Appendix ES-1 Spelling of Hawaiian Names

Place name	Hawaiian spelling
Aiea	ʻAiea
Aihualama	ʻAihualama
Aimuu	Aimuu
Alaiheihe	Alaiheihe
Alau	Alau
Ekahanui	ʻĒkahanui
Halawa	Hālawa
Haleauau	Haleʻauʻau
Halona	Hālona
Hawaii	Hawaiʻi
Hawaii loa	Hawaiʻiloa
Helemano/Halemano	Helemano/Halemano
Honolulu	Honolulu
Honouliuli	Honouliuli
Huliwai	Huliwai
Kaaikukai	Kaʻaikūkaʻi
Kaala	Kaʻala
Kaawa	Kaʻawa
Kaena	Kaʻena
Kahaluu	Kahaluʻu
Kahana	Kahana
Kahanahaiki	Kahanahāiki
Kaimuhole	Kaimuhole
Kaipapau	Kaipāpaʻu
Kaiwikoele	Kaiwikōʻele
Kalauao	Kalauao
Kaleleliki	Kaleleiki
Kalena	Kalena
Kaluaa	Kaluaʻā
Kaluakauila	Kaluakauila
Kaluanui	Kaluanui
Kamaileunu	Kamaileʻunu
Kamaili	Kamāʻili
Kamananui	Kamananui
Kapakahi	Kapakahi
Kapuna	Kapuna
Kauai	Kauaʻi
Kauhiuhi	Kauhiuhi
Kaukonahua	Kaukonahua
Kaumoku Nui	Kaumoku Nui
Kaunala	Kaunala
Kawaihapai	Kawaihāpai
Kawaiiki	Kawaiiki
Kawailoa	Kawailoa
Kawainui	Kawainui
Kawaipapa	Kawaipapa
Kawaiu	Kawaiū

Keaau	Keaʻau
Kealia	Keālia
Keawapilau	Keawapilau
Keawaula	Keawaʻula
Kihakapu	Kihakapu
Kipapa	Kīpapa
Koiahi	Koʻiahi
Koloa	Koloa
Konahuanui	Kōnāhuanui
Koolau	Koʻolau
Kuaokala	Kuaokalā
Laie	Lāʻie
Lanai	Lānaʻi
Lualualei	Lualualei
Lulumahu	Lulumahu
Maakua	Maʻakua
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	Mokuleiʻa
Molokai	Molokaʻi
Nanakuli	Nānākuli
Niu	Niu
Nuuanu	Nuʻuanu
Oahu	Oʻahu
Ohiaai	ʻŌhiʻaʻai
Ohikilolo	ʻŌhikilolo
Oio	ʻŌʻio
Opaeula	ʻŌpaeʻula
Paalaa Uka	Paʻalaʻa Uka
Pahipahialua	Pahipahiʻālua
Pahoa	Pāhoa
Pahole	Pahole
Palawai	Pālāwai
Palehua	Pālehua
Palikea	Palikea
Papali	Papali
Peahinaia	Peʻahināiʻa
Pohakea	Pōhākea
Puaakanoa	Puaakanoa*
Pualii	Pualiʻi

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

Appendix ES-2

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 a 18 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, 2017.

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

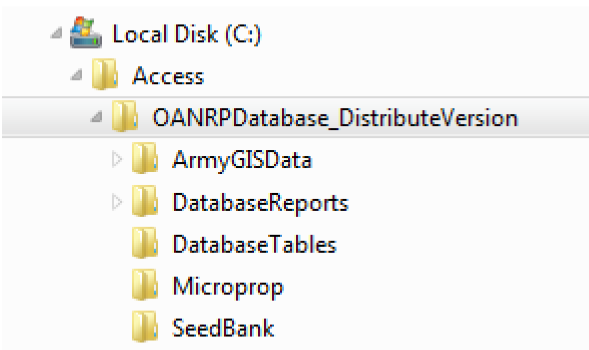
Linda Koch
Natural Resources GIS Specialist
Oahu Army Natural Resources Program
Email: lkoch@hawaii.edu

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

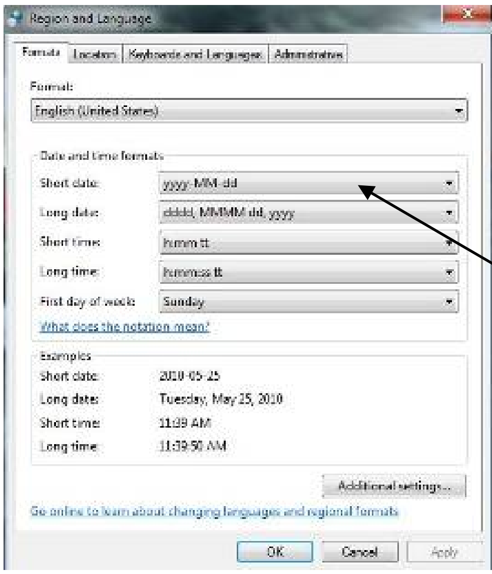
> Army SeedLab Database data. Contact Tim Chambers for more information.

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.



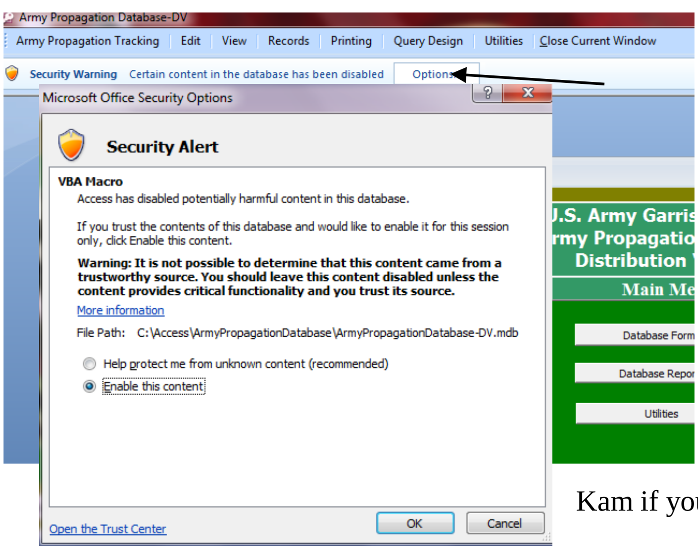
- Open Regional and Language Options by RIGHT clicking the **Start** button, clicking **Control Panel**, clicking **Clock, Language, and Region**, and then clicking **Region.** Under the Formats, change the **Short Date** to **yyyy-MM-dd.**

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.



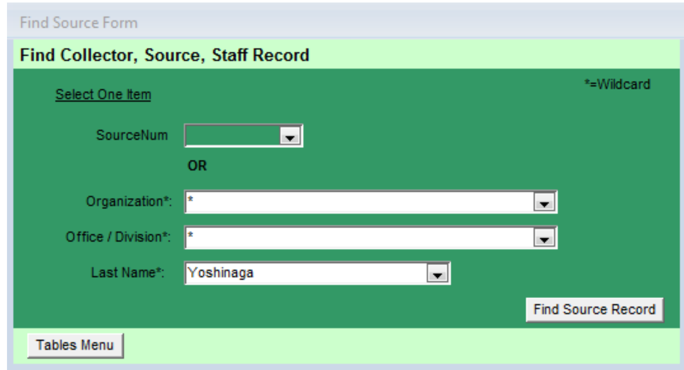
After opening the OANRPDatabase_DV.accdb file in Microsoft Access, click on Options when it appears at the top of your screen.

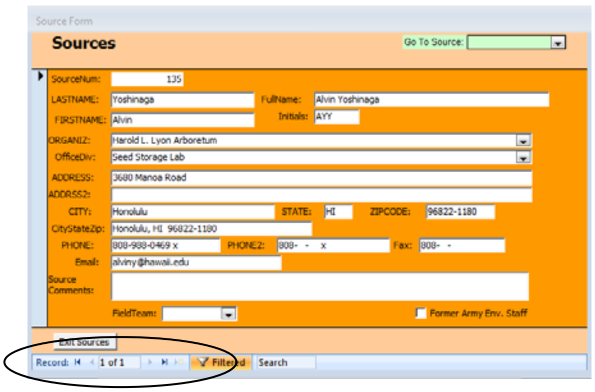
A window stating Security Alert will appear. Click on the button to select Enable this content, and click OK. Enabling the content will allow the database functions to operate.

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.

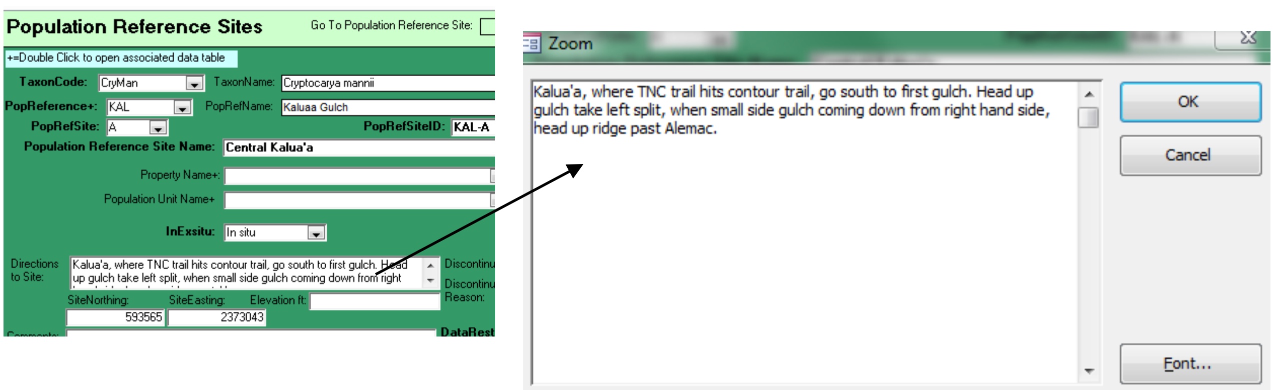
Using the * (asterisk), in a Find Form represents a wild card. Such as Organization *= Search for all Sources with any Organization. In this case, we will just search for the Last Name = Yoshinaga.





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.

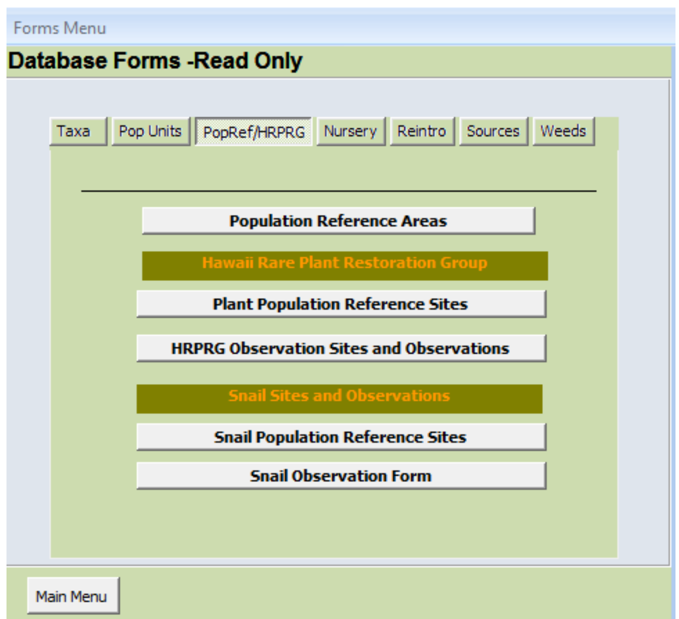
The database is broken up into 2 parts, Database Forms and Database Reports. We will primarily cover the Database reports. Database Forms are self-explanatory and is only for viewing purposes. The forms are provided for detailed review of individual observations. Only pertinent data fields will be discussed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

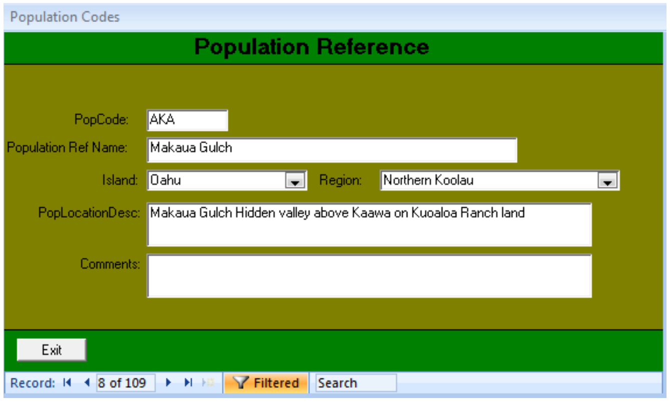
For the purpose of this tutorial, we will discuss forms of the PopRef/HRPRG tab with comprise of the Population Reference and Population Reference Sites. All other sections are supplemental and self-explanatory.



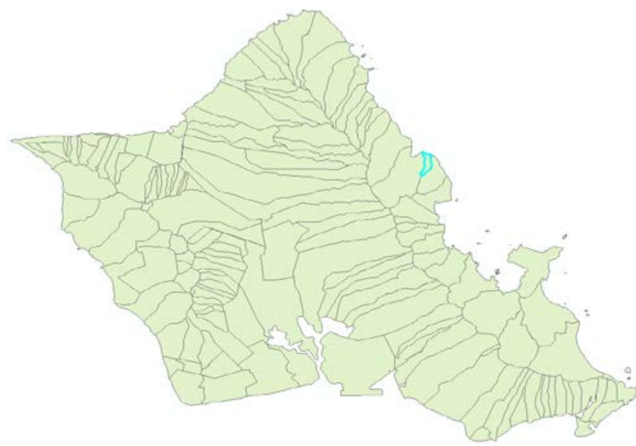
PopRef, Sites, and Observations

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.

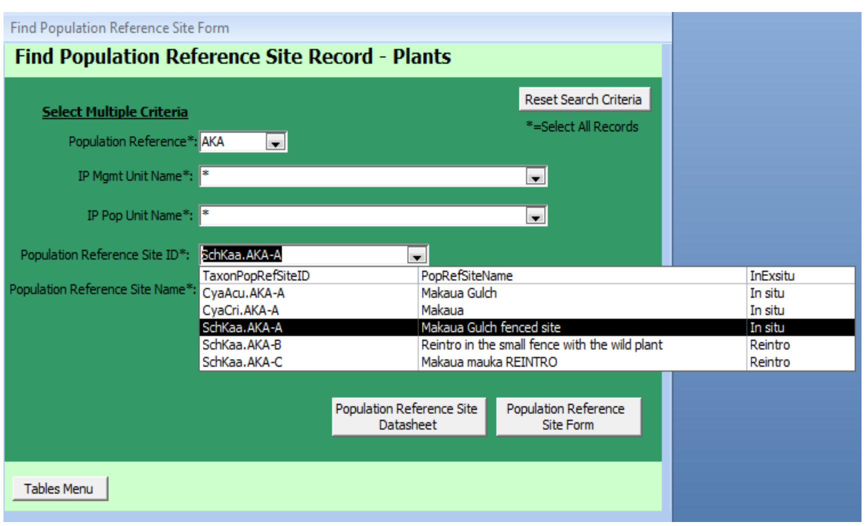


It should be noted that the Population Reference is not necessarily the name for any given population. It is only used as an identifier to compile different plant or animal populations within a given area. For example: Makaua on the Windward Koolau of Oahu (highlighted in blue). The GIS boundary is based 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)

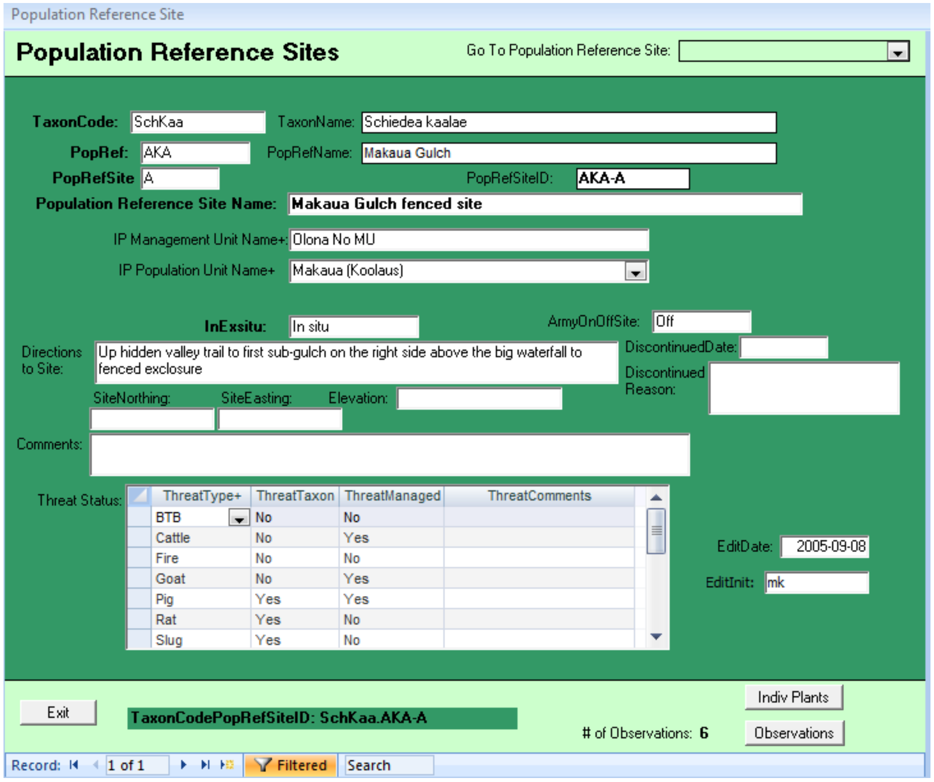
The Population Reference Site (PopRefSite) is the primary data table in establishing plant or animal population sites. The PopRefSite identifies the Population Name, whether it is In situ, Ex situ or Reintro, and provides directions to the site, etc. The PopRefSite is only site information; observation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

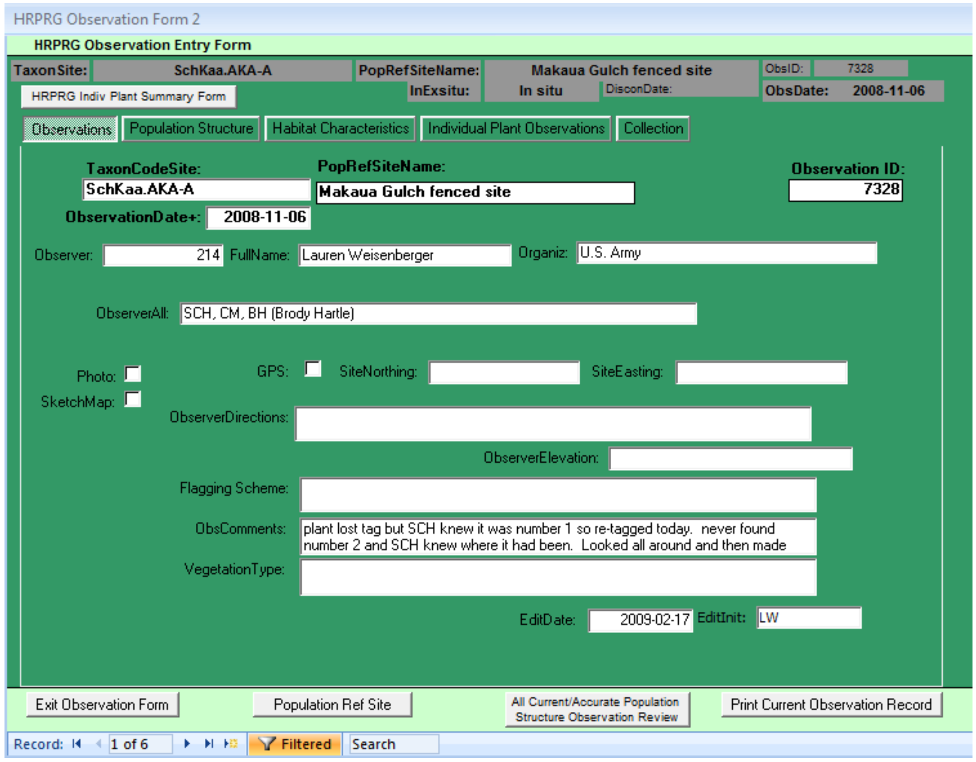
InExsitu: Identifies whether the PopRefSite is a naturally occurring wild (In situ), or Reintroduction (Reintro), etc.

Directions to Site: Detailed directions to locate the population.

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

Observations

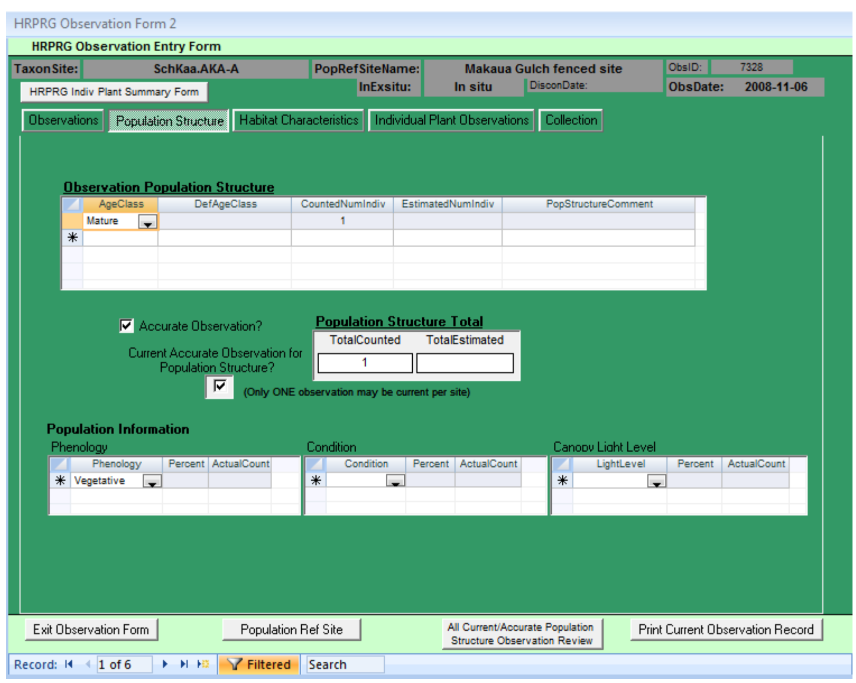
Clicking the Observations button on the bottom of the PopRefSite Form will open up the corresponding Observations.



