDA Wildlife Services has deemed NWRC's involvement with ESA/EA for this study as outline in this protocol as a Categorical Exclusion (email dated 10/24/2017).

**F. Animal Description**

1. Animals:

   Black rat (*Rattus rattus*)
   Pacific rat (*Rattus exulans*)
   House mice (*Mus musculus*)
   Metallic skink (*Lampropholis delicata*)

2. Species, subspecies (if applicable):
   See above

3. Number and Sex (known or estimated):

We are not catching any live rodents. OANRP catches invasive vertebrates as part of their management, and therefore rodents and other invasive vertebrates caught or collected dead by OANRP will be given to NWRC for residue testing.

We anticipate up to 20 Metallic skinks (*Lampropholis delicata*) will be captured using sticky traps. We expect equal sex ratios.

For the live-rodent tracking tunnel monitoring, we expect that there will be about 300 rodents per month/sampling exposed to the monitoring (ie, 150 tunnels and on average estimate of two rodents affected by it per tunnel); many of these rodents will probably be the same individuals from month-to-month, but the maximum number that could be exposed to tracking tunnels is estimated to be 3000 individuals (ie, 300 x 10 samplings). Note too that the number of rodents will decline significantly after the rodenticide, but then recover to pre-application status by ~4-6 months.

4. Additional contingency animals (number and sex):
   None

5. Acceptable Body weight criteria:
   All body weights (juveniles and adults)

6. Acceptable Age criteria:
   All ages (juveniles and adults)

**G. Rationale for involving animals, for appropriateness of species, and for numbers.** Provide justification why this study requires the use of animals, and for the numbers to be used.

1. Rationale for involving animals:
   Non-native rats are the target species for this study and their study is necessary in order to understand the effectiveness of the rodenticide bait. We cannot do this study without involving animals.

2. Rationale for appropriateness of the species to be used:

   The listed rats are introduced invasive pest to most of the world's islands, and these rodents are the species outlined on the Diphacinone label for which the product must be used to control. Furthermore, they negatively impact agriculture and native flora and fauna, and they are key animals that NWRC and our rodent project is trying to understand, eliminate, and/or suppress/control in areas where they threaten agriculture, natural resources, and human health and safety.

3. Rationale for numbers of animals to be used, including numbers of animal to be obtained as extra if appropriate (e.g. how many additional animals do you intend to hold in reserve to substitute in for animals found to be unfit for experimentation). Also explain how the numbers of animals requested/planned for relates to the analysis on how numbers were determined or how the numbers requested should satisfy the study requirements.

   We will be collecting carcasses of dead animals so we do not control how many rodents we will involve in our study. For skinks, this was the same number of samples required in a similar study (QA-2523) that would both provide an understanding of lizard exposure by this action and not significantly impact the lizard population (even though they are non-native species).

   Our experience and findings from lizard analysis from QA-2523 revealed 1) these lizards take more time to catch than we anticipated, so we were not able to get all 20 individuals, and 2) none of the skinks that we did collect had diphacinone residues. Thus, we would like to gain the full 20 individuals for this sampling, and not reduce our sample size, to ensure that we sampled enough to find residues if indeed they were in the lizard population.

In our use of rodent tracking tunnels in QA-2523, we had 42 tracking tunnels in the 36 ha treatment area; thus 1.17 tunnels/ha. The current study (QA-2859) is 430 ha of treatment area, and it is not logistically feasible to service such a high number of tunnels (eg, it would require us to have 502 tunnels). Therefore, we placed tunnels in the center of the treatment area, near the key natural resource that we aim to protect (and test this method for protection); thus 120 tunnels are placed in this area that is approximately 100 ha (~1.2 tunnels/ha), getting us to the density of tracking tunnels that we have shown to be effective in the past (ie, QA-2523, Shiels 2017; and additional studies such as Shiels 2010).

**H. Source**

Describe where the animals will be trapped or obtained, or identify the vendor by name and address.

Wild rodents other invasive vertebrates are trapped in the LMU as part of OANRP; they will also be collected dead off the ground within LMU. Wild skinks will also be obtained by trapping in the LMU.

**I. Method of identification of animals**

Explain briefly how animals will be marked or identified to prevent misidentification, and cite any appropriate SOP(s)

Dead animals will be placed in ziplock bags, labeled with their species, date of collection, and location of collection; they will then be stored frozen until analysis.

**J. Trapping/Collecting**

Explain briefly how trapping and collection will be done. As applicable, include the methods to be used and specific procedures such as the frequency of trap checks, removal of animals from traps, specific procedures for extreme temperatures and weather conditions, etc.) and cite any appropriate SOP(s).

Skinks will be restrained on sticky traps for up to 1-6 hour periods (variation based on the frequency of trap checking). Skinks will be euthanized by manually applied blunt force trauma to the head (hammer blow to the head while restrained on the sticky trap) (AVMA 2013).

Rodent tracking tunnels will be used to collect footprints of rodents. We will use 150 tracking tunnels (120 in treatment area, 30 in control area), which are baited ink cards placed in tunnels so that foot prints of animal visitors can be identified, to determine presence of invasive rodent species. OANRP has the tunnels in place and has been conducting quarterly assessments of rodents at both control and treatment sites over the last year as part of their rodent trapping efforts around ‘elepaio monitoring areas. Rodent monitoring will be done on the following schedule at the control and treatment sites simultaneously, using tracking tunnels: 1 day prior to first application, 1 day prior to second application, 4 weeks after 1$^{st}$ application, monthly thereafter for at least 6 months.

**K. Transport**

Explain briefly how transport will be done. As applicable, include the type of vehicle or method of conveyance; temperature control; type, size, and number of cages; numbers of animals per cage; food and water availability; specific procedures for extreme temperatures and weather conditions, total transit time, etc. and cite any appropriate SOP(s).

Animal carcasses from “carcass searches” and non-target collections will be transported in ziplock bags and frozen, stored in a freezer at OANRP until the samples can be sent frozen in bulk to Ft Collins chemistry lab for diphacinone residue analysis.

**L. Handling/restraint**
Explain briefly how the animals will be held or restrained (manual vs. chemical) throughout study, and cite any appropriate SOP(s).