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).

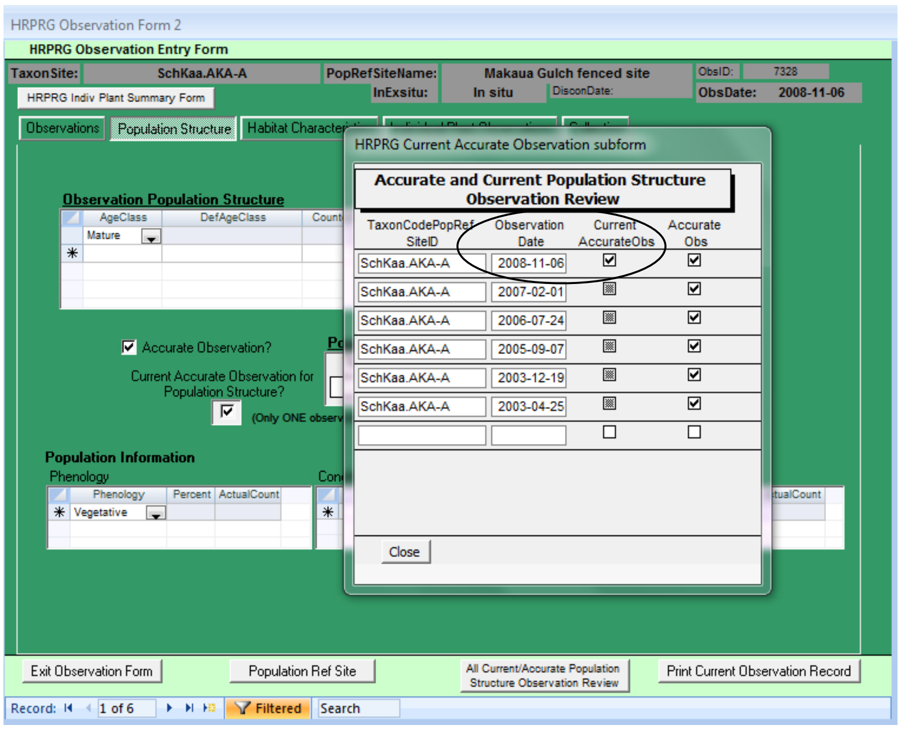


Age Class always is required, where **CountedNumIndiv** (Counted Number of Individuals) is considered a more accurate count of the number of plants. **EstimatedNumIndiv** (Estimated Number of Individuals) may be entered only when the CountedNumIndiv is not entered. EstimatedNumIndiv is used when the 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 **Current Accurate Observation** check off box may only have one observation checked. 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.

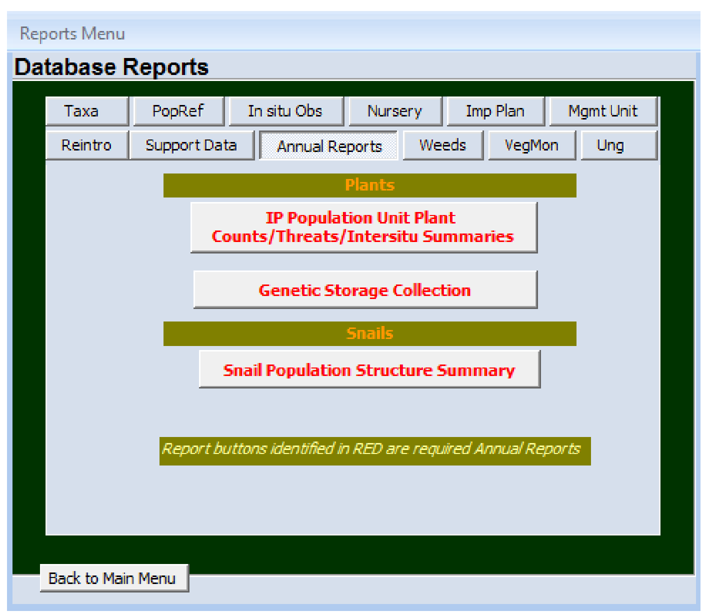
IV. Database Reports

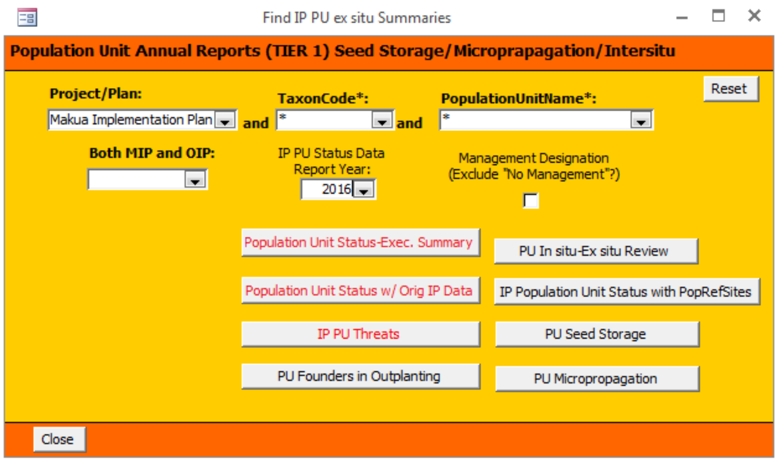
Starting from the Main Menu, click on the Database Reports button. The Database Reports menu provides reports for various sections of the database.

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

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	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				Threat Control				
				Large	Medium	Small	Unk	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.

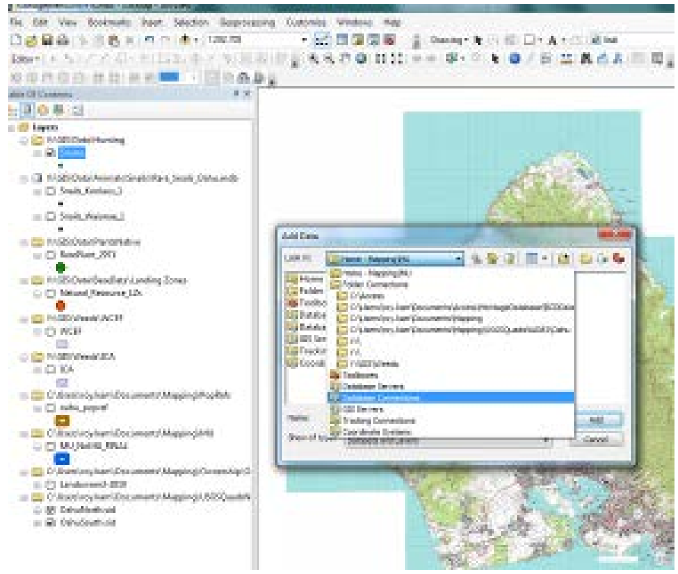
Population Reference Site: The first column lists the population reference code for each field site. This consists of a three-letter abbreviation for the gulch or area name. For example, MMR stands for Makua Military Reservation. Next, a letter code is applied in alphabetic order according to the order 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.

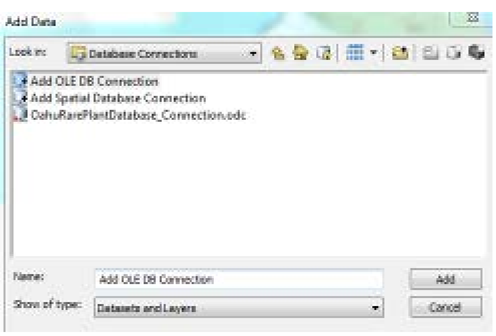
Linking Access Database Query into ArcGIS –Distribution Database Version



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.

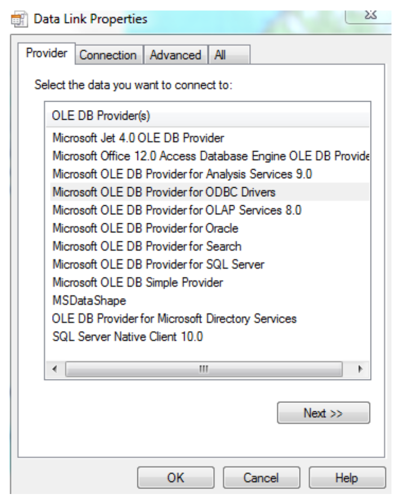
In your ArcGIS Project, make sure you have the Rare Plants or Rare Snails shapefile (or whatever shapefile you are linking) as one of your layers.

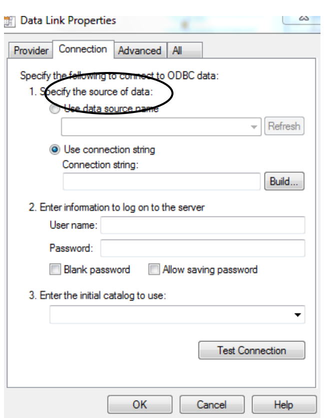
Click on the Add Button, and choose *Database Connections*. If you do not have Database Connections listed (versions ArcGIS 10.3 and up), you will need to add it before you start. Go to ArcCatalog>Customize (Tab)>Customize Mode>Under the Commands Tab, select ArcCatalog (left column) and on the right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

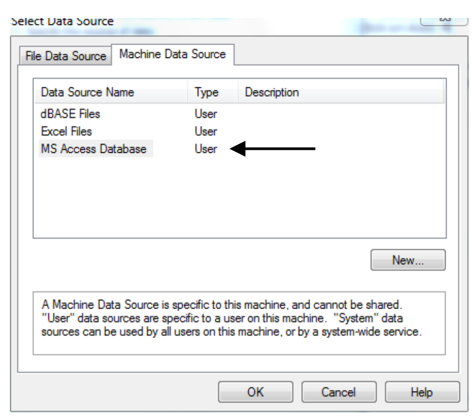
A Data Link Properties window will appear. Select *Microsoft OLE DB Provider for ODBC Drivers*.

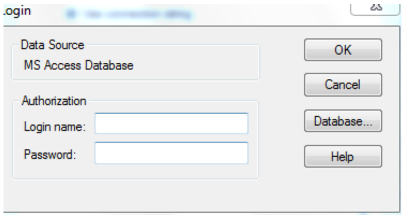




Then in the Data Link Properties window, select the *Connection tab*. Under the Connection Tab, select *Use Connection String* and click on the button *Build*.

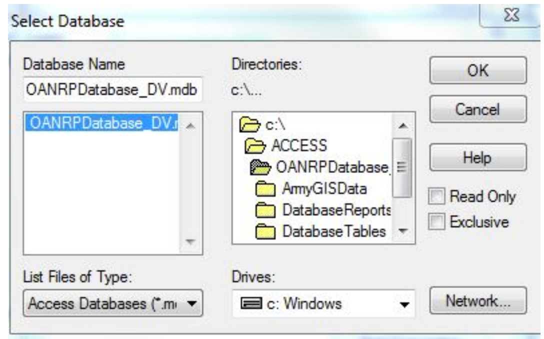
In the Select Data Source window, select the *Machine Data Source* tab, and select *MS Access Database then* click *OK*.





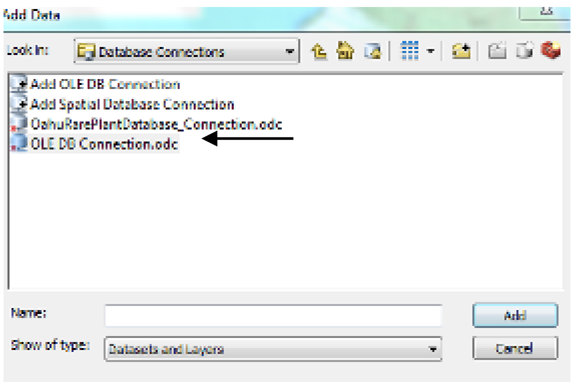
In the Login Window, Click on the *Database* button (leave Login Name and Password blank).

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

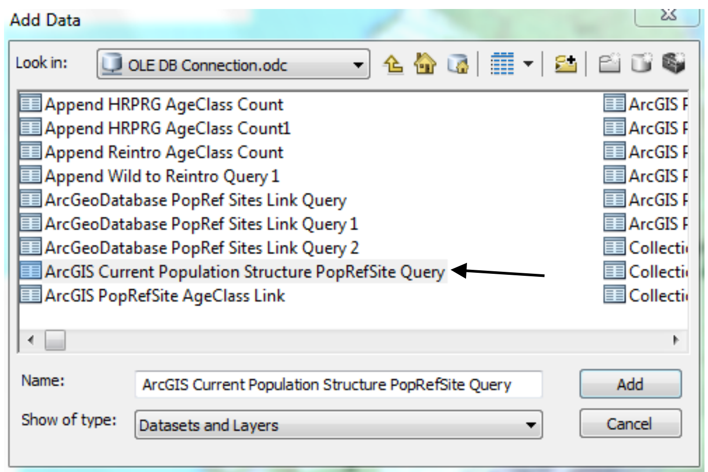


C:\Access\OANRPDatabase_DistributeVersion\ OANRPDatabase_DV.accdb

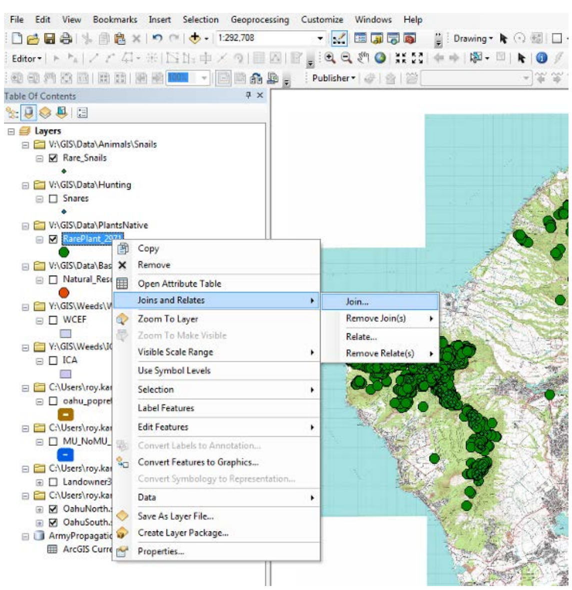
Click Ok to close the windows, until you are back at the Add Data window. You will now see a new OLE DB Connection.odc listed.



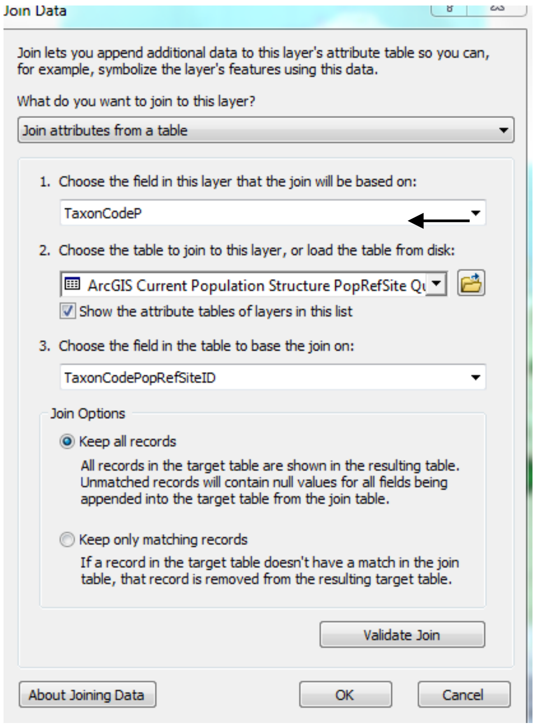
Double click on the OLE DB Connection.odc. The window will then open the Access Database and list all tables and queries.



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>
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A MULTI-SENSOR APPROACH
FOR VHR VEGETATION MONITORING

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE
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Dedication

This thesis is dedicated in loving memory of a champion of Hawaiian mixed-mesic forest restoration and conservation in Hawaii, Daniel K. Sailer. Thank you for your inspirational life's work in service of our imperiled, Hawaiian mixed-mesic forests and the many priceless plants and animals within them.

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Mahalo Nui Loa.

Abstract

The Hawaiian Islands are a showcase of biological diversity. With a myriad of vegetation communities, the tropical forests of Hawaii support a rich assemblage of endemic species, some of which are critically endangered. However, much of the Hawaiian forests are degraded and are subject to disturbance by invasive plants.

Monitoring the response of Hawaiian forests to management efforts and tracking how vegetation changes over time is a key component of conservation and restoration efforts. Traditional “on-the-ground” vegetation monitoring techniques are time consuming and costly, and can vary in accuracy and consistency. Recent advances in remote sensing technology hold potential for providing an accurate and timely assessment of vegetation at a set point in time. Until recently, the available satellite sensors lacked the spatial resolution required to differentiate individual tree crowns, and thus, classification was limited to the stand or community level. Several new very high resolution (VHR) platforms have emerged in the field of remote sensing that can differentiate individual tree crowns and, thus, have the potential to change the paradigm of vegetation monitoring and its efficacy. VHR, sub-meter imaging platforms are now readily available for public use with commercial VHR satellite and aircraft imaging, unmanned aerial system (UAS) digital imaging, and the Gigapan system.

The primary objective of this thesis was to determine the utility of new high spatial resolution remote sensing technologies for vegetation mapping and monitoring in Hawaiian forests. The strengths of the three platforms were evaluated and then combined, to produce an effective synthesis to implement remote sensing-based mapping to the species level and an OBIA procedural workflow was outlined. WV-3 imagery was classified with object based image analysis in eCognition into 7 vegetation classes and validated with UAS and Gigapan imagery.

The dense vegetation of the Hawaiian mixed-mesic forest presents a challenging task to separate vegetation classes to the species level. Validation results yielded an overall user’s accuracy of 65% with Sparse Veg representing the highest user’s accuracy of 94% and Strawberry guava representing the lowest user’s accuracy of 38%. Kukui=75%, Christmas berry=73%, Koa=50% and Native Complex=42%. Grouping native and non-native vegetation classes yielded an overall accuracy of 72% with non-native=94% and native=69%. The high accuracy of mapping sparse veg shows great potential for providing information towards fuel mapping via this method. Further work is needed to accurately separate native vs non-native vegetation to the species level. A stronger computer processer is needed to add additional geometric and textural features into the iterative classification process.

The UAS VHR platform shows the greatest potential for integration of remotely sensed imagery into an operational vegetation monitoring method. UAS allow for low cost, repeatable, high resolution data collection without risk to field personnel. A recommended method could employ a UAS to fly transects in a target area with visual or deep/machine learning analysis of random plots along the transects. Further advancements in multispectral sensors and longer lasting batteries will serve to allow for greater utility in monitoring, and management applications. Vertical takeoff and landing UAS may be of great use in areas without suitable landing area for typical fixed wing UAS.

The costs associated with the implementation of remote sensing based monitoring protocols were determined as compared to traditional ground based monitoring methods. Ultimately, if new imagery was obtained under contract, remote sensing based monitoring serves to be more expensive than traditional ground based methods. However, an operational

comparison which factors in either prior acquisition of imagery or capacity to gather data without going out to contract, shows a lower cost associated with remote sensing based monitoring.

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Acronyms

DSM- Digital surface model

GCP- Ground Control Point

GSD- Ground Surface Distance

MUs- Management Units

NDVI- Normalized Difference Vegetation Index

NIR- Near Infrared

OBIA- Object Based Image Analysis

OANRP-Oahu Army Natural Resources Program

USFWS- United States Fish and Wildlife Service

VHR- Very High Resolution

WV-2- WorldView 2

WV-3- WorldView 3

Appendix ES-3

Chapter 1. Introduction

1.1 Background

1.1.1 The Hawaiian Forest

The Hawaiian Islands are a showcase of biological diversity and host an array of unique and rare native species found nowhere else on earth. The native Hawaiian flora is represented by nearly 1,000 species of flowering plants, 89% of which are endemic (Wagner *et al.*, 1999). Hawaii has the highest known degree of endemism for terrestrial plants for any major island group (Juvik and Juvik, 1998). These species are distributed within a myriad of dry, mesic and wet forest vegetation communities across 600,000 forested hectares throughout the Hawaiian Islands (Juvik and Juvik, 1998; Gon, 2003; Sailer, 2003; Wagner *et al.*, 1999).

1.1.2 Disturbance of the Hawaiian Forest

Much of the Hawaiian forest has been severely impacted by disturbance and the subsequent introduction of many non-native species (Juvik and Juvik, 1998; Takahashi *et al.*, 2010; Mair and Fares, 2009). Disturbance of Hawaiian forests began with the early Polynesian settlers about 1,000 years ago, who started clearing leeward and coastal areas for agriculture and introduced a small number of alien species (Kirch, 1982; Kirch, 2011; Juvik and Juvik, 1998; Burny *et al.*, 2001; Staples and Cowie, 2001). However, extensive damage to mesic forests occurred with the arrival of Western settlement and agriculture during the 19th and 20th centuries (Juvik and Juvik, 1998; Friday, 2003). By the late 1800s and early 1900s forest decline was very high due to intentional burning to locate fragrant sandalwood, commercial logging, conversion to agriculture and pastureland, heavy grazing by hoofed mammals and the increased frequency of wildfires (Tomich, 1986; Cuddihy and Stone 1990; Friday, 2003).

Extensive disturbance of these areas has allowed for invasions of non-native plants. Many of the plants and trees that were introduced accidentally or intentionally as ornamentals, or used in agriculture and forestry have naturalized and are serious threats to disturbed, as well as intact, native ecosystems (Staples and Cowie 2001; Friday, 2003; Woodcock, 2003). Invasive species continue to be a major concern for conservation and resource management (D'Antonio and Kark, 2002). Invasive plants often outcompete native plants for resources as they rapidly grow, reach maturity at a relatively young age and excel at dispersal (Vitousek *et al.*, 1987; Mack *et al.*, 2001; Friday, 2003). In addition, they can affect ecosystem processes such as primary productivity, decomposition, hydrology, nutrient cycling and natural disturbance regimes (Vitousek *et al.*, 1987; Vitousek, 1990; Mack *et al.*, 2001).

1.1.3 Conservation and Monitoring of the Hawaiian Forest

Many efforts have been made to conserve native plant species and eradicate invasive plants and animals in Hawaiian forests. State, Federal and non-profit organizations work to control invasive species, propagate native plants and restore plant communities (Juvik and Juvik, 1998; Staples and Cowie 2001; Friday, 2003). The Oahu Army Natural Resources Program (OANRP) leads one of the most comprehensive endangered species mitigation, conservation and restoration efforts in Hawaii. The OANRP is required by the U.S. Fish and Wildlife Service (USFWS) to stabilize a targeted group of endangered species potentially threatened by U.S. Army training. In selected areas, active efforts are underway to manage target rare species and the native forest habitat that supports them. The OANRP has an active vegetation monitoring program that strives to measure change in vegetation over time in designated management units (MUs) (OANRP, 2010). Effective and efficient monitoring methods and tools suited to difficult terrain or sensitive ecosystems are actively evaluated prior to their implementation.

Monitoring the response to resource management and tracking how an area changes over time is a key component of conservation and restoration efforts. Monitoring provides a measure of progress towards the goals of stabilization (MIP, 2003). In addition, monitoring provides the basis for understanding the intricate distribution, composition, structure, and dynamics of the vegetation in an area. The baseline data provided by vegetation monitoring can be especially useful in areas that are being restored (Elzinga *et al.*, 2001; Jacobi, 2008). Monitoring the change in an area over time serves as a status update and allows natural resource managers to make informed adaptive management decisions (Moore *et al.*, 2003).

Vegetation species composition and percent cover are common indicators that are often recorded with vegetation monitoring (Moore *et al.*, 2003; USGS, 2011). These variables may be assessed by many methods, including “on-the-ground” data collection and remote sensing methods. The traditional, on-the-ground vegetation monitoring techniques, which include transects, point intercepts, quadrats, and measured plots, can be time consuming and costly, and may vary in accuracy and consistency depending on observer error and bias (Congalton, 1991; Mueller-Dombois and Ellenberg, 2002; Moore *et al.*, 2003; Milberg *et al.*, 2008; US Geological Survey, 2011; Cho *et al.*, 2015). One of the benefits of ground based monitoring is that all layers of vegetation can be documented from the ground up, including overlapping taxa (Akamine pers. com., 2017). Also, species identification can be better accomplished from the ground. However, on-the-ground monitoring may be damaging to sensitive native ecosystems and difficult or unsafe to accomplish in steep terrain and thick vegetation (Akamine pers. com., 2017).

1.1.4 Remote Sensing for Vegetation Mapping

Remote sensing is the science and art of collecting data about a specific object of interest without actual physical contact with that object (Jensen, 2007). Aerial or space-borne remote sensing has been used by the scientific community as an alternative or to compliment ground based field surveys to quantify vegetation and ecosystem processes (Cabello *et al.*, 2012). Analysis of remotely sensed imagery can provide an accurate and timely assessment of vegetation at a set point in time (Bunting and Lucas, 2006; Jacobi, 2008). This assessment can then be systematically replicated to monitor change in the vegetation communities and species composition of specific areas (Bunting and Lucas, 2006). Until recently, the available satellite sensors such as Landsat (30m spatial resolution) and MODIS (250-500m) lacked the spatial resolution required to differentiate individual tree crowns, and classification was limited to the vegetation stand or community level (Nagendra and Rocchini, 2008; Katoh, 2004).

Very high resolution (VHR) satellite sensors are distinguished by their capability to capture image data with a spatial resolution of less than 1m at nadir (Agrafiotis and Georgopoulos, 2015). Several new VHR imagery platforms have emerged in the field of remote sensing that can provide a different perspective and have the potential to change the paradigm of vegetation monitoring and its efficacy. These sub-meter imaging platforms are now readily available for general use and include commercial VHR satellite imaging, unmanned aerial system (UAS) digital imaging, and the Gigapan system (Adelabu and Dube, 2015; Boyle *et al.*, 2014; Bunting and Lucas, 2006; Carleer and Wolff, 2004; Stock *et al.*, 2010).

WorldView-3 (WV-3) VHR satellite imagery became available to the public in February 2015, by Digital Globe. WV-3 provides the finest spatial resolution data for civilian satellites and is an improvement of spatial resolution from the World View 2 (WV-2) satellite (Table 1) with imagery at a spatial resolution of 0.31m for the panchromatic band and 1.24m for the eight multispectral bands (Satellite imaging corp., 2015). Per the Satellite imaging corp. (2016), Digital Globe is awaiting approval from the US Department of Commerce to sell WV-3 imagery at the highest resolution it can collect, 0.25m panchromatic and 1.0m multispectral.

Table 1. Nominal Resolutions of Select Very High Resolution Satellite Sensors

Satellite Sensor	Spatial Resolution (for Nadir Viewing)		Spectral Resolution (Number of spectral bands)	Temporal Resolution (Revisit Time in days)
	Panchromatic m)	Multispectral (m)		
IKONOS	0.82	3.2	5	3
Quickbird	0.65	2.62	5	1-3.5
WorldView-2	0.46	1.84	9	1.1
WorldView-3	0.31	1.24	9	1

1.1.5 Past work

Multiple challenges exist for researchers seeking to map tree crown and canopy cover or tree density, including understanding gap dynamics, and/or discriminating and classifying species (Bunting and Lucas, 2006). Canopy reflectance can be influenced by shadowing between crowns, contributions from non-photosynthetic material (e.g., primary branches) in the crown and the underlying soils and vegetation, and variations within and between species and growth stages as a function of foliar biochemistry, moisture content, internal structure and age of leaves (Bunting and Lucas, 2006).

Currently, little work has been published on the utility of WV-3 for vegetation classification. The high resolution multispectral sensors of IKONOS, Quickbird and WorldView-2 (WV-2) have shown potential for species mapping in urban areas, plantations, and temperate forests (Cho *et al.,* 2015; Rapinel *et al.,* 2014). However, little work has been done mapping forests to the species level in tropical forests (Cho *et al.*, 2015). In Hawai'i Jacobi and Ambagis

(2013) used IKONOS and QuickBird imagery to map vegetation communities in the Hanalei watershed on Kaua‘i and in the Kawela watershed on Moloka‘i. The higher spatial resolution offered by WV-3 may allow for greater accuracy in land cover classification and finer species level mapping.

Traditionally, manned airborne systems such as airplanes, helicopters and balloons have been used to obtain VHR sub-meter spatial resolution imagery (Bourgeois and Meganck, 2005; Eisenbeiss and Sauerbier, 2011). Bunting *et al.,* (2010) used VHR manned-aerial imagery to conduct supervised classification of tree crowns in Queensland, Australia. Recent advancements in camera sensors and aerial platforms have led to new possibilities for acquiring aerial images with unmanned systems (Eisenbeiss and Sauerbier, 2011; Devaney pers. com., 2016). Unmanned aerial system (UAS) photogrammetry, although initially developed for military applications, is increasingly being applied for remote sensing of natural resources (Laliberte *et al.,* 2011, Eisenbeiss and Sauerbier, 2011; Keane and Carr, 2013). Among the available data products are ortho-imagery and 3-D imagery. UAS can fly completely autonomously, guided by GPS, along predetermined flight paths, allowing for precise data acquisition (Devaney pers. com., 2016). A major advantage of a UAS platform is the capability to inexpensively deploy the UAS repeatedly to obtain high temporal resolution data at high spatial resolution without risk to human life (Laliberte *et al.*, 2011).

Another VHR system that holds much potential for monitoring is the ground based Gigapan system. The Gigapan robotic unit allows a user to capture very high resolution digital images (<1cm) with billions of pixels (gigapan.com; Sargent *et al.,* 2010; Stock *et al.* 2010). The Gigapan robotic unit pans through a predetermined scene firing a mounted camera at regular intervals with 60% overlap. The Gigapan software is used in postprocessing to stitch the images together into a single very high resolution, often gigapixel file. The Gigapan company also hosts a website that allows users to upload, store and explore Gigapan images from around the world. The technology utilized by the Gigapan robotic unit was developed by Carnegie Mellon for the Mars Rovers, Spirit and Opportunity, to capture panoramic images of the red planet (gigapan.com, 2014). Gigapan is gaining use by researchers across many other fields of science to capture site information from geology to ecology, and to complement fieldwork (Sargent *et al.*, 2010). However, little work has been done to assess the utility of the Gigapan system for vegetation mapping and monitoring.

1.1.6 Object Based Image Analysis

With the advent of these high-resolution imaging technologies, a shift has also occurred in the approach to image analysis. A pixel based image analysis has been the accepted methodology since the launch of Landsat-1 in 1972 (Blaschke *et al.*, 2014). However, Blaschke *et al.* (2014) point out that once the spatial resolution is finer than the object of interest, it is advantageous to focus on the patterns that are created by the pixels. Research in the 2000s started developing object based image analysis (OBIA) focusing on the color, tone, texture, patterns, shape, shadow and context of groups of pixel objects. Development of these techniques represents a new paradigm in image analysis (Blaschke *et al.*, 2014).

Many different software packages incorporate OBIA. Definiens and Trimble have developed widely used software known as eCognition®. Bunting and Lucas (2006), described a study that focuses on using eCognition® to delimit tree crowns in the mixed forests of Queensland, Australia. Bunting *et al.* (2010) demonstrated a technique that mimics aerial photo interpretation, but eliminates some of the drawbacks of aerial photo interpretation that can be subjective and influenced by the skill of the observer by combining visual with supervised classification. In Hawai'i Jacobi and Ambagis, (2013) mapped vegetation communities in the Hanalei watershed on Kaua'i and the Kawela and Kamalo watersheds on the island of Moloka'i, Hawai'i, using OBIA with eCognition®. Their classification results were validated with high resolution aerial Pictometry® Online imagery.

The OBIA process with eCognition uses a hierarchy of image objects to group and classify pixel groups based on both spectral and shape data characteristics (Hay *et al*., 1996; Jacobi and Ambagis, 2013). Classification with eCognition begins with a segmentation process that separates an image into image objects based on spectral values. A supervised iterative process is then used to classify the image objects starting with broad classes of vegetation vs. non-vegetation, utilizing the normalized difference vegetation index (NDVI). Thresholding levels are used to create the guidelines for classification into finer classes of vegetation (Ambagis pers. com., 2015). Training samples may also be incorporated to guide the supervised classification process with a nearest neighbor classifier (Jacobi and Ambagis, 2013; Ambagis pers. com., 2015). A classified image may then be exported as a shapefile allowing for use with other mapping software such as ArcGIS for a final accuracy assessment.

1.2 Objectives

The primary objective of this thesis is to evaluate the utility of several new very high spatial resolution remote sensing technologies for vegetation mapping and monitoring in a Hawaiian forest. Specific objectives are to:

1. Develop an effective synthesis of the outputs from a VHR satellite platform, UAS and Gigapan using an OBIA procedural workflow to implement remote sensing-based mapping to the species level.
2. Make recommendations for the integration of remote sensing methods into vegetation monitoring.

3. Determine the costs associated with the implementation of remote sensing-based monitoring protocols as compared to traditional monitoring methods, including recommendations on how to scale back to facilitate cost saving.

Chapter 2 VHR Imagery Synthesis with WV-3, UAS and Gigapan

2.1 Introduction

2.1.1 Objectives

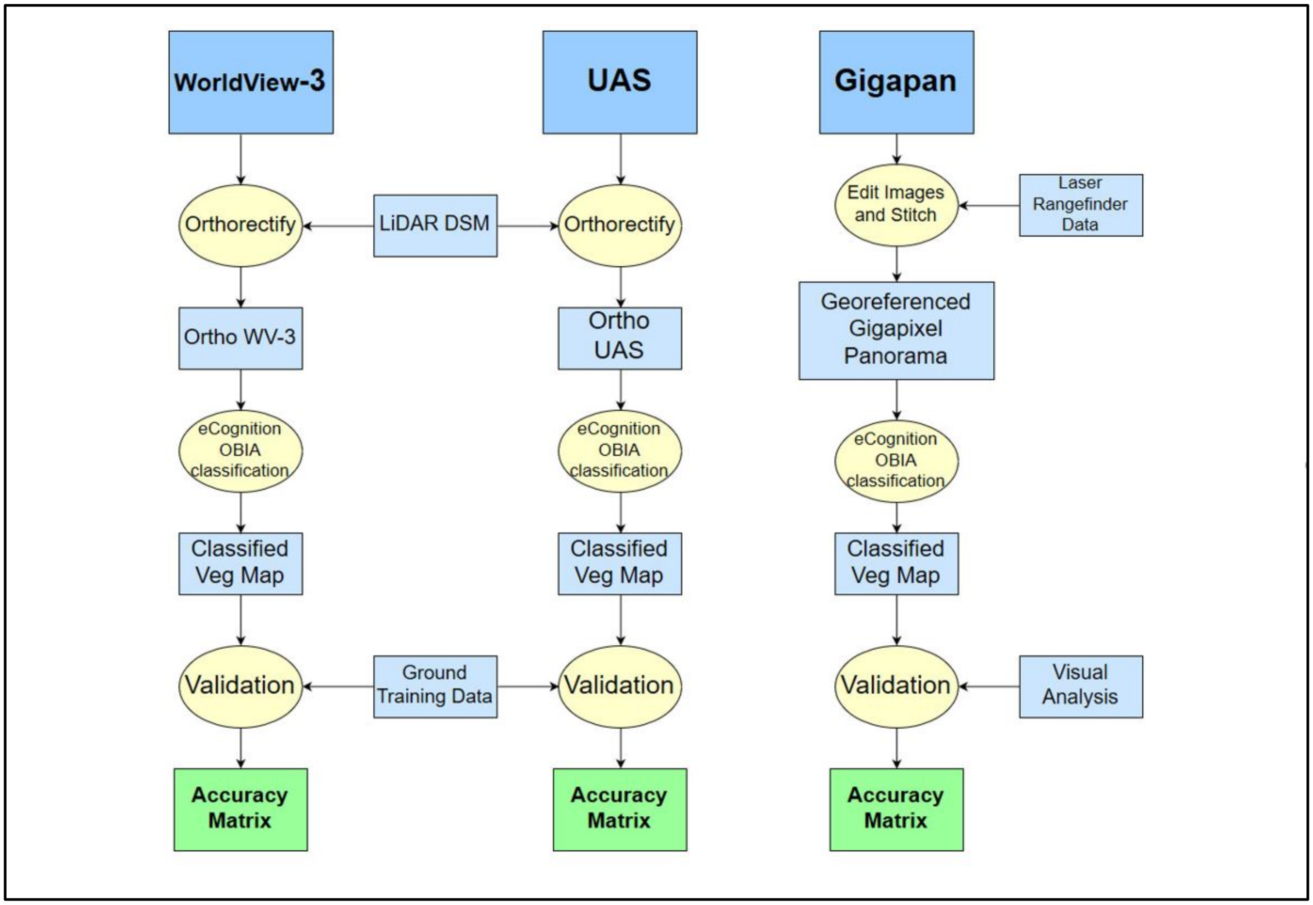
New technology is changing the face of vegetation mapping and its efficacy in the form of remote sensing and GIS. Analysis of VHR imagery can provide accurate and timely assessments of vegetation on a large scale at a set point in time (Bunting and Lucas, 2006). Accurate and timely classification of remote sensing imagery is vital to planning resource management efforts, tracking progress, and driving management decisions for restoration and resource management. Little work has been conducted in Hawaiian forests with supervised classification of remotely sensed imagery to the species level.

This chapter investigates the utility of VHR image data from WV-3, UAS, and Gigapan platforms for species-level classification. The objectives were to:

Objective 1. Develop an effective synthesis of the outputs from a VHR satellite platform, UAS and Gigapan using an OBIA procedural workflow to implement remote sensing-based mapping to the species level.

Objective 2. Make recommendations for the integration of remote sensing methods into vegetation monitoring.

The initial project objective was to evaluate each of the three VHR platforms independently with supervised classification via OBIA and eCognition® (Figure 1). Early testing was conducted to determine the effectiveness of classifying Gigapan imagery and VHR ortho-aerial Pictometry® imagery with supervised OBIA classification. Gigapan and ortho-aerial imagery did not serve to pair well with OBIA due to shadowing, differences in lighting during image capture and the limiting number of only three spectral bands. However, past work with



OBIA and multispectral VHR satellite imagery has shown potential for accurately classifying to the species level (Jacobi and Ambagis, 2013).

Figure 1. Initial proposed approach for achieving species level classification and an evaluation of each of the three VHR platforms.

High resolution UAS imagery with a spatial resolution of 1-2 cm may allow for visual identification of attributes needed for species identification of imagery of the target area. Preliminary visual analysis of ortho-aerial Pictometry® and Gigapan imagery has demonstrated potential for reliable visual classification of vegetation species. This initial work led to the project shift towards developing a synthesis of the three VHR platforms, in which the strengths of each platform are utilized to produce a validated, classified vegetation map, with WV-3 as the base layer, rather than an independent evaluation of each platform separately (Figure 2).

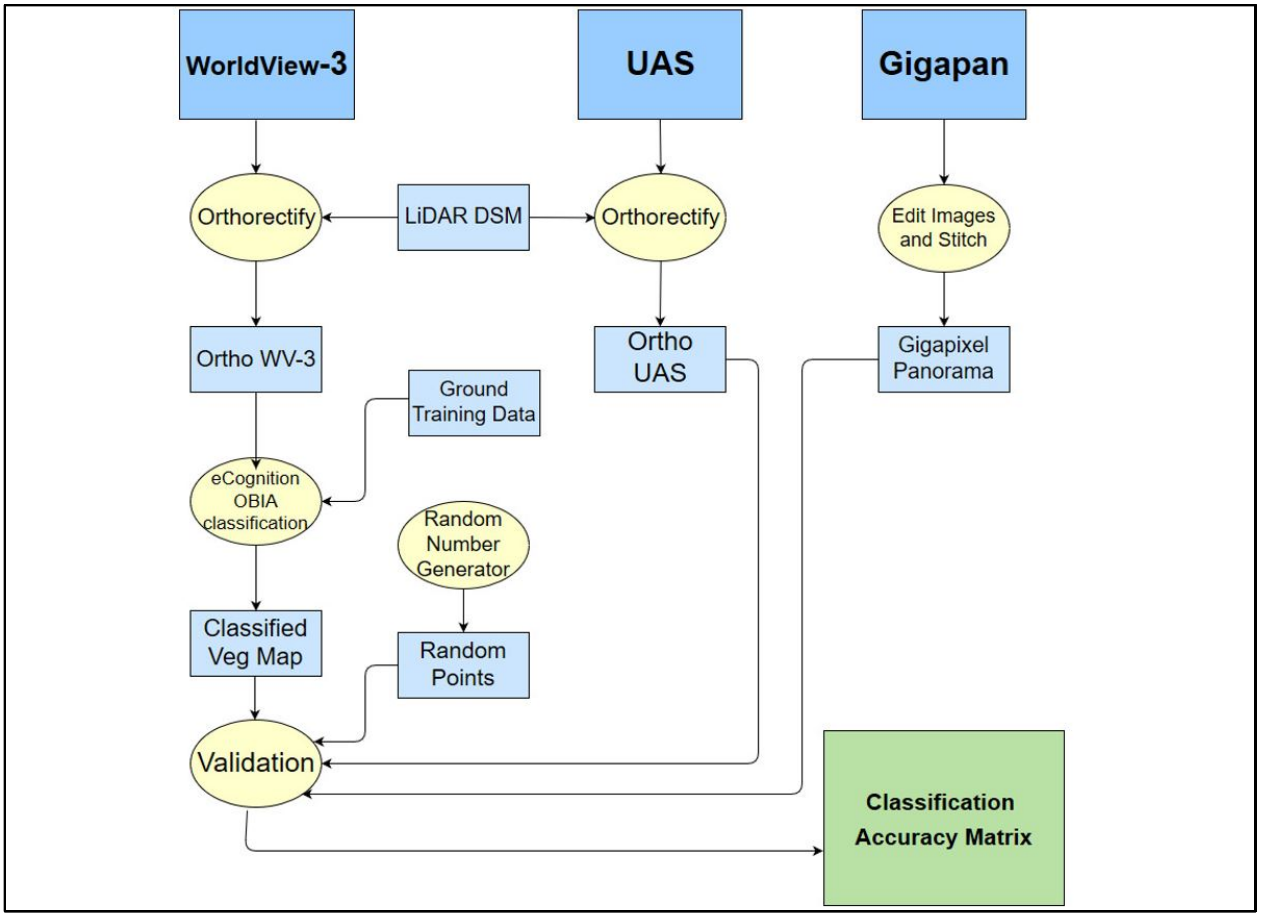


Figure 2. Final approach utilizing a synthesis of the three VHR platforms to produce a validated, classified vegetation map with WV-3 as the base layer.