Skinks will be restrained on sticky traps for up to 1-6 hour periods (variation based on the frequency of trap checking). Skinks will be euthanized by manually applied blunt force trauma to the head (hammer blow to the head while restrained on the sticky trap) (AVMA 2013).

Other than Skinks, no vertebrates will be handled or restrained by NWRC. Rodent tracking tunnels will be used to collect footprints of rodents, but live rodents will not be handled or restrained by this methodology.

**M. Quarantine**
Explain briefly the procedure for the quarantine of animals, and cite the appropriate SOP(s).

N/A (none will be quarantined)

**N. Housing/Caging**
Explain briefly how housing/caging will be done (including information on feeder animals if used). Provide information regarding special caging or housing requirements, and cite any appropriate SOP(s)

N/A (none will be housed or caged)

**O. Diet/Water**
Explain briefly how the animals will be fed and watered, and cite any appropriate SOP(s). Provide information regarding maintenance diets, special diets, and dietary manipulations, and describe components of any test substance formulations.

None will be housed or caged. The food bait used for tracking tunnels will be peanut butter or coconut; the food bait for skink sticky traps will be fruit or peanut butter.

**P. Monitoring**
Describe how animals will be monitored while on test, especially those who are involved in a toxicity or disease study, or have been injected with a test substance, etc.

None will be housed or caged. Insect sticky traps will be checked each 1-6 hours during the daylight hours and each trap will be removed and stored in a bucket with a lid each night. Captured skinks will be euthanized upon capture.

**Q. Study End Point:**
Describe how the end of the activities which involve the use of animals is determined.

Captured skinks will be euthanized upon capture. The end point for tracking tunnel use (thereby affecting rodent behavior) will be when the baited tracking cards are removed from each tunnel (ie, ~10 times during this study).

**R. Disposition of animals**
Address how ill, injured and non-target animals will be handled during the study. Describe the disposition planned for live and dead animals at the end of the study, and cite any appropriate SOP(s).

We do not expect any animals to become ill or injured by using sticky traps for lizards and tracking tunnels for rodents. All animal carcasses analyzed for residues will be disposed of (incinerated) at NWRC Fort Collins at the end of the study.

## S. Animal pain or distress

1) Consultation with Attending Veterinarian:
Consult with the Attending Veterinarian in advance to address any animal care and use issues. ***The Attending Veterinarian will determine if any portion of the study might cause more than momentary or slight pain or distress.*** Consultation should include discussion of alternative procedures, sedatives, analgesics, anesthetics, surgery and euthanasia.

**Note: Consult separately, and with appropriate advance notice, the Animal Facilities Supervisory Personnel for space allocation in designated Animal Facilities.**

Name of Attending Veterinarian: Dr. Tom Gidlewski

Date of Consultation: October 11, 2017

2) Is this study expected to cause more than momentary or slight pain or distress as determined by the Attending Veterinarian?

☒ No
☐ Yes - Continue with the following items.

a) Alternative procedures:
Provide a narrative of the sources consulted to determine whether or not alternatives exist to procedures which may cause pain or distress. The narrative should include databases searched or other sources consulted, date of search and years covered by the search, and the keywords and/or search strategy used.

Click here to enter text

b) Sedatives, analgesics, or anesthetics or Column E Explanation:
Describe the appropriate sedatives, analgesics, anesthetics, or other methods to be used to minimize or alleviate discomfort, distress or pain.

Click here to enter text

If sedatives, analgesics, anesthetics will be withheld, attach the **Column E Explanation** and complete items #4-6.

c) Surgery:

## T. Euthanasia

Describe the appropriate method of euthanasia to be used (cite the current AVMA Guidelines, appropriate SOP, or explain how this will be done). Methods of euthanasia which do not produce rapid unconsciousness and subsequent death, without evidence of pain or distress, must be scientifically justified. (Refer to the current AVMA Guidelines on Euthanasia for approved methods of euthanasia for laboratory and wild animals.)

Skinks will be euthanized by manually applied blunt force trauma to the head (hammer blow to the head while restrained on the sticky trap) (AVMA 2013).

## U. IACUC Approval

Date of IACUC Approval Letter: 11/9/17

## ENDANGERED SPECIES ACT (ESA) APPENDIX

All activities or programs that are authorized, funded, or carried out, in whole or in part, by federal agencies in the U.S. or upon the high seas are regulated under the ESA. This includes research activities authorized, funded, or conducted by federal agencies and employees.

Before any field activity can take place you must assess the potential effects the proposed action could have on species, populations, or critical habitat protected under the ESA, and then make "effects determinations". Finally, you must maintain an administrative record (i.e., documentation of the evaluation) for the field activity under the ESA.

This appendix will help you document your effects determinations for this action, and determine whether further consultation with the U.S. Fish and Wildlife Service (USFWS) and/or National Marine Fisheries Service (NMFS) is required under section 7 of the ESA.

**This appendix does not cover regulatory requirements for state listed species. You must determine those by contacting the State agency responsible for wildlife management.**

### Links to USFWS/NMFS Resources on Effects Determinations

Effects Determination Guidance (NMFS)
Effects Determination Step-by-Step Instructions (USFWS)
USFWS Consultation Handbook

### Effects Determinations Instructions and Decision Tool

**1.** Is another federal agency taking care of the section 7 responsibilities under ESA for this field activity?
☒ Yes Go to #5, check the box, and follow the instructions.
☐ No Go to #2.

**2.** Read all of the instructions under I, II, and III below in order to answer this question!

**I.** Determine the action area, which includes the area where the field activity will actually occur and all areas that reasonably could be directly or indirectly affected by the field activity immediately or in the future.

**II.** Go to: USFWS IPaC online planning tool (Hold Ctrl + Click on blue link), click and follow the instructions to map you action area determined in Step I. Then request an "official species list" under "Regulatory Documents" (instructional video; Hold Ctrl + Click on blue link). The official species list will be emailed to you. This official species list will include all species, experimental populations, and critical habitat protected under the ESA that occur in your action area.
*Note: Only consider resources protected under the ESA for this appendix (e.g., do not include species protected under the Migratory Bird Treaty Act or the Bald and Golden Eagle Protection Act).*

**III.** Based on the results from Step II, do any threatened, endangered, or proposed species (animals and plants), experimental populations, or designated or proposed critical habitat protected under the ESA occur in your action area?
☐ Yes Then go to #3.
☐ No Go to #6, check the box, and follow the instructions.