The following native and non-native canopy species may represent the predominant classes of vegetation that can potentially be separated via OBIA of WV-3 with respect to vegetation canopy size greater than WV-3 spatial resolution (Table 2). Vegetation monitoring by the OANRP in 2015 found these species to have high frequencies in the canopy within the study area described in the next section (i.e., Kahanahaiki Management Unit) (OANRP, 2015). In addition, the canopy diameters are greater than the 1.24 m spatial resolution of WorldView-3. The canopy crowns will be represented by multiple pixels on the satellite image, potentially allowing for classification. Certain species may not be discernable from others due to spectral and textural similarities. Strawberry guava and Christmas berry are the predominant invasive species in the target area. They also represent the most frequent targets during invasive species control actions in Kahanahaiki by the OANRP. The OANRP database shows that the initial installation of the belt plot monitoring took 294 hours. A remote monitoring procedure may involve less of an investment in time, however this must be weighed with the cost of image acquisition and analysis.

Table 2. Proposed vegetation classes with potential for separation with OBIA of WV-3.

Native tree	Non-Native tree	Others
Acacia koa (Koa)	*Aleurites moluccana* (Kukui)	Native ferns
Metrosideros polymorpha (Ohia)	*Psidium cattleianum* (Strawberry guava)	Non-native grasses
Diospyros sandwicensis (Lama)	*Schinus terebinthifolius* (Christmas berry)	Barren (bare ground)

2.1.2 Study Site

A key ecosystem within the islands is the Hawaiian mixed mesic forest, an area found in coastal, lowland, and montane areas that receive 1200 mm - 2500 mm rainfall annually (Wagner *et al.*, 1998). Mesic forests support a variety of common native and rare endemic species, significantly supplement groundwater recharge, and buffer wet forested areas from degradation by land use change, ungulate damage, and fires (Sailer, 2003; Juvik and Juvik, 1998; Mair and Fares, 2009). On Oahu, a representative example of a Hawaiian mixed-mesic forest is the valley of Kahanahaiki.

The Kahanahaiki Management Unit (MU), hereafter also referred to as Kahanahaiki, is located within Kahanahaiki valley on the leeward side of the northern Waianae Mountain Range on the island of Oahu. Kahanahaiki is in the Makua Military Reservation on the northeastern border of Makua Valley, at approximate UTM Coordinates: 04Q 583496 2382342 (Figure 3). With a total land area of 36 ha, ranging in elevation from 425 m to 707 m, Kahanahaiki has served as a model research and management site for a wide variety of past and present studies. It is representative of the many native resources and challenges faced for management in the Waianae Mountain Range of Oahu and was chosen as the primary project site.

The mixed-mesic forest of Kahanahaiki is made up of native and non-native flora and fauna. According to the OANRP year-end report (2015), native trees with the highest frequencies (in >10% of plots) were: *Psydrax odorata* (alahe'e), *Acacia koa* (koa), *Metrosideros polymorpha* (ohia), *Coprosma foliosa* (pilo), *Diospyros sandwicensis* (lama), and *Psychotria mariniana* (kopiko). Non-native trees with the highest frequencies (in >10% of plots) were *Psidium cattleianum* (Strawberry guava), *Aleurites moluccana* (kukui), and *Schinus teribenthifolius* (Christmas berry).

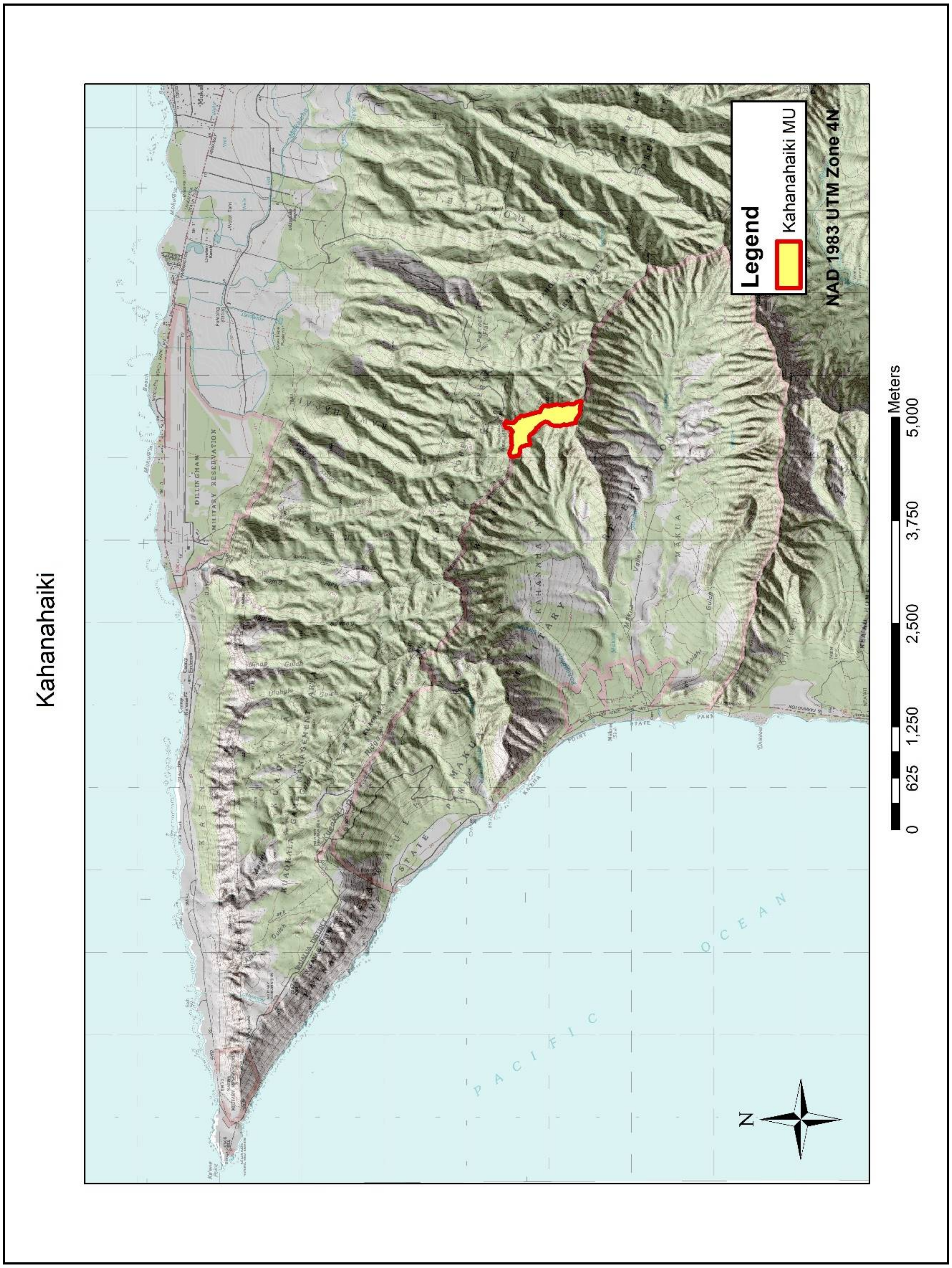


Figure 3. Map of study site location in Kahanahaiki within the Northern Waianae Mountain Range of Oahu, Hawaii.

2.1.3 Management History

The Oahu Army Natural Resources Program (OANRP) fenced the Kahanahaiki MU in 1996 to provide protection to 12 managed endangered taxa (OANRP 2009). Feral pigs were eradicated from Kahanahaiki and weed control was initiated targeting non-native vegetation with known ecosystem level impacts. The OANRP has spent thousands of hours working to restore the mesic forest in Kahanahaiki through a mix of threat management including: small mammal control, invertebrate control, and weed control. Yearly efforts are made to reintroduce common native and endangered plants throughout the MU. Active restoration efforts are underway with ecosystem level weed control conducted annually across the MU.

Vegetation monitoring was initiated with the installation of belt transect plots in 2009 to gather measurable data on how the vegetation composition is changing in Kahanahaiki over time. Objectives were to assess how coverage of native vs. non-native vegetation in the understory and canopy may be changing with response to active management of the Kahanahaiki MU. Transects were established at 100m intervals east to west in the moderate grade southern portion and south to north in the steeper gulch region. Five meter by 10m plots were installed along the transect every 50m (Figure 4). Full vegetation assemblage was recorded and the percent cover of understory and overstory species were estimated within the plots with ranges of 0-1%, 1-5%, 6-10%, 11-20%, 21-30% and so on to 91-100%. The transects were reanalyzed at three year intervals in 2012, and 2015. Ground vegetation monitoring has proven to be time intensive and may be subject to observer bias and inconsistency among observers, notably with canopy cover estimates. In addition, foot traffic may unintentionally impact sensitive areas with repeat visits and terrain in other areas makes ground work unfeasible, necessitating a change in the orientation of the transect.

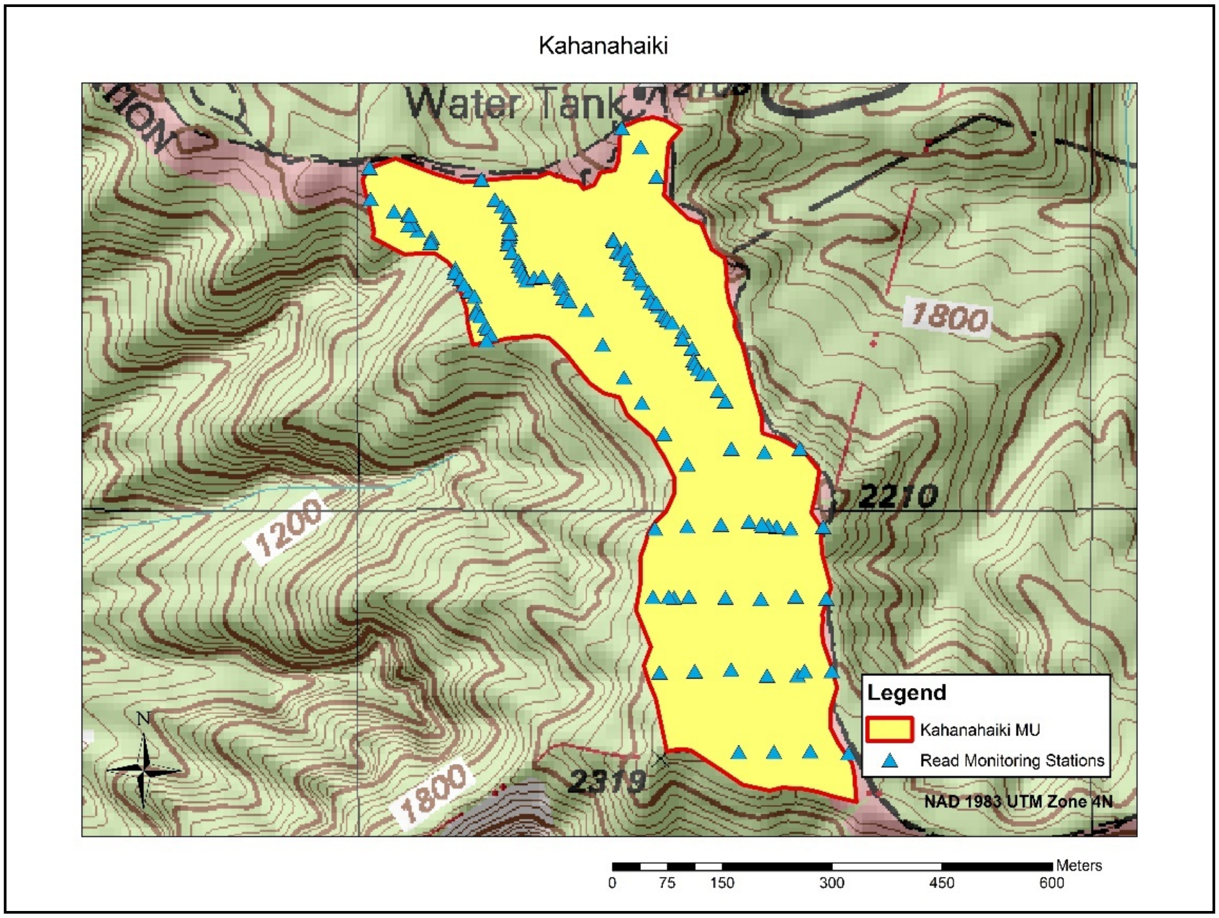


Figure 4. Kahahahaiki MU and ground vegetation monitoring plots installed in 2009 by OANRP.

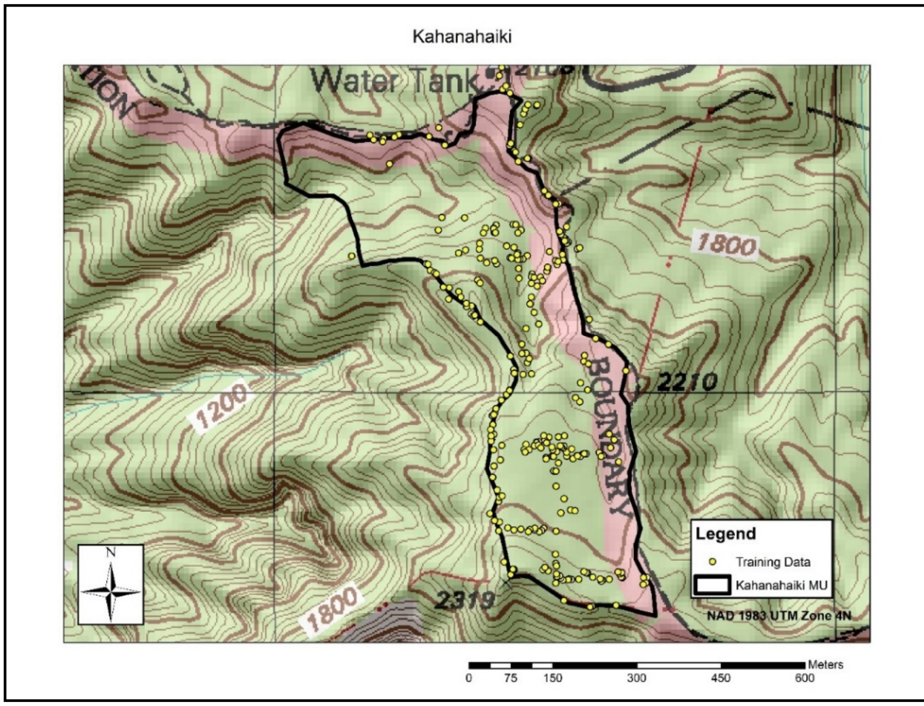
2.2. Materials and Methods

2.2.1 Field Data Collection

A Trimble Geo7XH GPS unit was rented from Pacific GPS for ground control point (GCP) and training data collection. The Geo7XH has the capacity to capture GPS ground locations with a positional accuracy of 50cm. GCPs were installed along the boundary of Kahanahaiki along the ridges and in the interior at open spaces with markers and spraypaint on the ground (Figure 5). These visual markers were installed to assist the orthorectification process of the high resolution aerial imagery. Locations of characteristic vegetation were identified throughout Kahanahaiki in a stratified non-random sampling strategy (Figure 6). These locations, to be used later for the collection of training data, were found on the gulch, flat upper plateau, and bordering ridgelines (Figure 7).

Figure 5. Orthorectification ground marker data collection.

Figure 6. Kapua Kawelo gathering training data locations of characteristic vegetation.



1	Bidtort	2
2	Diosan	9
3	Dodvisc	1
4	Diclin	2
5	Micstr	1
6	Nepexa	2
7	Phichi	1
8	Cibcha	1
9	Grerob	13
10	Acakoa	20
11	Melmin	34
12	Metpol	15
13	Nessan	1
14	Panmax	1
15	Pipalb	1
16	Pissan	1
17	Psicat	42
18	Psicatluc	7
19	Psyodo	9
20	Sanfre	2
21	Schter	33

Figure 7. Kahanahaiki MU with field collected training data of characteristic vegetation.

2.2.2 Gigapan

Scouting was undertaken along the rim of Kahanahaiki to find effective vantage points for Gigapan gigapixel mosaic imagery. Four locations were identified and imagery was taken between 11:00 a.m. and 1:00 p.m. Hawaii Standard Time to minimize variations in shadowing due to the change of the sun’s position. The northern portion of Kahanahaiki is composed of a moderate drainage and imagery was taken on both sides of this gulch (Figures 8-10). Equipment included: Canon EOS 60D, Canon 100-400mm F4-5.6L lens, tripod and Gigapan Epic Pro. Different settings were used to find an optimal compromise of manual focus vs. autofocus, aperture and shutterspeed, and manual mode vs. Aperture priority. The most effective panorama was taken with the following settings: full zoom to 400mm, AV priority mode, f8, ISO 400, and image stabilizer off. The camera needed tending as it would not focus on a background of sky or ocean, necessitating a manual switch over to manual focus during these scenes and back to autofocus with a forest background (Figure 8|). GPS offsets for use with the Gigapan were

explored with the integration of a Truepulse® 360R laser rangefinder connected by bluetooth to the Trimble® GPS (Figure 9).

Figure 8. Gigapan data collection at Kahanahaiki facing southwest into the main gulch.

Figure 9. GPS offset exploration with laser rangefinder and Trimble GPS.

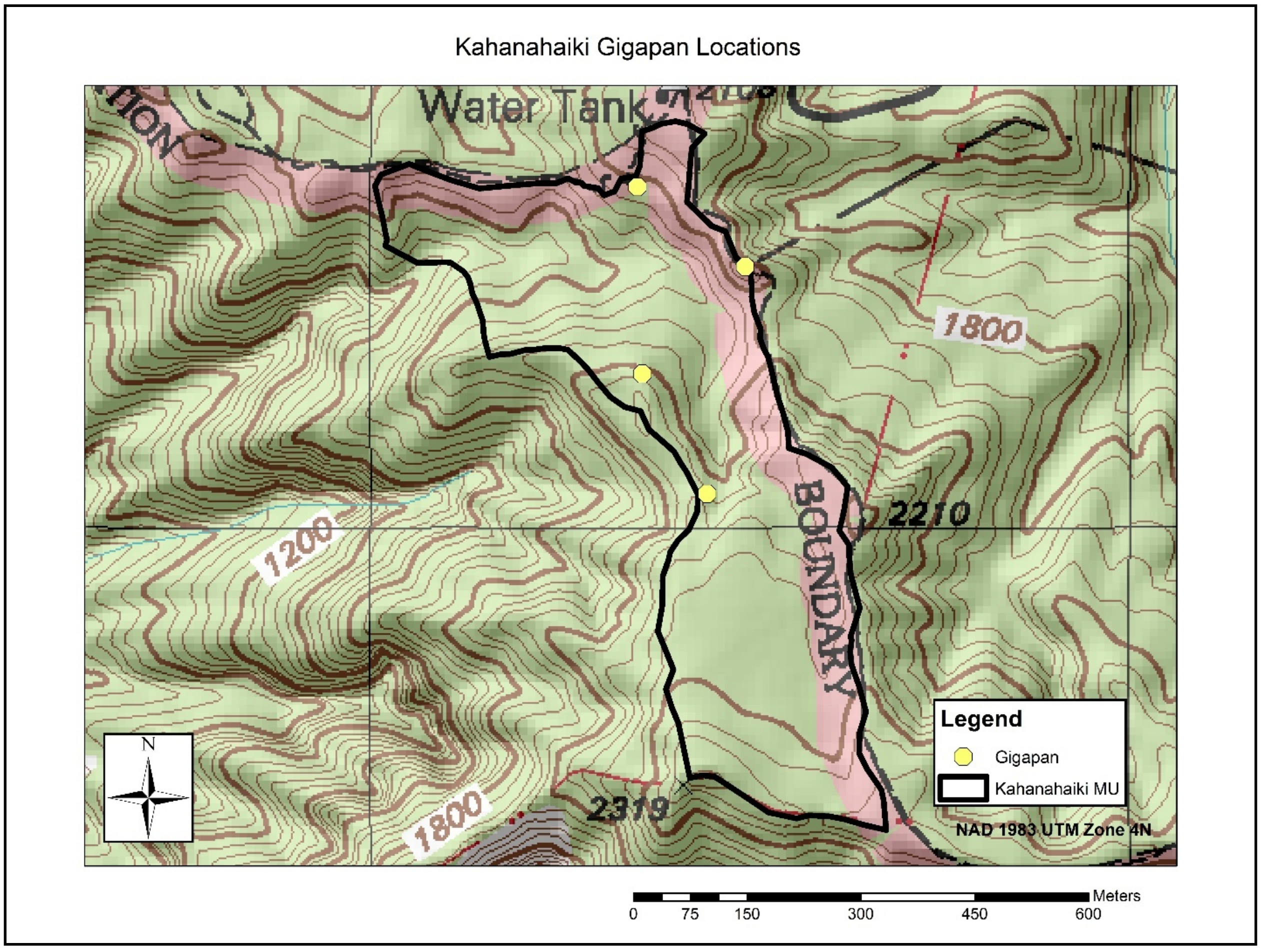


Figure 10. Gigapan image acquisition locations in Kahanahaiki.

2.2.3 High Resolution Aerial

Resource Mapping Hawaii was contracted in the spring of 2015 to collect high resolution orthorectified imagery of Kahanahaiki and Makaha. Four flights were made with a Cessna 206 in an attempt to image the target areas. Flights were made after 10 a.m. to capture imagery when the sun was overhead and casting the least amount of shadowing. Incidentally there were significant low level clouds during the flights and several missions were deemed to be unsafe to the pilot and crew. Partial imagery of upper Makaha was obtained (Figure 11).

Figure 11. Makaha subunit II image sample from a Resource Mapping flight. The Kumaipo LZ and MU fence is discernable with dark green Strawberry guava and light green koa canopy.

After four failed flights, focus switched to an Unmanned Aerial System (UAS) in order to safely collect data flying below the cloud ceiling. UH Manoa Geography graduate, Charles Devaney was brought on for the UAS phase. A test flight was conducted with a DJI Phantom and GoPro Hero 3 camera. Resulting imagery showed potential. The flight mission was preplanned in Mission Planner® by Mr. Devaney to image Kahanahaiki and a flight was coordinated with favorable weather conditions. A Y-6 rotary UAS was prepped and flown by Mr. Devaney. It flew 3 out of 5 preplanned flight segments on Pixhawk® autopilot after the initial launch (Figures 12 and 13). The Y-6 mission was aborted due to significant compass errors and potential firmware issues complicated by possible interference from nearby communication towers.

Figure 12. Y-6 rotary UAS being prepped for launch.

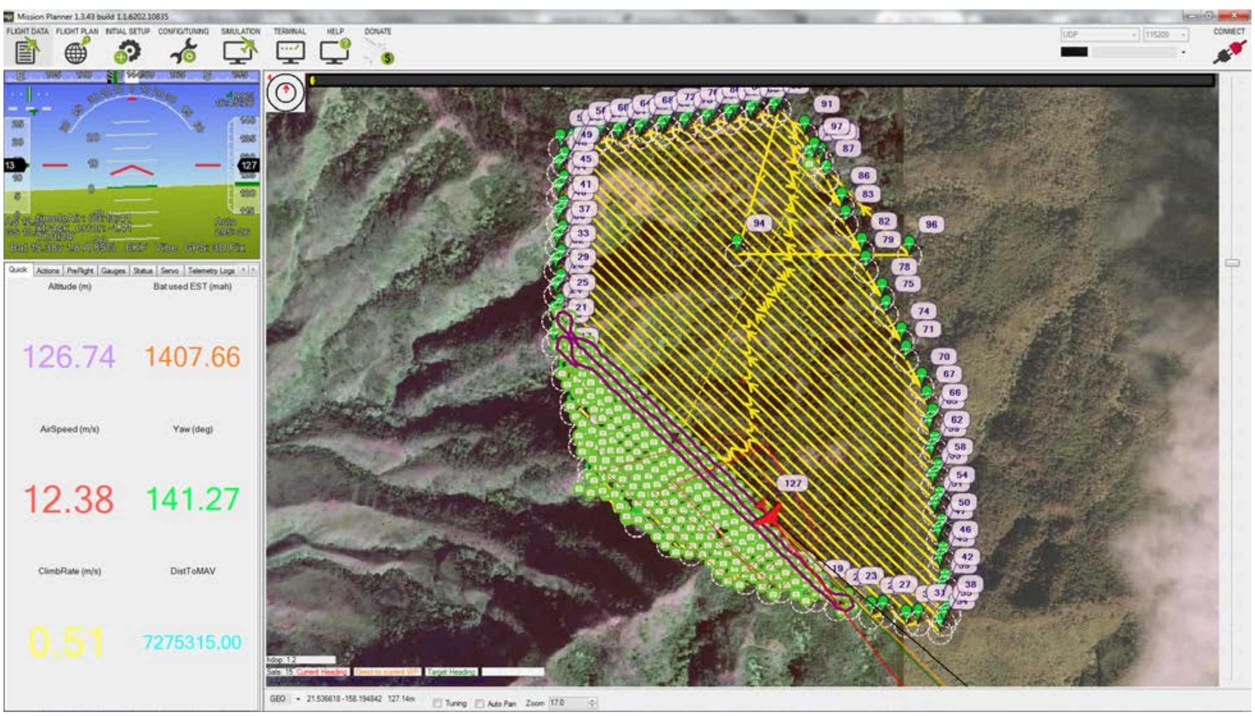


Figure 13. Flight mission planned in Mission Planner®.

A fixed wing, Skywalker 1900 UAS was identified as potentially more suitable for the mission (Figure 14). A launch and land location was identified and troubleshooting and equipment testing were conducted. It was flown under conditions that started optimally with light winds and a high cloud ceiling. Weather moved into Kahanahaiki from the south with a low cloud ceiling. An entire MU dataset was collected and the fixed wing performed well on Pixhawk® autopilot staying true to the planned flight. Line of site was achieved throughout the mission, however approximately 25% of the image dataset of Kahanahaiki was partially

obstructed by low clouds.

Figure 14. Skywalker 1900 fixed wing UAS pre-launch for test flight by Charles Devaney.

2.2.4 VHR Satellite Imagery Collection

Apollo mapping was contracted to deliver cloud free, 8-band multispectral, 1.24m spatial resolution WV-3 satellite imagery of 185km^2 of the Waianae mountain range. A cloud free portion of the dataset for the northwestern Waianae mountain range including the target MU Kahanahaiki was collected in May, 2015.

2.2.5 Data Processing

Gigapan

Image post-processing was conducted with a Dell XPS ONE_2710, with processor: Intel ® Core ™ i5-3450S CPU @2.80 GHz, Installed memory (RAM): 6.0GB, and System type: 64-bit operating system. Images were processed in Adobe Light Room® 5.0. A 10% level increase was applied to contrast, vibrance, clarity, saturation, sharpening and noise reduction of each image. The gigapixel panorama of the study site was merged using GigaPan Stitch® 2.3.0307.

UAS

Two image deliverables were obtained from the Skywalker 1900, a 3-D image mosaic of and orthorectified tiles of the cloud free southern portion of the MU. Agisoft Photscan ® was used to mosaic the images and orthorectify both mosaics collected by the two platforms. Ground control points were used to orthorectify the image mosaics. Both image sets were merged in Agisoft Photscan® to create a final image mosaic of Kahanahiki. Spatial resolution (horizontal cell resolution) was determined to be approximately 2cm.

WV-3

Apollo mapping delivered a georeferenced WV-3 dataset with approximately 100m positional horizontal error. Figure 15 shows this error with the Kahanahaiki fence overlain on the

WV-3 image. WV-3 Imagery for Kahanahaiki was orthorectified with a LiDAR Digital Surface Model (DSM) with the help of Dr. Qi Chen in the UH Geography department (Figure 15). The LiDAR data was derived from the 2013 coastal dataset collected by NOAA with a 1m horizontal accuracy with vertical positional accuracy of 10.1cm. ENVI® was used with a rigorous orthorectification procedure to orthorectify the WV-3 imagery with the LiDAR Digital Surface Model (DSM).

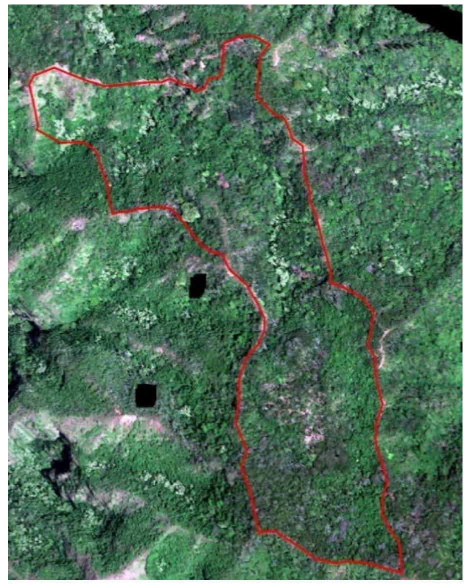


Figure 15. The WV-3 area of interest with Georeference error shown with before and after orthorectification. The red line denotes the MU fence boundary. The reference point on both images shows the location of the southwest corner of the MU fence.

2.2.6 Imagery Classification

The WV-3 satellite image was used as a base image layer classified with eCognition® OBIA and validated with the UAS and Gigapan imagery. Training data collected from the study site were used as representative vegetation samples to develop the eCognition classification algorithm decision ruleset. Image processing was conducted with a Dell™ XPS 8500, Processor: Intel® Core™i7-3770 CPU @ 3.40 GHz, Installed memory (RAM): 16.0GB, System type: 64-bit Operating system. The orthorectified WV-3 imagery was processed in eCognition® Developer 9.1 using an object based approach to classify vegetation classes. The process began with a segmentation algorithm that divides the image up into image objects. The image objects were separated into classes through an iterative process of setting threshold values for the 8 different spectral bands. Training data were obtained from GPS locations of target species to run a nearest neighbor classification algorithm. The classes were: Bare ground, Sparse Vegetation (which included grasses, herbaceous weeds and understory ferns), Kukui (*Aleurites molucanna)*, Psicat (*Psidium cattleianum)*, Schter (*Schinus terebinthifolius)*, Koa (*Acacia koa)*, and Native Complex (which includes a host of native vegetation species). See Figures 16-22 for images taken during the OBIA process. See Appendix B for a complete eCognition® procedural workflow. The Gigapan mosaics were used for cross-referencing ortho-aerial imagery through visual comparison to improve the training dataset and assist with the accuracy assessment.

Gigapan imagery was used in instances where the UAS imagery showed distortion from vegetation movement due to wind, insufficient image overlap and terrain, or blur by cloud cover during the data collection (Appendix C).

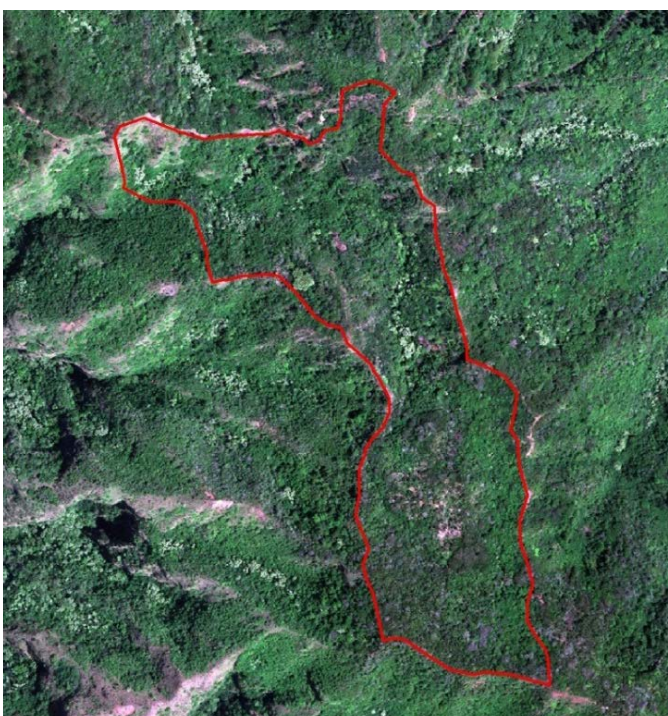


Figure 16. Area of interest for image classification. The red line denotes the MU fence boundary

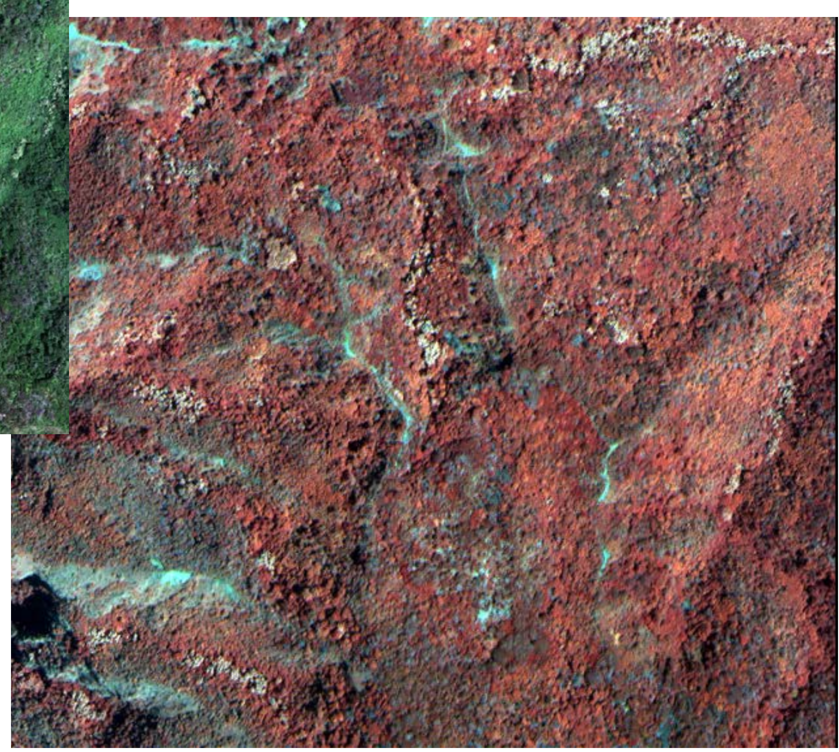


Figure 17. The 6 layer mix false color composite.

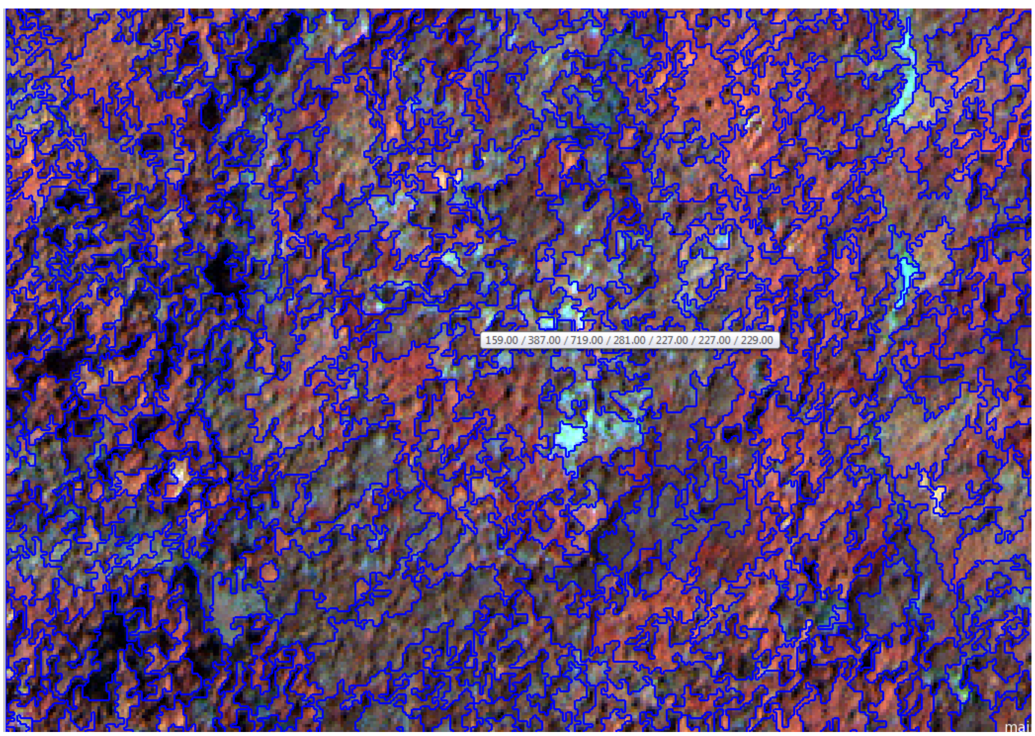


Figure 18. Segmentation algorithm separating tree crowns into image objects by reflectance values.

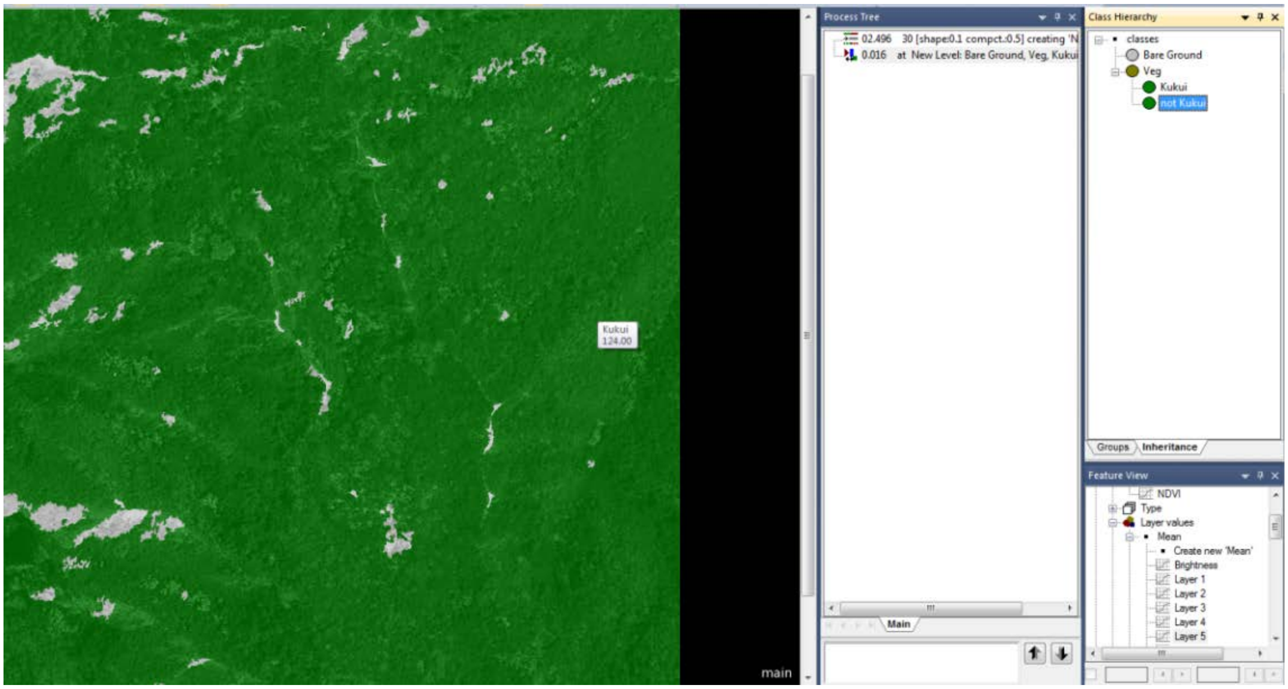
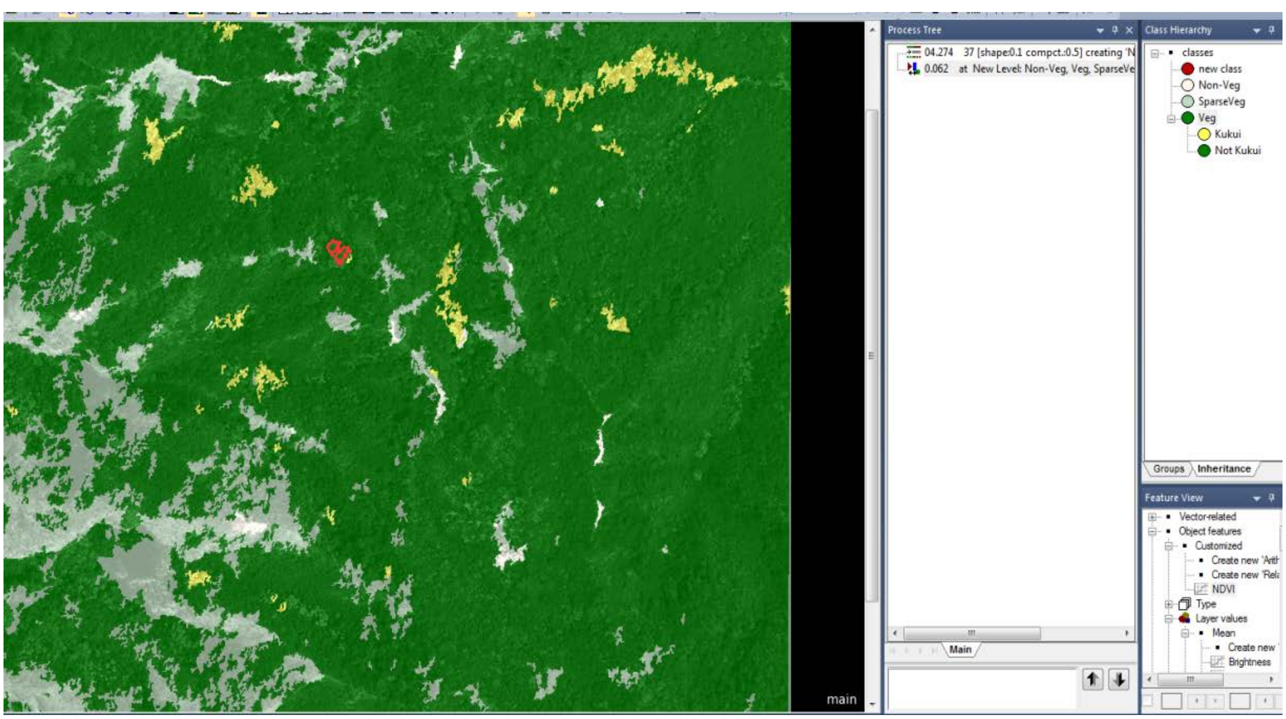


Figure 19. Vegetation vs. non-veg bare ground with vegetation in green and bare ground as



grey.

Figure 20. Kukui classification result in yellow.