3. <u>Read all of the instructions under I, II, and III below in order to properly fill out the table below.</u>

**I.** Assess all potential effects of the proposed action **on each** protected species, experimental population, or critical habitat that occurs in your action area by doing the following:

a. Identify all potential stressors resulting from the action to one or more individuals of the species and/or to "primary constituent elements" of the species' habitat; and
   - *<u>Primary constituent elements</u> include: 1) space for individual and population growth, and for normal behavior, 2) food, water, air, light, minerals, or other nutritional or physiological requirements, 3) cover or shelter, 4) sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal, and 5) habitats that are protected from disturbance or are representative of the historic geographic and ecological distributions of a species.*

b. Evaluate all potential pathways in which one or more individuals of the species and/or primary constituent elements of the species' habitat could be exposed to those stressors, including the potential intensity, frequency, and duration of the exposure.

When doing this, you must consider all of the following types of potential effects:
- Direct effects: Changes that occur during implementation of the action.
- Indirect effects: Changes that occur after implementation of the action (at any point in time).
- Interrelated effects: Changes that are the result of a larger action and depend on the larger action for their justification.
- Interdependent effects: Changes that are the result of other actions that would not occur without the action under consideration.
- Cumulative effects: Changes that are the impact of future activities (federal, state, and private) that are reasonably certain to occur after the action has occurred.

**II.** Then:

**A) For the following ESA protection status classifications:**
- **Threatened species**
- **Endangered species**
- **Designated critical habitat**
- **Essential experimental population**
- **Non-essential experimental population (inside of a National Park or National Wildlife Refuge)**

a) Determine whether those potential effects are:
   - Zero: No potential for exposure to a stressor.
   - Beneficial: Effects are immediate and wholly positive.
   - Insignificant: Effects relate to the size of the impact and should never reach the scale where "take" occurs. Based on best judgment, a person would not be able to meaningfully measure, detect, or evaluate insignificant effects.
     - *<u>Take</u> includes intentional or incidental harassment, trapping, capture, injury, or death, or otherwise changing the behavior of an individual of a protected species in a way that negatively impacts their fitness, reproduction, or survival, or damaging or altering designated critical habitat.*
   - Discountable: Based on best judgment, a person would not expect these effects to occur, because they are extremely unlikely (this must be justified).
   - Adverse: All other effects are adverse effects. Take must be considered an adverse effect.

b) Identify potential <u>mitigation</u> or conservation measures that can be taken to potentially reduce an adverse effect to an insignificant or discountable effect.
   *Note: A mitigation measure <u>cannot</u> reduce an insignificant, discountable, or adverse effect to zero effect.*

c) Make the appropriate effect determination for the species, experimental population, or critical habitat:

- **No effect (NE)**: The proposed action will have no impact, because there is zero potential for exposure to a stressor resulting from the proposed action (e.g., the species uses completely different habitat units than those directly or indirectly impacted by the action, or is seasonally absent and primary constituent elements of its habitat will not be affected).
  - *Any potential beneficial, insignificant, discountable, or adverse effects of the action means you cannot make an NE determination, even when the potential effects are improbable.*
  - *You also cannot mitigate to an NE determination, but you can move the location of your field activity to another site where the species or critical habitat will have zero exposure to a stressor resulting from the action and then make an NE determination.*
- **May affect, but not likely to adversely affect (NLAA)**: Only applies if the potential effects of the proposed action are wholly beneficial, insignificant, or discountable.
  - *Any potential take resulting from the action means you cannot make an NLTAA determination, even when the take is improbable.*
- **May affect, and is likely to adversely affect (LAA)**: Applies if the proposed action has the potential to cause adverse effects.
  - *You can potentially mitigate to reduce an LAA to an NLAA determination.*

Or:

**B) For the following ESA protection status classifications:**

- **Proposed species**
- **Proposed critical habitat**
- **Non-essential experimental population (outside of a National Park or National Wildlife Refuge)**

a) Determine whether those potential effects will:

- **Not likely to jeopardize/adversely modify**:
  A) The proposed action is not likely to reduce the reproduction, numbers, or distribution of the proposed species or the non-essential experimental population in a way that would reasonably be expected to directly or indirectly reduce appreciably the likelihood of both the survival and recovery of that species; or
  B) The proposed action is not likely to adversely modify the proposed critical habitat.
- **Likely to jeopardize/adversely modify**:
  A) The proposed action could reasonably be expected to directly or indirectly appreciably reduce the likelihood of both the survival and recovery of the proposed species or the non-essential experimental population by reducing reproduction, numbers, or the distribution of that species; or
  B) The proposed action is likely to adversely modify the proposed critical habitat.

**III.** Finally, **for each ESA-protected resource** record in the table below: **a)** the name, **b)** the protection status, **c)** the appropriate effect determination, and **d)** an explanation/rationale/justification for the effect determination for each species (including mitigation measures, if applicable), experimental population, or critical habitat in your action area. Archive all supporting documentation (e.g., USFWS informational resources, peer-reviewed publications, survey data). Once you have completed the table, go to #4.

**Note:** To add species, experimental populations, or critical habitat: 1) click anywhere in the table cells above, and then 2) click the "+" in the bottom right corner of the cells selected.

**4.** Once you have completed the table above, select the appropriate option below:

☐ All species, experimental populations, and critical habitat effect determinations are NE or "Not likely to jeopardize/adversely modify". Go to #6, check the box, and follow the instructions.

☐ One or more species, experimental populations, or critical habitat effect determinations are NLAA, and none of the determinations are LAA or "Likely to jeopardize/adversely modify". Go to #7, check the box, and follow the instructions.

☐ One or more species or critical habitat effect determinations are LAA or "Likely to jeopardize/adversely modify". Go to #8, check the box, and follow the instructions.

## ESA Appendix Conclusion

5. ☒ Another federal agency is fulfilling the section 7 responsibilities for this proposed action.

Supplemental EA Finding of No Significant Impact. 2017. Protecting endangered O'ahu 'elepaio using rodenticide within Schofield Barracks Military Reservation, O'ahu, Hawai'i. Prepared by: Directorate of Public Works, U.S. Army Garrison, Hawai'i. September 2017. 92pp.

- Do not conduct the requested field activities until no effect determinations have been made by the other agency or consultation/conference with USFWS/NMFS is complete. You must be informed of and follow the requirements of the consultation/conference.
- **You are finished with the ESA Appendix and your responsibilities under the ESA unless an additional species or critical habitat is protected under the ESA in the action area during the action or if the action area expands.**

6. ☐ A **no effect** or **not likely to jeopardize/adversely modify** determination is made for all species, experimental populations, and critical habitat protected under the ESA for the proposed action.
   - Save and archive your official species list and any other information used to reach this conclusion.
   - **You are finished with the ESA Appendix and your responsibilities under the ESA unless an additional species or critical habitat is protected under the ESA in the action area during the action or if the action area expands.**

7. ☐ The proposed action is **may affect, but is not likely to adversely affect** one or more species, experimental populations, or critical habitat protected under the ESA within the action area.
   - The NWRC NEPA contact will initiate the informal consultation process with USFWS/NMFS Ecological Services. **Written concurrence from USFWS/NMFS Ecological Services on the NLAA determination(s) is required before the action may be undertaken, or before an irreversible or irretrievable federal commitment to the action is made.** Correspondence from USFWS Refuge personnel will not suffice. This process usually takes at least 1 month.
   - Save and archive all documents and correspondence, including the official species list and concurrence letter from USFWS/NMFS.
   - **You are finished with the ESA Appendix, but not with your responsibilities under the ESA.**

8. ☐ The proposed action **may affect, and is likely to adversely affect** or one or more species, experimental populations, or critical habitat within the action area, and/or is **likely to jeopardize** the continued existence of proposed species or experimental populations, and/or is **likely to adversely modify** proposed critical habitat.
   - Contact the NWRC NEPA contact to initiate a formal consultation and conference process with USFWS/NMFS Ecological Services. **The formal consultation must be concluded before the action may be undertaken, or before an irreversible or irretrievable federal commitment to the action is made.** This process takes a minimum of 6 months.
   - Save and archive all documents and correspondence, including the official species list, the Biological Assessment, Section 10 permits (if applicable), and the Biological Opinion from USFWS/NMFS.
   - **You are finished with the ESA Appendix, but not with your responsibilities under the ESA.**

## NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) APPENDIX

This appendix is intended to aid the Study Director with determining whether a proposed project qualifies for a categorical exclusion as allowed by the USDA APHIS Implementing Regulations (7 CFR, part 372). Categorical exclusions are classes of federal actions that do not individually or cumulatively have a significant effect on the human environment.

➢ **Complete the Endangered Species Act (ESA) Appendix prior to completing this appendix.**

➢ **This appendix does not cover regulatory requirements for States. You must determine those by contacting the appropriate State agency.**

**A.** Is another agency completing the NEPA and ESA requirements for the proposed action, <u>and</u> do they adequately address all proposed NWRC activities?

☒ Yes – Please contact the NWRC NEPA Contact to determine the appropriate level of documentation. (A copy of the document must be included when your study is archived).

Supplemental EA Finding of No Significant Impact. 2017. Protecting endangered O'ahu 'elepaio using rodenticide within Schofield Barracks Military Reservation, O'ahu, Hawai'i. Prepared by: Directorate of Public Works, U.S. Army Garrison, Hawai'i. September 2017. 92pp.

The USDA Wildlife Services NEPA staff determined that based on the analysis of the Army EA that a categorical exclusion is appropriate for the NWRC involvement in this project. Details can be found in the study records in an email dated 10/24/17.

☐ No – Continue to question B.

**B.** What was your conclusion in the ESA Appendix?

☐ The proposed action will require a formal consultation with USFWS or the National Marine Fisheries Service (NMFS) – This study does not qualify for a Categorical Exclusion, and an EA or EIS should be prepared before initiation of the project. You are done with this appendix. Contact the NEPA Coordinator for assistance.

☐ The proposed action will require an informal consultation with USFWS or NMFS – This study may qualify for a Categorical Exclusion if you determined that the proposed action may affect, but is not likely to adversely affect all listed species, experimental populations, or critical habitats **AND** USFWS or NMFS concurs in writing. – Continue to question C.

☐ No consultation (formal or informal) with USFWS or NMFS is required under the ESA – Continue to question C.

**C.** Do any agency actions classified as undertakings under the National Historical Preservation Act (NHPA) result in adverse effects to historic properties within the area of potential effects (http://www.achp.gov/flowexplain.html).

***Undertakings*** are projects, activities or programs either funded, permitted, licensed or approved by a Federal Agency. Undertakings may take place either on or off federally controlled property and include new and continuing projects, activities, or programs and any of their elements not previously considered under Section 106 of the NHPA.

***Adverse Effects*** occur when an undertaking may directly or indirectly alter characteristics of a historic property that qualify it for inclusion in the Register. Examples of adverse effects include physical destruction or damage;

alteration not consistent with the Secretary of the Interior's *Standards*; relocation of a property; change of use or physical features of a property's setting; visual, atmospheric, or audible intrusions; neglect resulting in deterioration; or transfer, lease, or sale of a property out of Federal ownership or control without adequate protections.

Use one of the following links to determine if historical properties fall within the proposed action area:

a. https://www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466 (Useful for smaller geographic areas)
b. http://nepassisttool.epa.gov/nepassist/entry.aspx (Useful for larger geographic areas)

☐ Yes – Contact the State Historic Preservation Office (SHPO) for consultation (http://ncshpo.org/shpodirectory.shtml). This study may not qualify for a Categorical Exclusion and an EA or EIS may need to be prepared before initiation of the project if there are concerns from the SHPO. (A copy of the letter to the SHPO and any other information regarding the consultation must be included when your study is archived). – Continue to question D.

☐ No – Continue to question D.