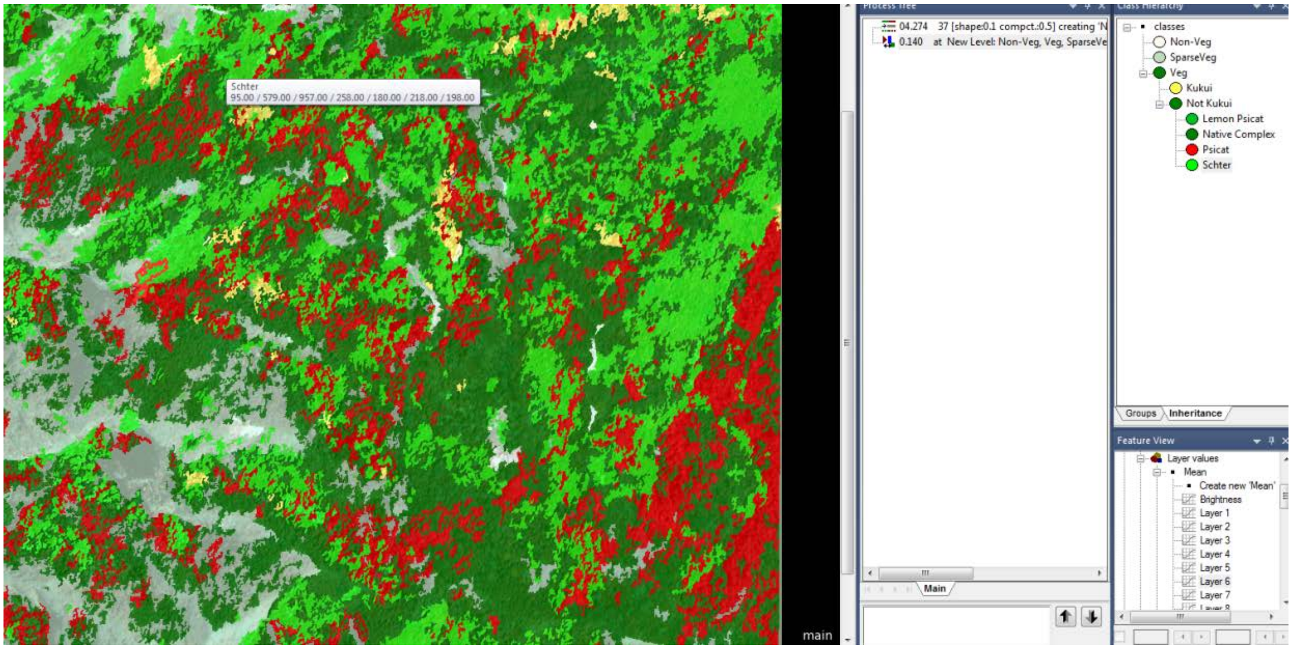


Figure 21. Classification of Bare ground (white), Sparse veg (grey), Kukui (yellow), Strawberry guava (red), Christmas berry (light green), and Native Complex (dark green).

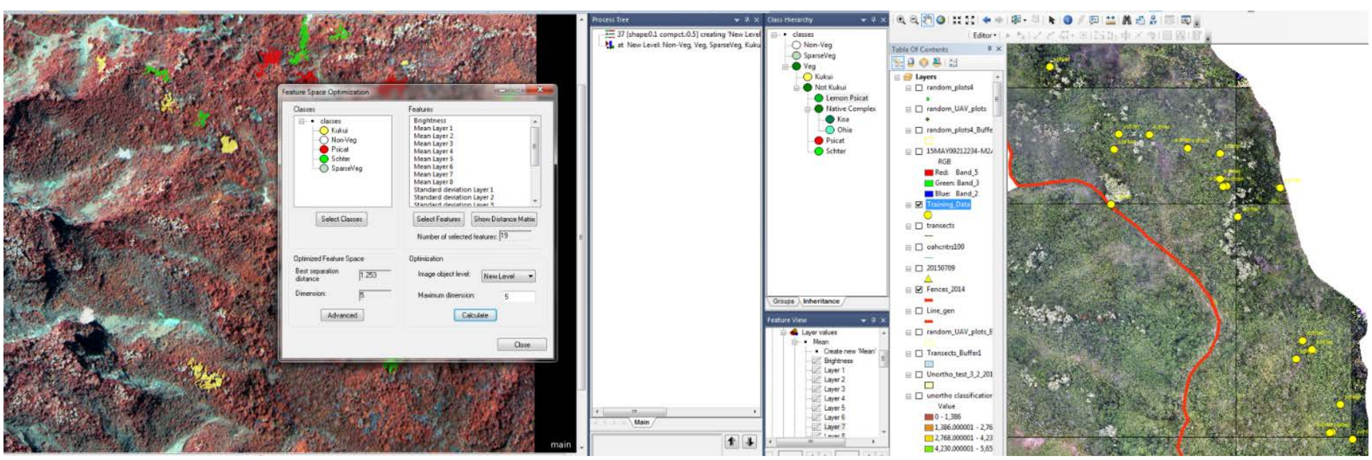


Figure 22. Selecting samples with training data from ground work and running the nearest neighbor algorithm.

2.2.7 Validation

The classified imagery was analyzed using ArcMap® to overlay the various image layers for the study area. A stratified random design was utilized by randomly deploying 50 random points per class or strata in ArcMap® using the Create Random Points tool. In order to achieve an objective validation assessment, the list of points was randomized using a random list generator from www.random.org and the class of each point was determined blindly without referencing the classified map (Figure 23). UAS and Gigapan images were used in a visual assessment of each point to determine the accuracy of the classified vegetation map (Appendix C). The classification of each point was compared to the eCognition® classification results and a confusion matrix was generated to show the "overall accuracy" of the map, or the percentage of correctly classified map units. In addition, a "producer's accuracy" was generated showing how well a classified unit can be mapped, and a "user's accuracy" representing the probability that a pixel classified in the map is actually that unit on the ground (Congalton, 1991; Jacobi and Ambagis, 2013). The Gigapan mosaics were used for cross-referencing ortho-aerial imagery through visual comparison to assist with the accuracy assessment. Gigapan imagery was used in instances where the UAS imagery showed distortion from vegetation movement due to wind, insufficient image overlap and terrain, or blurry cloud cover during the data collection. ArcMap® 10.1 was used to determine the percent cover of each class.

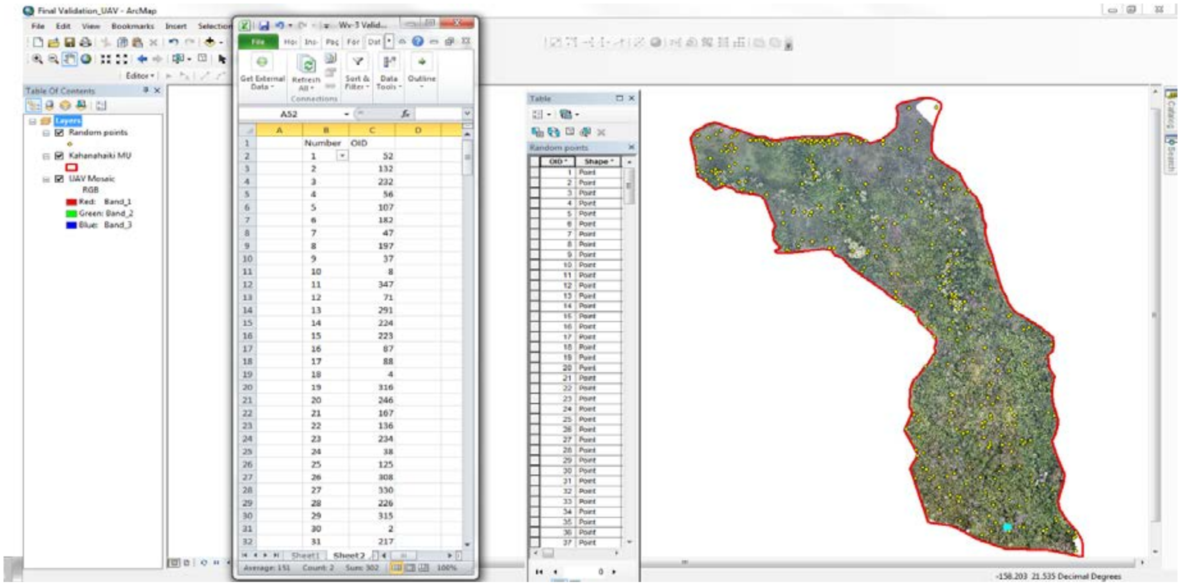


Figure 23. Validation with 50 randomized points per class.

2.3 Results

2.3.1 Comparison of Gigapan, UAS, and WV-3 Images

The WV-3 satellite image covers the greatest area and has consistent exposure and tone. Topography and broad vegetation cover are visually discernable with the 1.24m spatial resolution (Figure 30).

Figure 24. WV-3 satellite image from Apollo Mapping, acquired May 9, 2015.

The UAS imagery extends across the Kahanahaiki MU and shows some inconsistency in lighting and some blurred areas due to clouds. The high spatial resolution of 2cm allows for visual identification of vegetation to the species level (Figure 25).

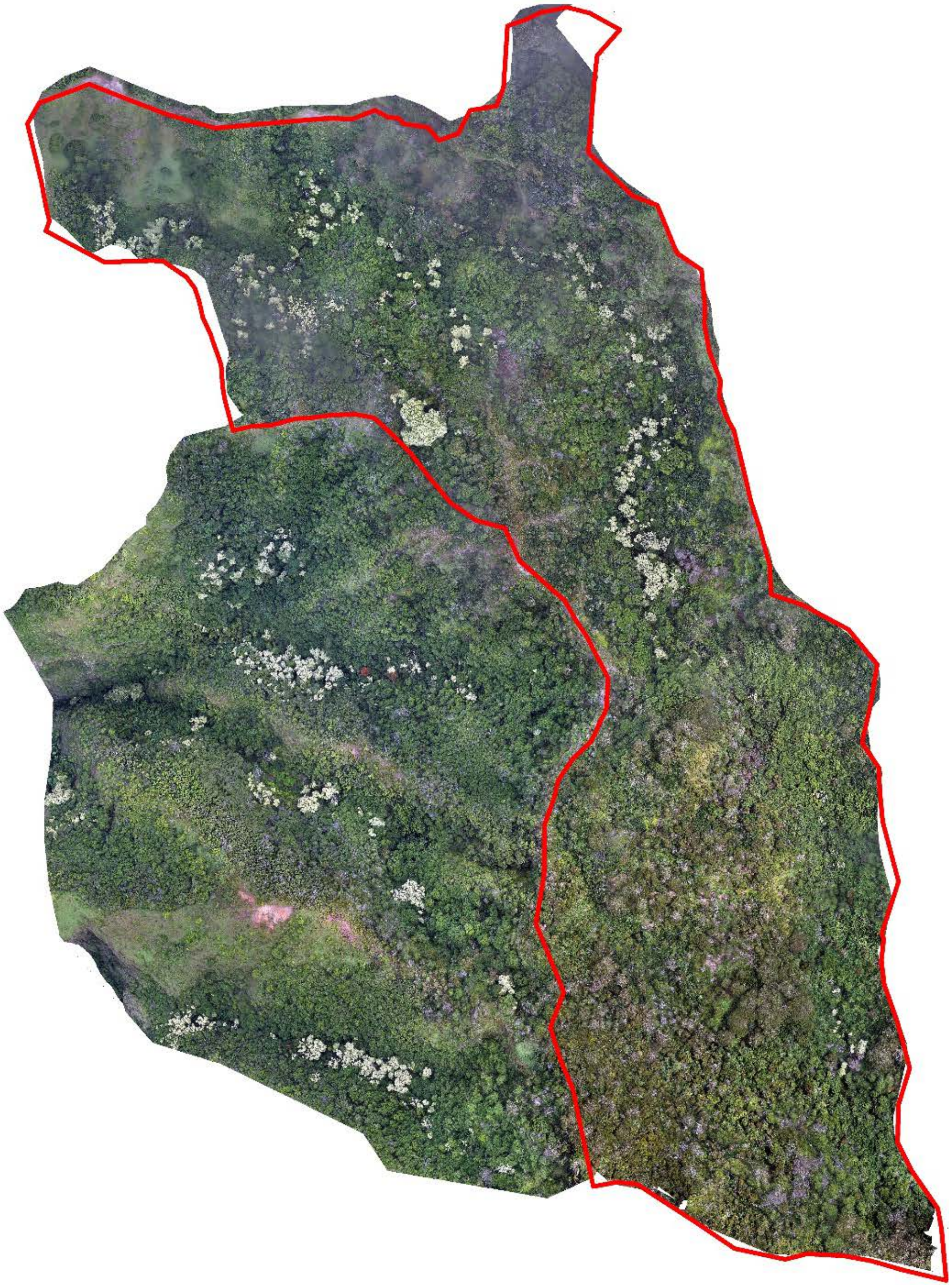


Figure 25. Complete UAS image mosaic with MU fence boundary in red.

The Gigapan imagery extends across parts of the Kahanahaiki MU and shows much inconsistency in exposure due to changes in lighting. The southern portion of the MU was not imaged as terrain is fairly flat and there were no suitable vantage points. The high spatial resolution of 0.5-1cm allows for visual identification of vegetation species and in some instances, vegetation phenology (Figures 26-28).

Figure 26. Gigapan 1- 900 image Gigapan mosaic of the northeast facing main gulch.

Figure 27. Gigapan 2. 660 image Gigapan mosaic of northwestern portion of gulch

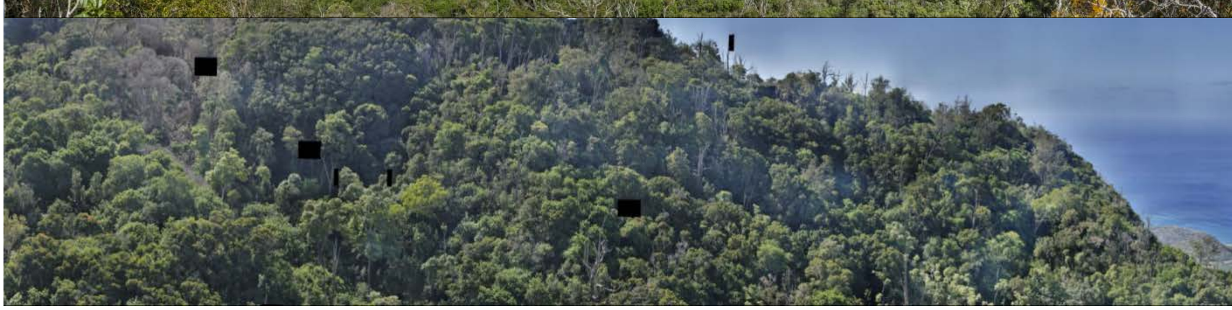


Figure 28. Gigapan 3. 720 image Gigapan mosaic of southwest facing slope of the main gulch.

Figures 29-31 depict approximately the same scene collected by WV-3, UAS and Gigapan. In the WV-3 image (Figure 29) the pixels are prominent but a trained observer can discern different plant species. The light green in the gulch is kukui (*A. moluccana)*, whereas the dark green on the upper slope is strawberry guava (*P. cattleianum*). In Figure 37, the same kukui and strawberry guava prominently stand out, in addition to a host of other plant species. The gigapan image (Figure 31) shows a high oblique perspective. Plant species are easily discernable.

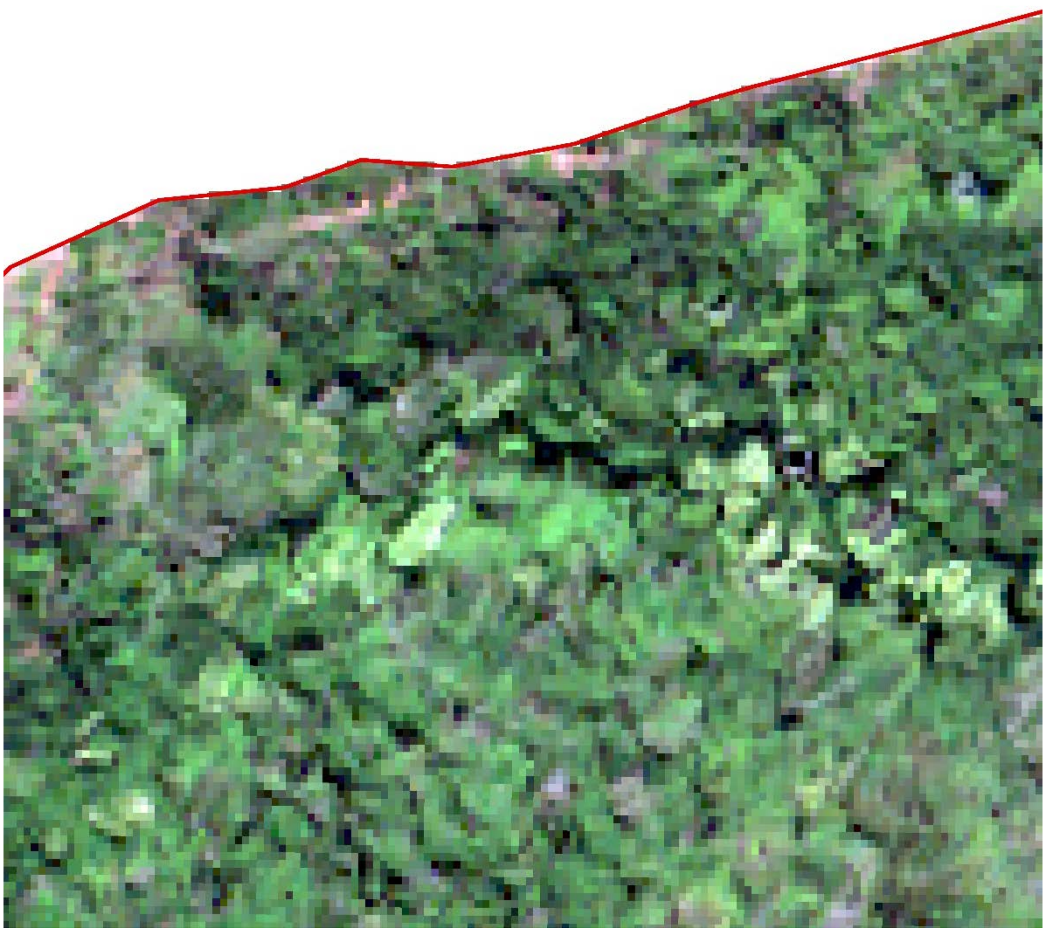


Figure 29. Cropped WV-3 image of a target location for comparison.

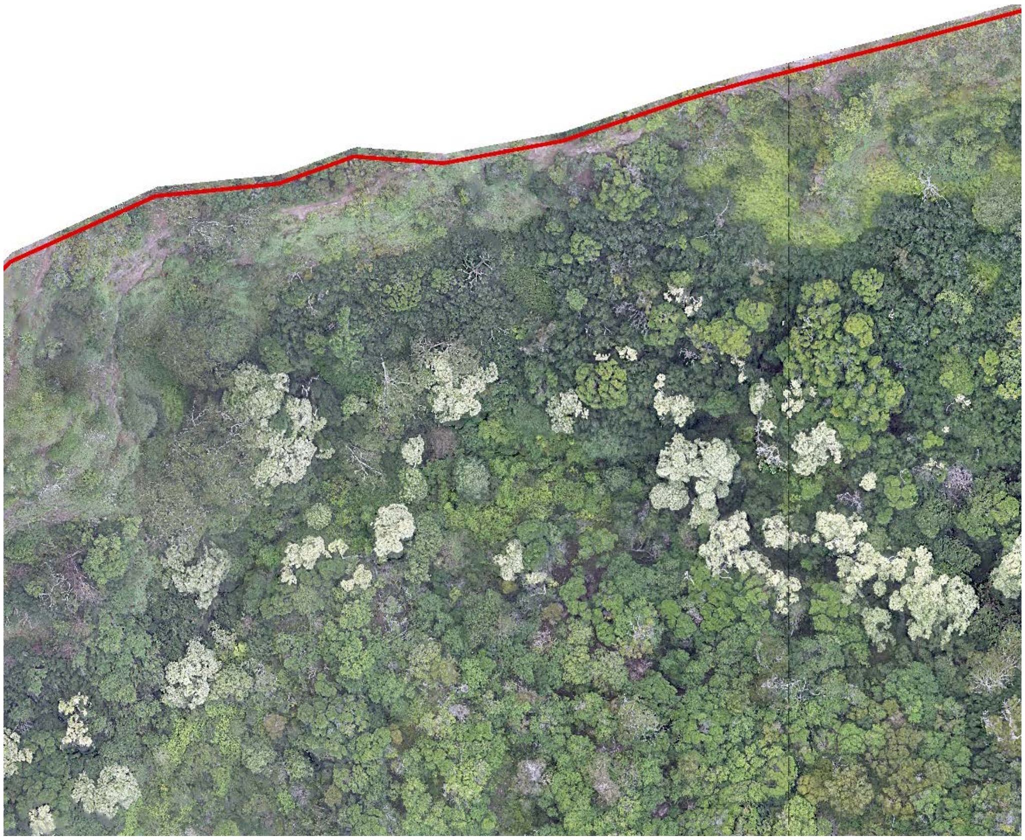


Figure 30. Cropped UAS image of a target location for comparison.

Figure 31. Cropped Gigapan image of a target location for comparison.

Zooming in further on the chosen scene yields the images displayed in Figure 32. The WV-3 image is extremely pixelated and vegetation is undiscernible without comparison to other imagery. The UAS and Gigapan imagery shows a prominent dead tree surrounded by strawberry guava (*P. cattleianum)* with kukui (*A. molucanna)* and koa (*A. koa*) below.