**D.** Do any agency actions occur on tribal lands or ceded tribal lands? Use the following link to determine if tribal lands fall within the proposed action area:

a. http://www.arcgis.com/home/webmap/viewer.html?webmap=2a19e6ffe6934e09aaa0fa82f1bc0148

☐ Yes – Contact the WS State Director and WS tribal liaison to determine if there is a need for formal consultation on the program/study. This study may not qualify for a Categorical Exclusion and an EA or EIS may need to be prepared before initiation of the project if there are any tribal concerns. (A copy of the tribal letter must be included when your study is archived). – Continue to question E.

☐ No – Continue to question E.

**E.** Is the study a routine measures activity, such as identification, surveying, testing, removals, control, and sampling that will not cause physical alteration of the environment?

☐ Yes – You must be able to check all the below boxes and provide justification (if you are unable to check all the boxes, you must check "No") - Continue to question F.

☐ 1. Be localized or contained in areas where people are not likely to be exposed, and is limited in terms of quantity

☐ 2. Does not cause contaminants to enter water bodies (this includes runoff, drift or volatilization)

☐ 3. Does not cause bioaccumulation (the accumulation of a toxicant at a rate faster than it can be metabolized or excreted from an organism. In aquatic systems the bioconcentration factor (BCF) can be used to determine the potential for bioaccumulation. The octanol water partition coefficient (Kow) can also be used to determine the potential for bioaccumulation in aquatic and terrestrial organisms).

☐ 4. No extraordinary circumstances identified (adverse effects to environmentally sensitive areas or resources, or public controversy over the environmental effects of the proposed action)

Justification: We are not trapping, handling, or harassing animals. We are placing native fruit and seed on the ground and monitoring them with cameras and we are luring animals with peanut butter or coconut to pass over a tracking plate. We are not using any toxicants/chemicals. We are not altering the environment through these methods.

☐ No – Based on the information provided above this study does not qualify for a Categorical Exclusion and an EA or EIS should be prepared before initiation of the project. You are done with this appendix. Contact the NEPA Coordinator for assistance.

**F.** Summarize the risk to each group in the below with consideration of effects and the potential for exposure individually, and in relation to other impacts that may occur in the study area. Provide a justification for each endpoint and check the appropriate box below.

***Cumulative impacts*** are impacts on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal of non-Federal) or person undertakes such other actions. Cumulative impacts can result in individually minor but collectively significant actions taking place over a period of time.

1. Risk to human health
2. Risk to target species
3. Risk to non-target species

Justification: No risk to human health; no risk to target species (non-native rodents); no risk to non-target species. We are not trapping, handling, or harassing animals. We are placing native fruit and seed on the ground and monitoring them with cameras and we are luring animals with peanut butter or coconut to pass over a tracking plate. We are not using any toxicants/chemicals. We are not altering the environment through these methods

Does this activity pose a risk to human health or target and non-target species (including cumulative impacts) that will not be minimized or mitigated?

☐ Yes – Based on the information provided above this study does not qualify for a Categorical Exclusion and an EA or EIS should be prepared before initiation of the project. You are done with this appendix. Contact the NEPA Coordinator for assistance.

☐ No – Continue to question G.

**G.** Will this study have a disproportionate adverse effect to children, minorities and low income populations? (Use the information under letter F (Risk to human health) and the location of the proposed study (i.e., potential for exposure) to discuss whether there would be any disproportionate impacts to children, minorities, and low income populations).

No, it will not; there is no risk here to humans. We are not trapping, handling, or harassing animals. We are placing native fruit and seed on the ground and monitoring them with cameras and we are luring animals with peanut butter or coconut to pass over a tracking plate. We are not using any toxicants/chemicals. We are not altering the environment through these methods

☐ Yes – Based on the information provided above this study does not qualify for a Categorical Exclusion and an EA or EIS should be prepared before initiation of the project. You are done with this appendix. Contact the NEPA Coordinator for assistance.

☐ No – The study meets the criteria for Categorical Exclusion - No further action is needed for NEPA.

## ANALYTICAL CHEMISTRY APPENDIX

If chemical analysis by NWRC Analytical Chemistry is required, a consultation with the NWRC Chemistry Lab Unit (CLU) Leader is needed. List the approximate number of samples to be analyzed, the storage conditions, the Analytical method and the name and date of the CLU consultation.

**A. Number of samples to be analyzed (by type):**

We have limited field access, and this may prevent much (usable) carcass collection. We will collect water samples prior to and following application. My estimates are here:

Rodents: ~35 for liver only
Water: ~30
Non-targets: ~40 liver or whole body

**B. Storage conditions (temperature, container type, light/dark, duration):**

frozen

**C. Method title and number:**

Diphacinone residue analysis of liver and whole body, and water.

**D. Chemistry Lab Unit Leader consultation: __Dave Goldade__________ Date: ___10/3/17________**

☐ Chemical analysis will be performed by a laboratory outside of NWRC.
Include items A-C above and attach the method to be used as an appendix to this protocol.

**Experimental Protocol for ContraPest Trial in Forest Areas**

**Tyler Bogardus**
**Small Vertebrate Pest Stabilization Specialist,**
**Pacific International Center for High Technology Research (PICHTR),**
**Under cooperative agreement with the U.S. Army Garrison - Hawaii**

**Purpose:** In order to protect endangered plant, bird and snail populations from the depredations of rats, we propose an experiment to determine whether ContraPest can be deployed effectively and safely in a forest setting. Our study addresses the following: 1. Does ContraPest reduce populations of *Rattus* spp. monitored by tracking tunnels, 2. Document with ink cards whether non-target visitors access the stations, and 3. Use histology to determine proportion of rats displaying reduced fertility.

**Problem Statement:** Rodents (*Rattus* spp. and *Mus musculus*) have been introduced to many ecosystems worldwide and are among the most widespread and problematic invasive animals affecting islands (Towns et al. 2006; Angel et al. 2009). Through mostly unintentional introductions by humans, these rodents occupy > 80% of the major islands worldwide (Atkinson 1985; Towns 2009). As a consequence of their omnivorous diet and large incisor teeth, introduced rats are probably the invasive animals responsible for the greatest number of plant and animal extinctions on islands (Towns et al. 2006).

Mesic forests are among the most diverse ecosystems in Hawaii, and many rare, threatened, or endangered plants, snails and insects reside in Hawaiian mesic forests. The U.S. Army is required to stabilize populations of endangered species and their habitat as per Biological Opinions issued by the U.S. Fish and Wildlife Service. Due to the large negative effects of introduced rats on natural resources at Kahanahaiki, which is an Army-managed 36-ha tract of mesic forest on the island of Oahu, the Army natural resource program on Oahu (OANRP) has been engaged in rodent control since 1995 using various techniques including snap traps, automatic traps, diphacinone rodenticide (the only approved rodenticide for use in conservation areas) applied in bait stations, and physical barriers. OANRP rat-control tools became more limited in 2012, which was when OANRP halted rodenticide use at all of the sites they manage (including Kahanahaiki) because of a change in the Special Local Needs (SLN) label that made bait-station application unfeasible in the steep, rugged terrain. Due to the high habitat quality and small size of Kahanahaiki, a large scale Victor Snap-trap grid of 402 traps was installed in May 2009 for ecosystem wide protection. In general, these traps were re-baited twice per month. After a general knock-down in the rat population in 2009, much fluctuation had occurred and the targeted levels of rat suppression were not always being met with the large-scale snap-trapping (Pender et al. 2013); this resulted in noticeable losses of native and endangered seeds and predation of native snails by rats. During a trial in 2012 and 2013, Goodnature A24 rat + stoat traps (Goodnature Limited, Wellington, NZ), which are self-resetting traps that can function 24 times with one $CO_2$ cartridge, were shown to be effective in controlling rat activity at a nearby site, Pahole gulch. Because of these results, a grid of A24s was installed at Kahanahaiki and snap-traps were discontinued. In July 2014, 83 Goodnature A24s were installed on existing trails at a spacing of 50 x 100 meters. In December 2014, an additional 36 A24s were installed within the gulch area to achieve a device spacing of 25 x 100 meters. In November 2015, a two-application ("one-time") hand-broadcast of Diphacinone-50 according to SLN label (Diphacinone 50: Conservation, EPA Reg. No.: 56228-35, State of Hawaii Lic. No. 8600.1) was conducted. The goal was to reduce the rat population (and therefore tracking) at Kahanahaiki during the seasonal peak (roughly November-February), thereby improving conditions for the native and endangered species during this period.

Monitoring of rat activity at Kahanahaiki as well as a control site via tracking tunnels was implemented to determine efficacy of trapping devices (Figure 1). The OANRP management objectives for Kahanahaiki articulate that there should be less than 10% activity levels in rat tracking tunnels. An acceptable level of rat activity, which promotes stable or increasing native/endangered snail (*Achatinella mustelina*) and plant (*Cyanea superba* subsp. *superba*) populations, has not been clearly identified, but New Zealand studies have shown that rat activity levels of 10% are low enough to maintain certain rare bird populations (Innes et al. 1999). A 10% activity level may also be the most achievable level using a large scale trapping grid. Results of the past seven years of monitoring of the control grid (May 2009-February 2017) show seasonal winter spikes of rat activity up to 78.4% (Figure 1). Therefore, relying solely on traps (snap-traps or A24s) has not been effective in keeping populations below the targeted 10% tracking in monitoring tunnels, particularly during the period of peak rat abundance (typically Fall/Winter; Figure 1).