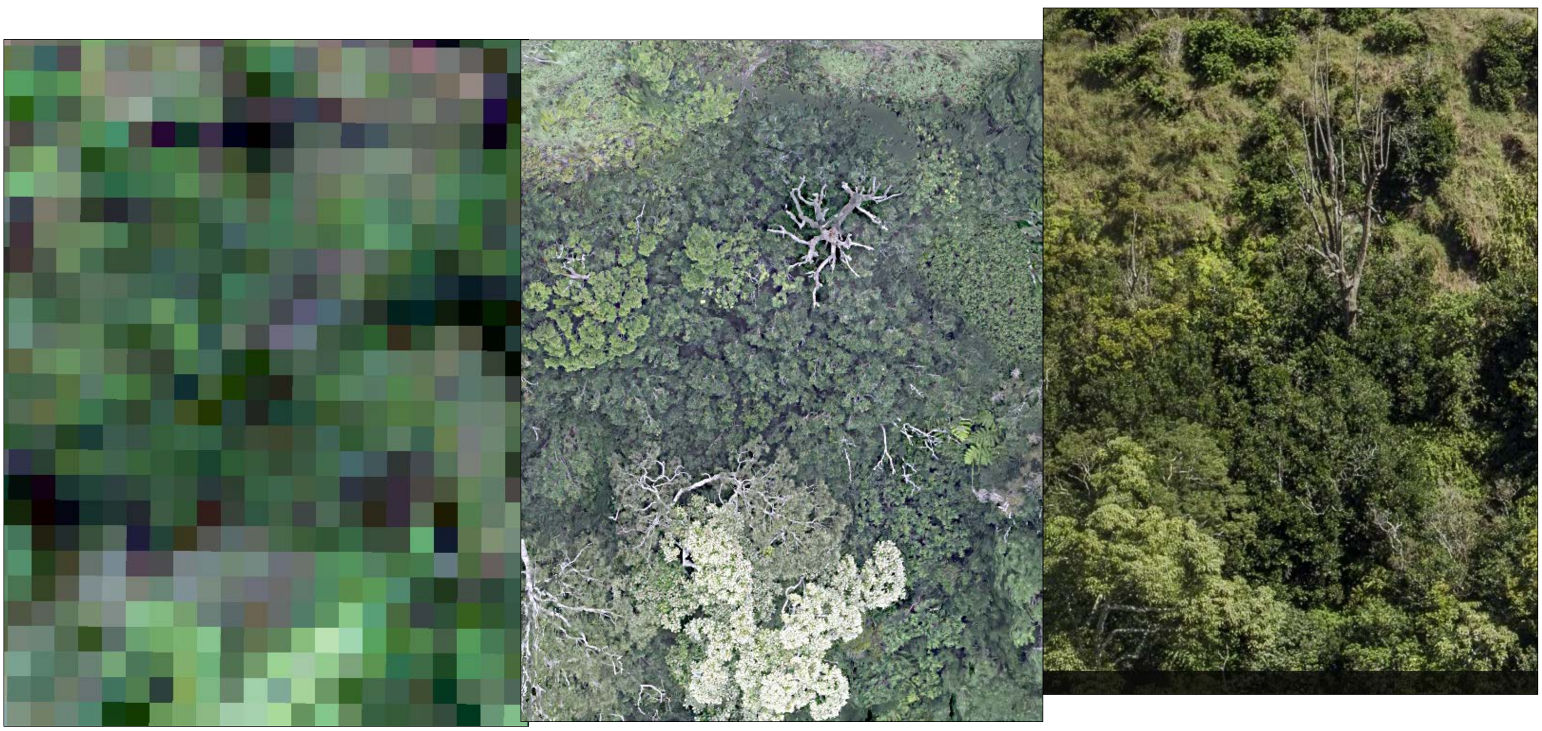


Figure 32. Extreme zoom of the target location with WV-3, UAS and Gigapan imagery.

2.3.2 Vegetation Classification

The result of vegetation classification of the WV-3 imagery is shown in Figure 33. Seven classes were mapped across the Kahanahaiki MU. The Kukui class seems to show a distribution in the lower gulch. Christmas berry is spread dominantly across the MU. Native Complex is distributed across the MU with the highest frequency in the southern portion. Table 5 shows a percent cover analysis with the breakdown of percent cover per class and the overall percentages of Native vs. Non-native cover, Native Cover = 42.99% and Non-native Cover = 53.38%.

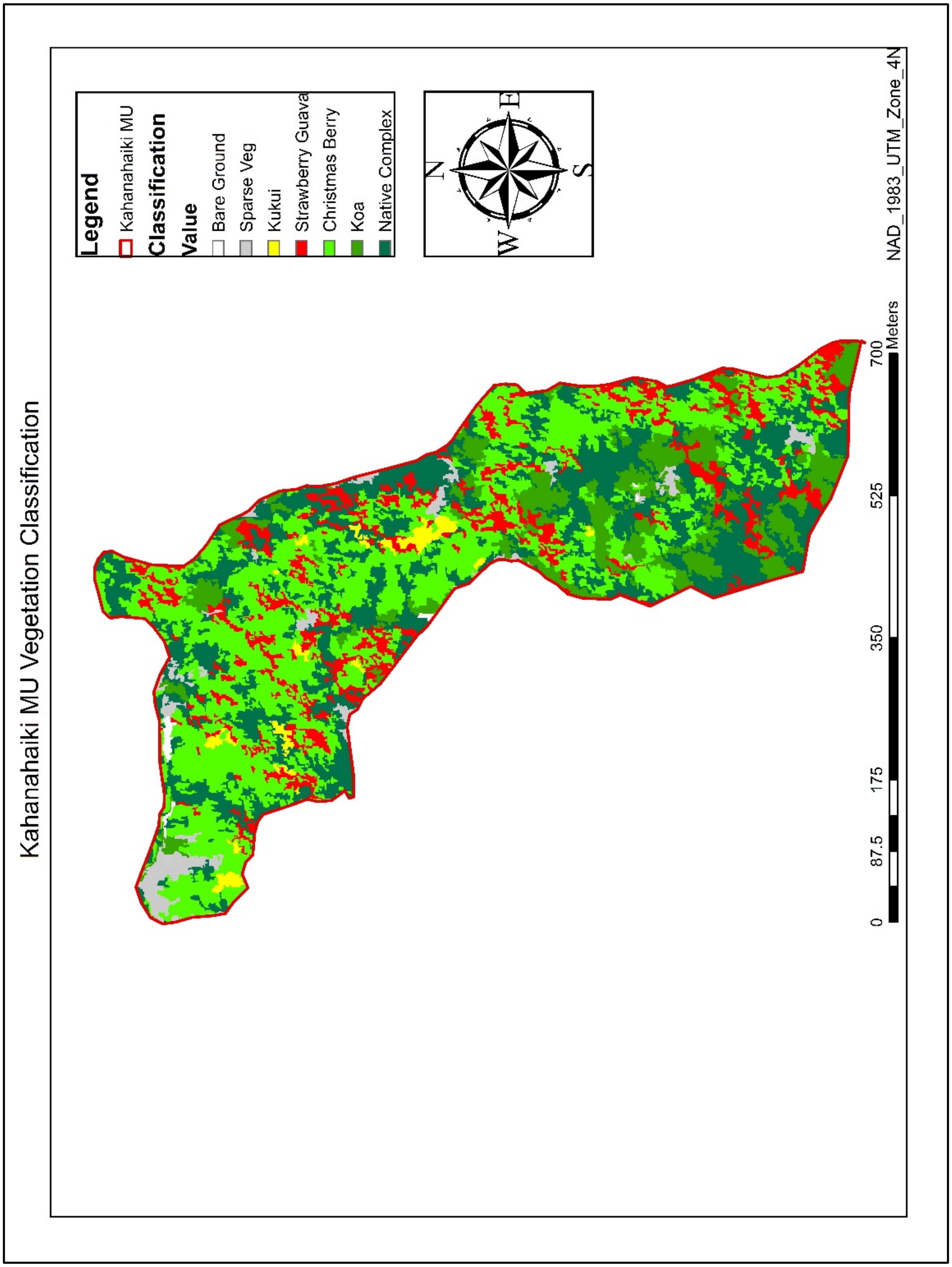


Figure 33. Final Kahanahaiki MU vegetation classification map generated with WV-3 imagery.

Table 5. Percent cover of classes

Class	Description	Pixel Count	%Cover			
1	Bare Ground	580	0.35%			
2	Sparse Veg	5395	3.28%			
3	Kukui	2809	1.71%			
4	Strawberry guava	20398	12.42%			
5	Christmas Berry	64478	39.25%			
6	Koa	21124	12.86%			
7	Native Complex	49481	30.13%		Native Cover	42.99%
		164265	100.00%		Non-native Cover	53.38%

Validation results yielded an overall user's accuracy of 65% with Sparse Veg representing the highest user's accuracy of 94% and Strawberry guava representing the lowest user's accuracy of 38% (Table 5). The user's accuracies of the other classes were: Kukui=75%, Christmas Berry 73%, Koa=50% and Native Complex=42% (Table 5). Grouping native and non-native vegetation classes yielded an overall accuracy of 85% with non-native = 93% and native = 69% (Table 6).

Table 6. Confusion matrix for the validation results of the classification map.

	UAS Reference										User's Accuracy	
eCognition Veg Map		Class	Bare Ground	Sparse Veg	Kukui	Strawberry guava	Christmas Berry	Koa	Native Complex	Total	% Correct	
		Bare Ground	40	10						50	80%	
		Sparse Veg		46			2	1		49	94%	
		Kukui			35	7	7	1		47	75%	
		Strawberry guava	1	5	1	16	13	5	3	42	38%	
		Christmas Berry		1	4	5	33	2		45	73%	
		Koa		3		4	3	22	12	44	50%	
		Native Complex		1		4	10	6	15	36	42%	
		Total	41	66	40	36	68	37	30	318		
	Producer's Accuracy	% Correct	98%	70%	88%	44%	49%	60%	50%		65%	Overall Accuracy

Table 7. Simplified confusion matrix of validation results grouping native and non-native classes.

	UAS Reference						User's Accuracy	
eCognition Veg Map		Class	Bare Ground	Non-Native	Native	Total	% Correct	
		Bare Ground	40	10		50	80%	
		Non-Native	1	175	12	188	93%	
		Native		25	55	80	69%	
		Total	41	210	67	318		
	Producer's Accuracy	% Correct	98%	83%	82%		85%	Overall Accuracy

2.4 Discussion

2.4.1 Data Collection Challenges

Spring of 2015 was chosen as the image collection window as much of the vegetation flushes and blooms during this time, allowing for change in phenology to assist in vegetation classification. However, spring and summer of 2015 were also a period of unstable weather and low clouds, which presented data collection issues. Fortunately, a relatively clear window of weather allowed for a cloud free data collection for WV-3 in May, 2015. June and July were unseasonably wet in the Waianae Mountains. Four missions were attempted with the Cessna 206 but low clouds served to be an issue and this data collection method was abandoned for UAS. The UAS approach was taken to fly below the clouds and four flights were made. Two out of four missions were partially successful and a workable dataset was produced from the merging of two image datasets. On these occasions weather was favorable in the morning; however, during mid-flight the clouds set in. This highlights the difficult nature of capturing cloud free ortho-imagery around the remote, mountainous areas of Oahu. Often conditions are clear in the morning hours and then become cloudy when the collection window at midday nears. It may have been better to collect imagery during the winter months, targeting a window with a change in weather following a cold front when the wind shifts from the north, the trade wind inversion is interrupted, and clear weather persists.

2.4.2 Gigapan Challenges, Utility and Recommendations

Gigapan image collection faced challenges with camera focus and proper exposure of images due to weather changes. The Gigapan occasionally skipped images if proper focus was not found due to a sky background. To avoid this, the operator must switch the camera back and forth between autofocus and manual focus as the Gigapan pans through the scene. Setting the manual focus to infinity for the duration of the scene was tried with poor results. Image stitching was impacted with gaps in data due to skipping. A blank "no data" image was inserted in instances where images were skipped to keep the rest of the row in line. As clouds moved into the scene images were rendered darker in the shadows. Post-processing in LightRoom® was conducted to even out the exposure changes due to clouds. This served to be time consuming. Ultimately, it was best to choose an optimal weather day with consistent cloud cover.

Three different gear configurations were tested. A $6,000 Canon 300mm f2.8 lens was rented and tested in Makaha Valley (Appendix A). A $1,700 Canon 100-400mm F4-5.6 lens was purchased and used for the primary project discussed and shown in Chapter 2. Finally, a $479 Canon SX60 with 60x zoom was evaluated. The least expensive option, the superzoom Canon SX60 showed the most potential and captured the highest resolution imagery with the best autofocus system. The Canon 60D and zoom lens systems would not focus on a blank background such as the sky or ocean, whereas the point and shoot Canon SX60 did not have an issue focusing on the sky due to its autofocus system. In addition, the Canon SX60 offers a longer zoom reach at 1,360mm than the costly 300mm or 100-400mm lenses. Thus, the Canon SX60 is a recommended camera for Gigapan with better performance at a fraction of the price.

Various classification methods were initially explored to analyze the Gigapan imagery. Supervised and unsupervised methods explored with OBIA and Isodata analysis did not yield acceptable results. The Gigapan system showed highest utility for native and target invasive species detection via visual analysis (Appendix A). It shows great utility for capturing imagery of steep target areas that may be unreachable on-foot. In addition, the method is easily repeatable, allowing for repeat image capture of target areas to show change over time and may serve as a VHR panoramic photopoint in forest monitoring. Visual classification of a subset of the image was undertaken to be used for the classification accuracy assessment using visual cues, such as canopy shape, canopy size, canopy color, texture, and relationship to other objects (Jensen, 2007) (Table 8). The Gigapan image was imported into ArcMap® 10.1 and a subset of the panorama was selected and delineated by a polygon feature class.

	Visual Attributes					
Species	**Canopy shape**	**Canopy size**	**Canopy color**	**Canopy texture**	**Bark/ stem color**	**Relationship to other canopy objects**
Strawberry guava	Uniform relatively flat canopy surface	small	dark green	uniform texture	dark bark	Large monotypic stands
Ohia	irregular canopy with light dead branches	medium	dark green	irregular texture	grey bark with many dead branches	solitary well-spaced
Koa	Irregular canopy	large	light green	irregular texture	greyish white	solitary to

Table 8. Examples of visual cues used for visual classification of the imagery

					bark	clumped

The low accuracy of the object based classification method may be attributed to a host of factors with the first being the nature of the Gigapan image incident view angle coupled with the very fine spatial resolution (0.8 cm). The Gigapan image is a very high oblique and the image may be subject to substantial shadowing that did not allow the segmentation process to form classifiable objects. In contrast, the very high resolution is a benefit for visual identification and classification of plant species and serves to be useful during the object based process. However, this is a result of the combination of hundreds of images that take a while to capture. It took nearly 40 minutes to cover just half of the scene of upper Makaha Valley. The cloud cover was relatively uniform, which was beneficial, however the light levels fluctuated during the data collection and the scene was brighter as the sun emerged from behind the clouds. This complicated and led to errors in classification as much of the preliminary segmentation was based on reflectance values. The file size is also effectively quite large as a gigapixel file making for time consuming post-processing.

Perhaps the greatest drawback to Gigapan imagery and the specific equipment used for this study was the limiting factor of only three available bands: red, green and blue (RGB). The lack of a fourth near infrared (NIR) band was a hindrance in the object based classification process as several of the classification algorithms rely on this NIR band to run a normalized difference vegetation index (NDVI) vegetation index sequence. eCognition offers manual classification techniques that allows for a higher classification accuracy, but this leads to the question, at what point is it simply more effective to conduct visual classification?

Visual classification of the Gigapan image served to be very effective even to the incipient invasive species level. The very high spatial resolution and this researcher's familiarity with the region and its associated species helped to facilitate this. This highlights perhaps the greatest utility of the Gigapan system with vegetation mapping and monitoring for managers to detect target native species and incipient invasive species in management areas and visually track landscape changes over time. Exploration and close examination of Gigapan #1 yielded the identification of the extirpated, critically Endangered *Cyanea superba* subsp. *superba* in Kahanahaiki gulch (Figure 34). The vantage point used had an unobstructed view and was higher in elevation than the target area. It is of note that this suitable vantage point allows for the best utility of Gigapan. The Gigapan system will serve to be a very useful tool if images can be georeferenced with the Truepulse® system incorporated with a Trimble GPS unit to assist in ground location of target plants.

Figure 34. A zoomed in view of Gigapan 1 yields the identification of the critically Endangered *Cyanea superba* subsp. *superba.*

It would be of great value to identify a process or tool that would georeference Gigapan gigapixel imagery allowing for integration with other base layers and target location identification. The Truepulse® 360R laser rangefinder has high potential to allow for key georeference point collection of gps offsets and showed horizontal error of 1-10m from up to 500m from selected targets. Attaching the Truepulse® to the camera introduced significant compass error to the GPS offsets due to the proximity to the metal components of the lens and camera. However, this error could be calibrated as it showed to consistently offset the true GPS location.

2.4.3 UAS Challenges and Recommendations

Benefits of UAS include but are not limited to: cost effectiveness while delivering a quality suite of image data products, reduction of risk, easier mobilization and the capability of flying safely below the cloud ceiling. The rotor and fixed wing UASs were flown with a Sony Mirrorless camera delivering sharp, high resolution images**.** Battery life of rotor UAS was a limiting factor with 10 minute flights. If a safe landing is achievable the fixed wing UAS shows great potential, as battery life is expanded significantly. The Skywalker 1900 flew on a single battery for 67 minutes with approximately 60% usage. A suitable landing area was not available for Kahanahaiki so the fixed wing UAS was flown into low vegetation at a reduced speed. Minimal damage occurred but this method was not optimal. A UAS with the capacity for a vertical takeoff and landing that would transition into a fixed wing mode would have been best for this area and may be the platform of the future as it may stay airborne longer than a typical rotor UAS.

There are many UAS's available. Table 9 shows a recommended starter system suitable for vegetation mapping as per personal communication with Charles Devaney. Mission preplanning and image processing is key component of UAS use in mapping and monitoring. Several software programs exist including Pix4D® and Agisoft Photoscan® among the premium options. Dronedeploy® is a leading freeware application offering much of the same function.

Table 9. Recommended UAS system

1- DJI Inspire 1 PRO	
1- Transmitter for Inspire 1 Quadcopter	
1- Zenmuse X5 Camera and 3-Axis Gimbal	
1- MFT 15mm f/1.7 ASPH Prime Lens	
2- TB47 Intelligent Flight Battery for Inspire 1 (99.9Wh)	
1- Flight Battery Charger	
1- Remote Controller Charging Cable	
1- Power Cord	
2- Micro USB Cable	
1- Gimbal Clamp	
1- DJI Harness	
1- Camera With Gimbal Box	
4- Spare Prop CW/CCW Pairs	
1- DJI Professional Hard Case	
1- Lexar 16GB MicroSD Card	
1- SanDisk 64GB Extreme MicroSD Card	
	$4,400

2.4.4 WV-3 Recommendations

The WV-3 imagery was georeferenced by Apollo mapping but full orthorectification was needed. The LiDAR DSM showed high accuracy of approximately 10.1cm vertical positional error allowing for orthorectification with minimal distortion. Apollo mapping was contracted to obtain current imagery within the same collection window as UAS and Gigapan, however this may not be necessary. Other less recent data sets exist and may be suitable at no cost. The NRCS accepts requests for current imagery acquisition via Tony Kimmet. Datasets are delivered orthorectified at a substantial cost saving.

2.4.5 Image Classification Results Discussion

As described in Section 2.3.3, validation results yielded an overall user's accuracy of 65% with Sparse Veg representing the highest user's accuracy of 94% and Strawberry guava representing the lowest user's accuracy of 38%, whereas Kukui=75%, Christmasberry=73%, Koa=50% and Native Complex=42% (Table 5). Are these acceptable levels? According to the U.S. Department of Agriculture Forest Service (Brohman and Bryant eds. 2005), for a base level classification with a mapping unit less than 5 acres for vegetation map attribute of cover type, the accuracy goal standard is 65-85% (See Table 10). The overall accuracy of 65.1% is acceptable by this standard. The high accuracy of mapping sparse vegetation shows great potential for providing distributions of light fuels for fuel mapping via this method. Mapping of Strawberry guava, Koa and Native Complex classes were not in an acceptable range when mapped separately but combining them brought them to an acceptable level at 72%. However, Kukui and Christmas berry were within the acceptable range.

Table 10. Recommended accuracy assessment standards for vegetation mapping (Brohman and Bryant eds., 2005).

Vegetation map attribute	Map level			
	National goal standard (%)	Broad goal standard (%)	Mid goal standard (%)	Base goal standard (%)
Physiognomic order	80–70	90–80	90–80	90–80
Physiognomic class	80–70	90–80	90–80	90–80
Physiognomic subclass		90–80	90–80	90–80
Alliance		80–65	85–65	85–65
Association		80–65	85–65	85–65
Cover type		80–65	85–65	85–65
Dominance type		80–65	85–65	85–65
Tree canopy closure		80–65	85–65	80–65
Tree diameter class			80–65	80–65

Some of the limitations and challenges of OBIA with eCognition® include the difficulty of mapping a complex, densely vegetated area and capturing the "human cognition," and ecological knowledge (Bunting *et al*, 2015). The dense vegetation of the Hawaiian mixed-mesic forest is among the most difficult forest type to separate classes to the species level (Ambagis pers. com., 2015). The intent in this project was to use more detailed classes for the native complex but the computer used for the analysis could not handle processing the addition of texture and geometry into the hierarchical classification workflow with the nearest neighbor algorithm. A more powerful computer processer and RAM is needed to incorporate additional geometric and textural features into the iterative classification process. The system crashed when these components were integrated into the OBIA workflow. NDVI thresholding showed much potential to separate out sparse vegetation for light fuels for fuel mapping applications.

Future work with deep/machine learning of VHR imagery shows promise. Dr. Ryan Peroy at UH Hilo has been working with deep/machine learning processing to identify target incipient invasive vegetation with UAS imagery. Early research shows much potential with sample UAS images of Miconia to train a deep/machine learning algorithm (Peroy pers. com., 2016).