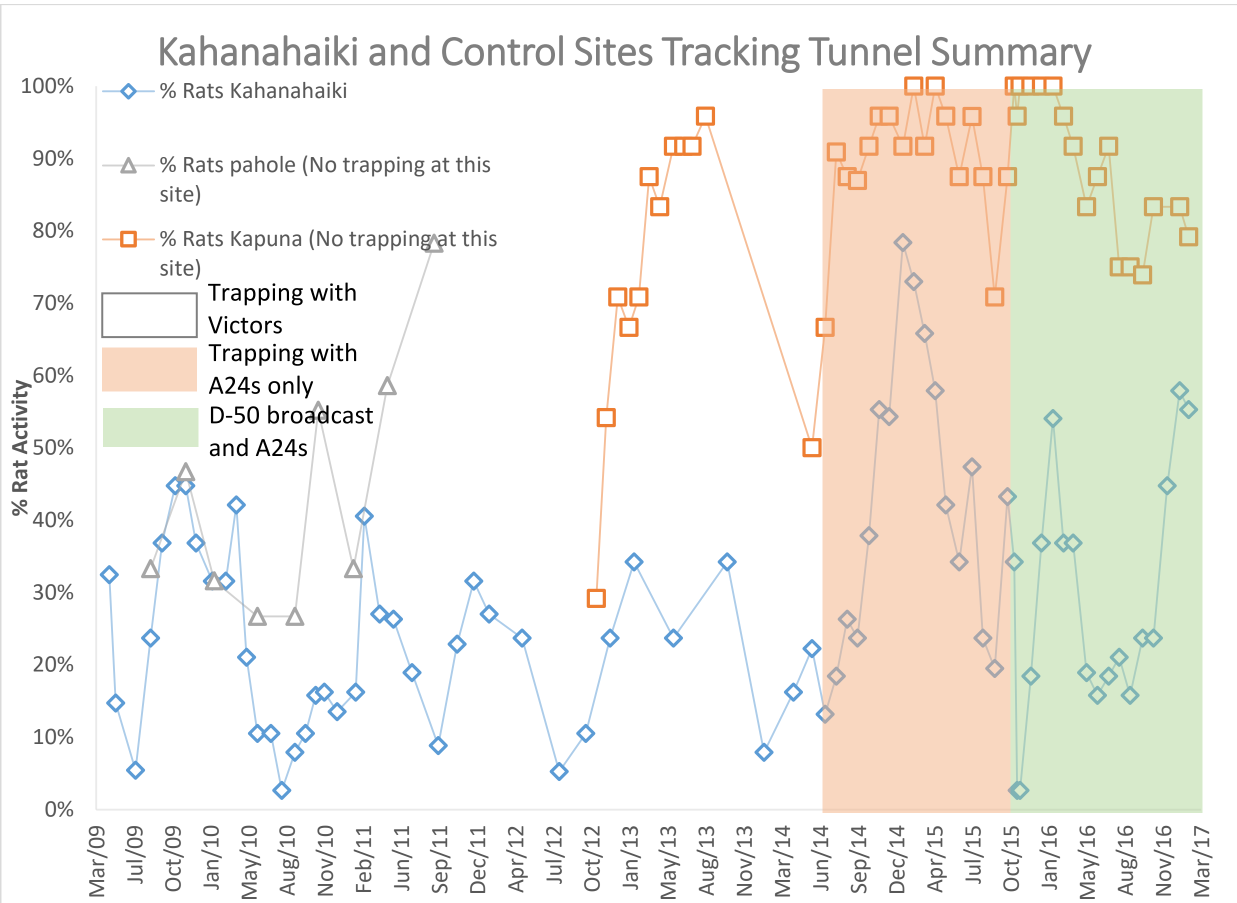


**Figure 1.** Percent rat activity (based on tracking tunnels) at Kahanahaiki (the rat-trapping site), and two nearby sites where no rat trapping occurred (Pahole and Kapuna). The shaded area from November 2015-Present is when A24 traps were continued after a two application hand broadcast of Diphacinone 50 in November of 2015; July 2014-October 2015 is when only A24 traps were used at the rat-trapping site; whereas the non-shaded (May 2009-April 2014) was when only Victor snap-traps were used at the rat-trapping site.

**Study Site:** The Kahanahaiki Management Unit (MU) is located at 500-660 m elevation in the Waianae mountain range (21° 32’ N, 158° 11’ W), within the Makua Military Reservation (MMR), on Oahu, Hawaii. The total MU area is approximately 36 ha and is fenced to exclude ungulates. Overall, the north and east aspects are relatively native while the south and west exposures are dominated by weeds.

Kahanahaiki is home to many rare taxa, including plants and snails; 15 plant species and two animals are listed as endangered (OANRP Staff, 2009). Non-native rodents are ubiquitous at Kahanahaiki, including black rats (*Rattus rattus*), Pacific rats (*R. exulans*), and house mice (*M. musculus*); black rats are numerically dominant, outnumbering Pacific rats by >10-fold (Shiels 2010; Shiels and Drake 2011). Negative impacts of each of these three rodent species at Kahanahaiki has been reported to span native plants, insects, snails, and birds (Shiels et al. 2013). One endangered plant, *C. superba* subsp. *superba*, is highly vulnerable to black rat predation, and large-scale and intensive snap-trapping at Kahanahaiki reduced seed predation by rats from 47% to just 4% in one season (Pender et al. 2013). Several additional native plants receive high predation by black rats at Kahanahaiki (Shiels and Drake 2011), implying that these native forests may potentially experience a shift in species composition attributable to invasive rats (particularly black rats).

**Methods:** For this trial two 4-hectare grids will be delineated at the Kahanahaiki MU, one to be used as a control site and the other as the treatment site. The entire A24 grid will be discontinued and removed from the site for the duration of this trial. Localized control around rare resources just outside of the treatment area will be conducted when needed. Existing tracking tunnels will be maintained throughout the entire management unit. A grid of 25 ContraPest stations in JT Eaton 903TP tamper resistant bait stations (Figure 2) at a spacing of 50 x 50meters will be deployed over the 4-hectare (9.88 acre) treatment site (Figure 3). Within the control and treatment sites we will continue to monitor existing tracking tunnels as well as install an additional 14 tracking tunnels per site. A master control site located approximately 1 mile away where no rodent management has ever been conducted will also be monitored via tracking tunnels for comparison. Tracking tunnels will be monitored monthly at all sites.

A total of 12 monthly checks will be conducted starting August 2017 and continuing through July 2018. ContraPest stations will be re-baited with 1 liter of ContraPest per station (two 500 ml containers) on a monthly interval and data will be recorded such as; amount of bait taken, any observations on the status/quality of bait, and non-target presence as evidenced by ink cards.

We feel the best thing to do will be to "bench" out/dig the dirt at each station site so it is level, we will then secure the stations with 2 metal 6" pegs attached through the holes near the two entrances and one metal 9" spike through the hole inside the station. The MU is pig free and has an ungulate fence that is in working order and inspected every 3 months.

Tracking tunnel data will be analyzed using a Pearson's chi-squared test ($\chi 2$) and results will be compared to the control site and historical tracking data.

At the conclusion of the trial period rodent trapping will be conducted at the control and treatment sites to collect tissue samples for histological examination of the reproductive system. Traps will be set and checked daily by OANRP staff. All animals will be weighed. Carcasses will be sampled and then buried on site. Ovaries will be trimmed of fat and weighed prior to being placed in 10% neutral buffered formalin for tissue fixation. The samples will be processed, paraffin-embedded and serially sectioned (5 µm), mounted and stained with hematoxylin and eosin, this will be conducted by trained SenesTech staff. Follicles will be counted in every $40^{th}$ section and classified as primordial, primary, secondary, or antral. Testes will be weighed and length and width documented.

Samples will be compared between the treated and control sections. Tracking tunnels will also be compared within the treatment and control sites as well as a master control site.

**Non-Target Concerns:** It is not anticipated that any native species will visit the bait stations or consume the ContraPest product.

**Deliverables:** Within 3 months of the conclusion of the field trial, we will produce a report on the efficacy of ContraPest to reduce rat activity relative to the control site. We will also compare its efficacy with other methods of rat control (traps and broadcast rodenticide). Any non-target impacts to other species will be noted. During each monthly check a carcass survey will be conducted on all of the trails looking for any non-target effects.

**Figure 2.** JT Eaton 903TP tamper resistant bait station with 500ml of ContraPest liquid bait inside station.

Purchasing:

We will be purchasing the product from SenesTech, Inc. We will be acquiring 300 liters of product total that will be shipped in batches from July 2017-June 2018.

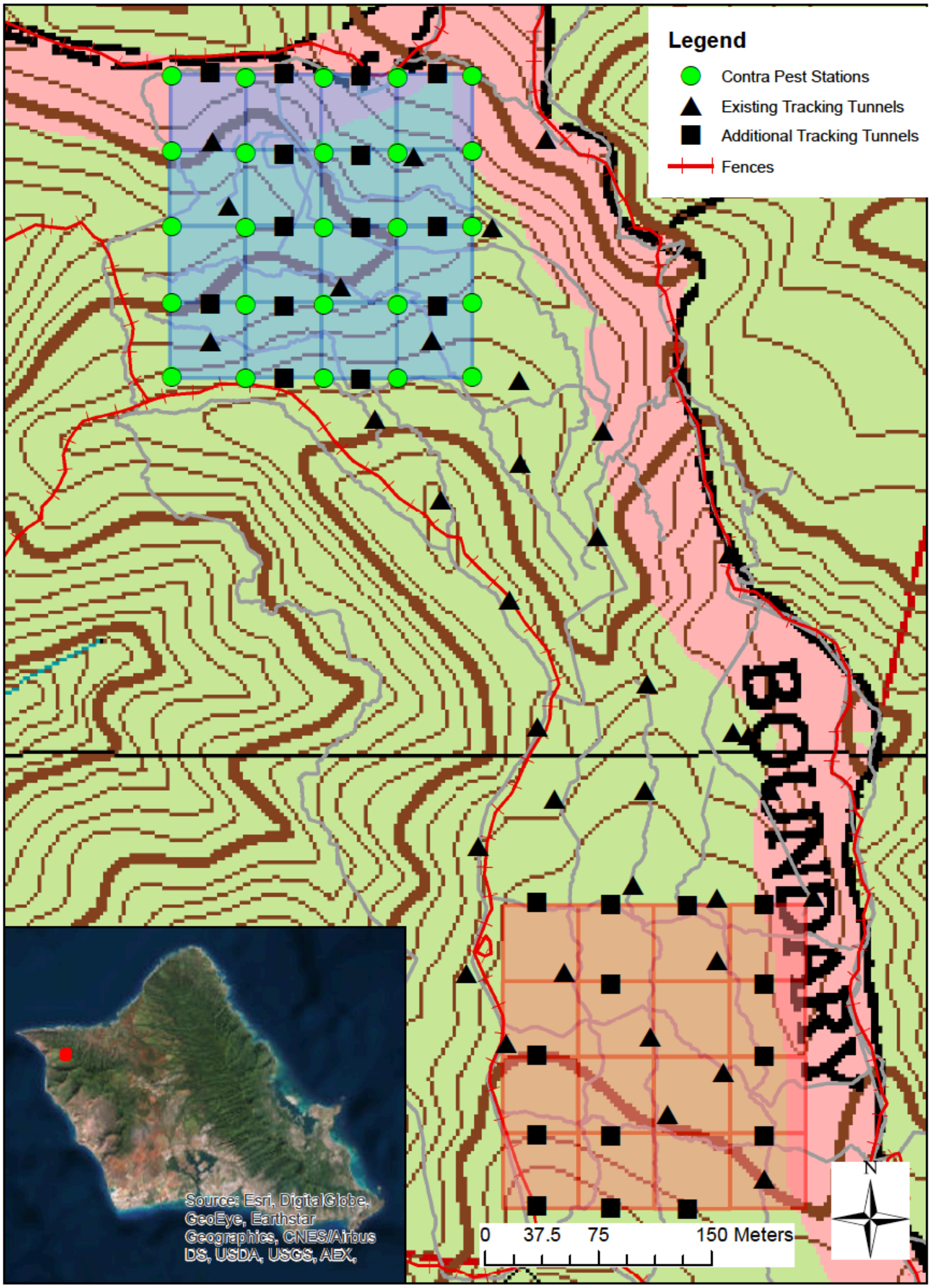


**Figure 3.** Kahanahaiki management unit study site showing control (red grid) and treatment site (blue grid).

Angel, A., R.M. Wanless, and J. Cooper. 2009. Review of impacts of the introduced house mouse on islands in the Southern Ocean: are mice equivalent to rats? *Biological Invasions* 11: 1743-1754.

Atkinson, I.A.E. 1985. The spread of commensal species of *Rattus* to oceanic islands and their effects on avifaunas. In: Moors PJ (ed) Conservation of island birds, pp. 35-81. ICBP Technical Publication No. 3.

Innes, J.G., R. Hay, I. Flux, P. Bradfield, H. Speed, and P. Jansen. 1999. Successful recovery of North Island kokako *Callaeas cinerea wilsoni* populations, by adaptive management. *Biological Conservation* 87: 201-224.

OANRP Staff. 2009. Kahanahiki Ecosystem Restoration Management Unit Plan *in* 2009 Status Report For the Makua and Oahu Implementation Plans. Available on-line: *http://manoa.hawaii.edu/hpicesu/DPW/ERMUP/2009_Kahanahaiki.pdf*

Pender, R.J., A.B. Shiels, L. Bialic-Murphy, and S.M. Mosher. 2013. Large-scale rodent control reduces pre- and post-dispersal seed predation of the endangered Hawaiian lobeliad, *Cyanea superba* subsp. *superba* (Campanulaceae). *Biological Invasions* 15: 213-223.

Shiels, A.B. Ecology and impacts of introduced rodents (*Rattus* spp. and *Mus musculus*) in the Hawaiian Islands. Ph.D. Dissertation. University of Hawaii at Manoa. 218 pp.

Shiels, A.B., and D.R. Drake. 2011. Are introduced rats (*Rattus rattus*) both seed predators and dispersers in Hawaii? *Biological Invasions* 13: 883-894.

Shiels, A.B., C.A. Flores, A. Khamsing, P.D. Krushelnycky, S.M. Mosher, and D.R. Drake. 2013. Dietary niche differentiation among three species of invasive rodents (*Rattus*, *R. exulans*, *Mus musculus*). *Biological Invasions* 15: 1037-1048.

Towns, D.R., I.A.E. Atkinson, and C.H. Daugherty. 2006. Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions* 8: 863-891.

Towns, D.R. 2009. Rodents. In: Gillespie, R.G., and Clague, D.A. (Eds.), *Encyclopedia of Islands.* University of California Press, Berkeley, pp 792-796.