2.4.6 Recommended VHR Operational Monitoring

The VHR imagery and analysis performed in this thesis show much potential for use in vegetation monitoring and, in particular, UAS shows a wide range of potential applications for incorporation into monitoring. A recommended operational protocol is to fly a rotor UAS at low altitude along preplanned transects in target MUs. Complete coverage may be obtained for smaller target areas, but for large areas transects may serve to be easier to image due to relatively short lived batteries of rotor UAS. Random plots may be generated within the transect-based strips of imagery allowing for a stratified random sampling design (Figures 35 and 36). These plots could then be analyzed by segmentation into image objects to separate vegetation cover (Figure 37). The image segments could then be classified by species for cover analysis using visual classification as visual classification. Deep/machine learning algorithms are worth pursuing in place of visual analysis, especially in instances with large datasets (Peroy pers. com., 2016).

Figure 35. UAS image transect example for Kahanahaiki with random 20 meter diameter plots.

Figure 36. Sample UAS imagery to show a transect method and 20 meter diameter plots.

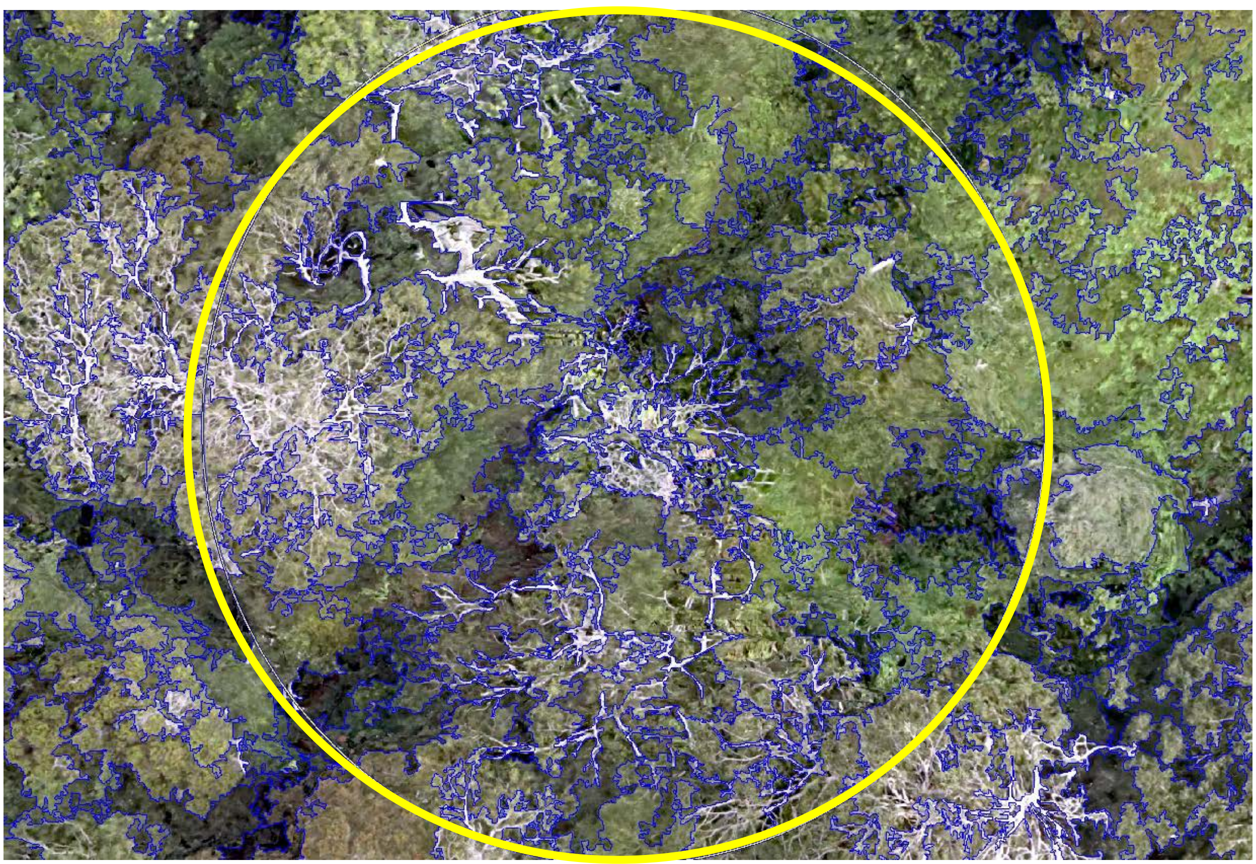


Figure 37. 20meter plot with segmentation of vegetation.

Chapter 3. Cost Analysis

3.1 Rationale

Accurate and timely classification of remote sensing imagery is vital to planning resource management efforts, tracking progress, and driving management decisions for restoration and resource management. As described in Chapter 1, traditional on-the-ground vegetation monitoring techniques can be time consuming and costly. The OANRP database shows that the initial installation of the belt plot monitoring took 294 hours. Analysis of VHR imagery can provide accurate and timely assessments of vegetation on a large scale at a set point in time (Bunting and Lucas, 2006). A remote monitoring procedure may involve less of an investment in time, however this must be weighed with the cost of image acquisition and analysis.

3.2 Objective

Objective 3. Determine the costs associated with the implementation of remote sensing based monitoring protocols as compared to traditional monitoring methods in the same target area.

3.3 Results

A cost analysis was conducted comparing the cost of vegetation classification and validation using the synthesis of WV-3, UAS and Gigapan to that of the current ground-based monitoring in Kahanahaiki. The analysis included data acquisition, field time, and data analysis and processing. Time spent learning to use software was not included. As described in the Study Site section, the OANRP has conducted vegetation monitoring for Kahanahaiki three times on a three-year interval since 2009. Time spent to conduct and analyze the monitoring is kept in the OANRP database and was determined to take 294 hours to conduct in 2009. The remotely sensed vegetation procedure cost $17,073 whereas the ground based method cost $7,350 (Table 11). An operational cost was also determined with estimates once gear is purchased and imagery obtained without contracting. The estimated operational costs is $3,500 (Table 12).

Table 11. Project costs to get up and running

	Rate	Amount	Price	
Equipment				
Gigapan Epic Pro		1	**$960**	
Canon SX60		1	**$479**	
Tripod		1	**$250**	
Batteries		2	**$110**	
Gigapan Image Processing	$21.5/hour	12hours	**$258**	
Trimble Geo7XH		3week rental	**$1,360**	
Contracted Service				
Resource Mapping Hawaii			**$3,900**	
Software Training			**$500**	
WV-3 Satellite Imagery	$50.75/km^2	100km^2 *	**$5,075**	
Software				
eCognition Developer	$90/year (student license)	1 year	**$90**	
Field Time				
GA in the field	$21.5/hour	49hours	**$1,053.50**	
Image Analysis				
GA conducting classification	$21.5/hour	52hours**	**$1,118**	
			$17,073	**TOTAL**
OANRP Plot Monitoring				
Field Time/Data Entry/Analysis	$25/hr	294hours	**$7,350**	**TOTAL**
** 100km^2 is the minimum collection area required for Digital Globe*				
*** Estimate of time spent processing image*				

classification				

Table 12. Operational costs of remote monitoring once gear is purchased and imagery obtained without contracting to private companies.

	Rate	Amount	Price	
Gigapan image collection	$25/hr	15hours	**$375**	
Gigapan image processing	$25/hr	20hours	**$500**	
UAS image collection	$25/hr	40hours	**$1,000**	
UAS image processing	$25/hr	20hours	**$500**	
WV-3 image Collection			**0***	
Image classification	$25/hr	30hours	**$750**	
Analysis of Data	$25/hr	15hours	**$375**	
			$3,500	**TOTAL**
*Current WV-3 can be obtained from the NRCS at no additional cost				

3.4 Discussion

Ultimately, if new imagery was obtained under contract, remote sensing based monitoring serves to be more expensive than traditional ground based methods. However, an operational comparison that factors in either prior acquisition of imagery or capacity to gather data without going out to contract, shows a lower cost associated with remote sensing based monitoring. Although it is of great merit to look to the experts, it would be advantageous for conservation organizations with active monitoring to look to build capacity to collect UAS imagery or collaborate with universities with active UAS programs.

Chapter 4. Conclusion

The primary project goal was to evaluate the utility of new high spatial resolution remote sensing technologies for vegetation mapping and monitoring in Hawaiian mixed-mesic forests. Three specific objectives were addressed:

Objective 1: Develop an effective synthesis of the outputs from a VHR satellite platform, Gigapan, and ortho-aerial to implement remote sensing-based mapping to the species level and outline an OBIA procedural workflow.

The strengths of the three platforms were evaluated and then combined with the goal of producing a useful and accurate vegetation map for the Kahanahaiki study area. The WV-3 satellite image served as a base layer image to be classified with eCognition OBIA and validated with the UAS and Gigapan imagery. Training data collected from the study site were used as representative vegetation samples to develop the eCognition classification algorithm decision ruleset. The Gigapan mosaics were used for cross-referencing ortho-aerial imagery through visual comparison to help train the classification process and assist with the accuracy assessment. An effective synthesis of the outputs from WV-3, Gigapan, and UAS was determined to implement remote sensing-based mapping to the species level and an OBIA procedural workflow was outlined. WV-3 imagery was classified in eCognition into 7 vegetation classes and validated with UAS and Gigapan imagery.

The dense vegetation of the Hawaiian mixed-mesic forest presents a challenging task to separate vegetation classes to the species level. Validation results yielded an overall user's accuracy of 65% with Sparse Veg representing the highest user's accuracy of 94% and Strawberry guava representing the lowest user's accuracy of 38%, while Kukui=75%, Christmas berry=73%, Koa=50% and Native Complex=42%. Grouping native and non-native vegetation classes yielded an overall accuracy of 72% with non-native=94% and native=69%. The high accuracy of mapping sparse veg shows great potential for providing information towards fuel mapping via this method. Further work is needed to accurately separate native vs non-native vegetation to the species level. A stronger computer processer is needed to add additional geometric and textural features into the iterative classification process.

Objective 2: Make recommendations for the integration of remote sensing methods into vegetation monitoring.

The UAS VHR imagery shows the greatest potential for integration of remotely sensed imagery into an operational vegetation monitoring method. UAS allow for low cost, repeatable, high resolution data collection without risk to field personnel. A recommended method could employ a UAS to fly transects in a target area with visual or deep/machine learning analysis of random plots along the transects. Further advancements in multispectral sensors and longer lasting batteries will serve to allow for greater utility in monitoring, and management applications. Vertical takeoff and landing UAS may be of great use in areas without suitable landing area for typical fixed wing UAS.

Objective 3: Determine the costs associated with the implementation of remote sensing-based monitoring protocols as compared to traditional monitoring methods, including recommendations to facilitate cost saving.

The costs associated with the implementation of remote sensing based monitoring protocols were determined and compared to traditional ground based monitoring methods. Ultimately, if new base imagery was obtained under contract, remote sensing based monitoring serves to be more expensive than traditional ground based methods. However, an operational comparison which factors in either prior acquisition of imagery or capacity to gather data without going out to contract, shows a lower cost associated with remote sensing based monitoring.

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Appendix A. Gigapan Exploration in Makaha

Plate 1. Tested Gigapan®, camera and lens configuration with Truepulse® laser rangefinder.

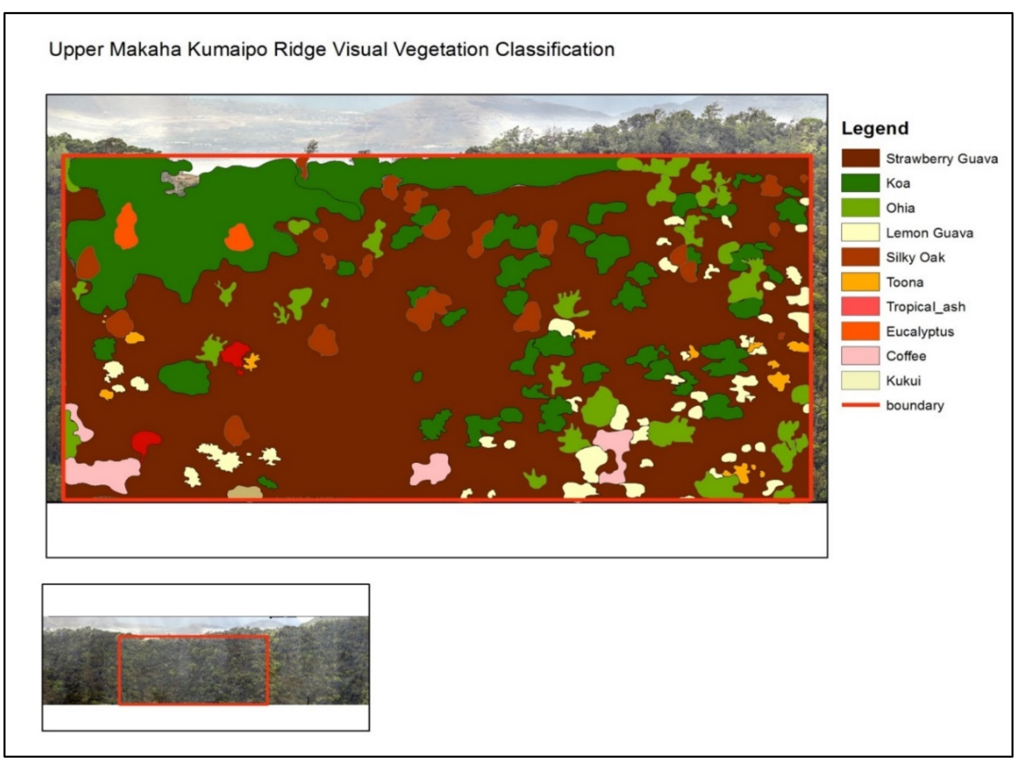

Plate 2. Species level classification map of a target area in Makaha Valley with visual classification methods.

Appendix B. eCognition procedural workflow

>Open eCognition® Developer 9.1
>Load orthorectified WV-3 data
>Select the area of interest
>Select the 6 layer mix false color composite
>Open process tree, class hierarchy, feature view windows as splitscreens
>Insert process- Image segmentation
>Edit process- Algorithm- multiresolution segmentation
>Domain- pixel level
>Image layer weights: 0,1,2,2,2,2,1,0
>Scale parameter- 30
>Compactness- 0.43
>Insert class into Class hierarchy-Non Veg, Veg
>Non Veg- Mean layer 1≥238
Mean layer 5≥158
Standard Deviation Layer 5 ≥33
>Veg- NDVI≥0.62
>Veg- Not Non Veg
>Run Classification- Algorithm- Hierarchical classification
- Domain- Image object level
>Insert class- Sparse Veg- Not Non-Veg
- Not Veg
>Run Classification- Algorithm- Hierarchical classification
- Domain- Image object level
>Insert class- Kukui- Not Sparse Veg
- Standard deviation layer 3 ≥ 34
- Standard deviation layer 4 ≥ 40
>Insert class- Not Kukui- Not Kukui
>Insert class- Native Complex- Not Kukui
- Not Psicat
>Insert class- Psicat- Mean Layer 4 ≤ 157
- Not Schter
>Insert class- Schter- Mean Layer 6 ≥ 395
- Mean Layer 7 ≥ 680
>Run Classification- Algorithm- Hierarchical classification
- Domain- Image object level
>Insert class- Koa- Geometry feature- GLCM Homogeneity (all dir) ≥ 0.052
>Insert class- Other Native- Not Koa
>Run Classification- Algorithm- Hierarchical classification
- Domain- Image object level
>Select Samples-Using training data locations for cross reference
>Run Nearest Neighbor algorithm
>Run Classification- Algorithm- Hierarchical classification
- Domain- Image object level
>Export classified image as a shapefile
>Import into ArcMap® 10.1 and create feature classes for each vegetation class.

Appendix C. Sample UAS images used for validation of vegetation classes

Plate 3. Characteristic depiction of bare ground class (outlined).

Plate 4. Characteristic Sparse veg class made up of herbaceous weeds, ferns, or grass (outlined).

Plate 5. Characteristic bright, light colored Kukui class (outlined).

Plate 6. Characteristic Christmas berry Schter class (outlined).

Plate 7. Dark green characteristic Strawberry guava Psicat class (outlined).

Plate 8. Characteristic large canopy of Koa class (outlined).

Plate 9. Characteristic mixed vegetation of Native Complex class.

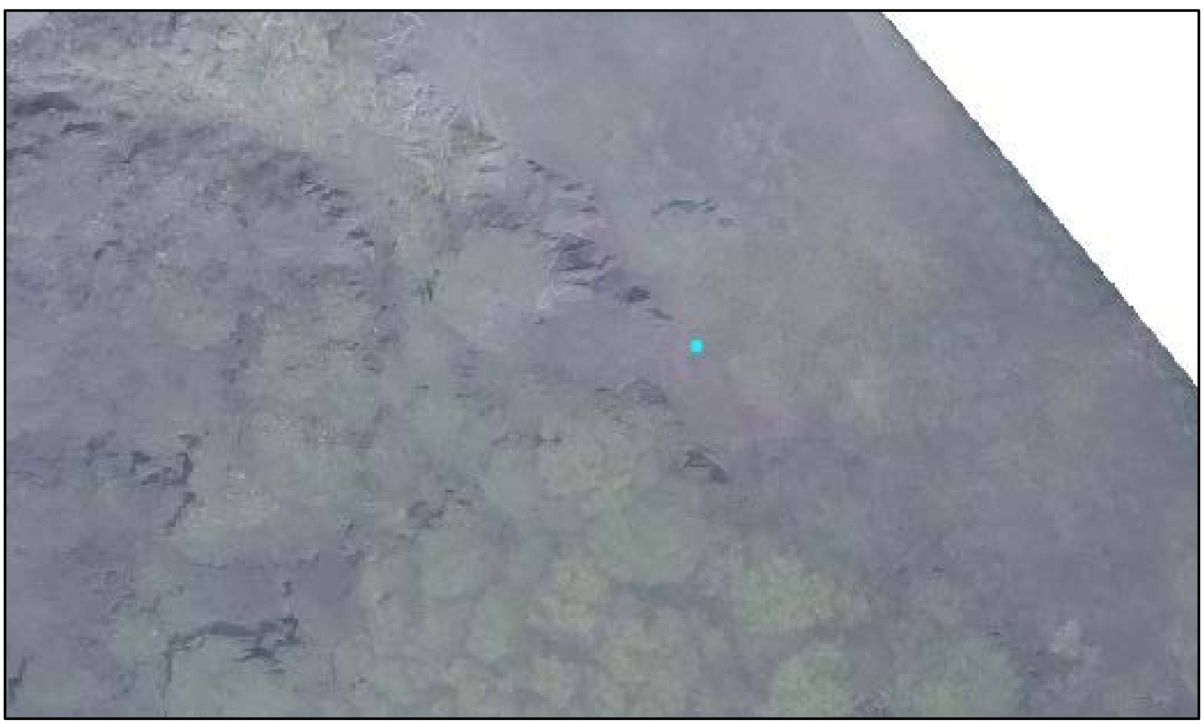

Plate 10. Cloudy, blurred UAS imagery.

Appendix ES-3

Mokuleia Fire Memorandum for Record
AKA "Mango Fire"
June 7-11, 2017

June 7, 2017

The Mango fire burned private and state land at Mokuleia. Area impacted included the low gulches and farm land west of Kaala road to Kapuna gulch (see map below Figure 8). The fire started by a truck on the Pioneer land sometime in the morning after 8 am. It was reported that the individual was picking mangos, hence the "Mango Fire." The fire was reported to OANRP at around 1100 hours by the Support Operations Associate (Schneller) that was out doing a vehicle inspection.

It was a hot day (80° F) and a steady trade was blowing (ENE at about 20 mph). RH was around 40%. There was no precipitation recorded on the 7th. The fire spread quickly to the west across the lower elevations. OANRP communicated with the DOFAW on details and Schneller stayed on site to monitor and report. DOFAW Forester Peralta was out on vacation and DOFAW NARS (Takahama) initially took charge. Takahama was later replaced as DOFAW Incident Commander (IC) by Wildlife (Misaki).


Figure 1: Mango fire soon after ignition on June 7 2017

As the fire continued to spread and appeared to threaten the Forestry areas OANRP deployed Ungulate Coordinator (Burt) to assist in observing and advising the Senior Natural Resource Management Coordinator (Rohrer) and the Army Natural Resource Manager (Kawelo). Burt met with Takahama at around 1400 hours and began to report observations. The team was stationed on the Pahole road. Schneller observed from the Kaala road side where Honolulu Fire Department (HFD) set up an IC. Due to the severity of the reports Kawelo redirects plans and reports to the site meeting Burt and Takahama at about 1530 hrs.

Figure 2: Explosive spread of Fire burning ridges East of Kapuna

Rohrer coordinates for K&S to respond to the fire at the request of DOFAW (Miller). The bill is covered by DOFAW. Airborne Aviation is dispatched from Kauai by DOFAW. In order of appearance Air One was the first bird on site dropping at about 1pm. They then had to go respond to a rescue. The HPD bird for flew alone until K&S arrived, then Airborne arrived form Kauai, the Sikorsky was next on site. DOFAW contracted a Sikorsky (Sillas Air) to assist with larger bucket capacity (approximately 1000 gallons). Sikorsky has an operating cost of approximately $6000/hour.

Schneller uses Arc On-line to produce a map in the field that greatly clarifies spread and potential risk to resources (Figure 3). GIS staff are able to see points Schneller plots and produce a map for OANRP and DOFAW review.

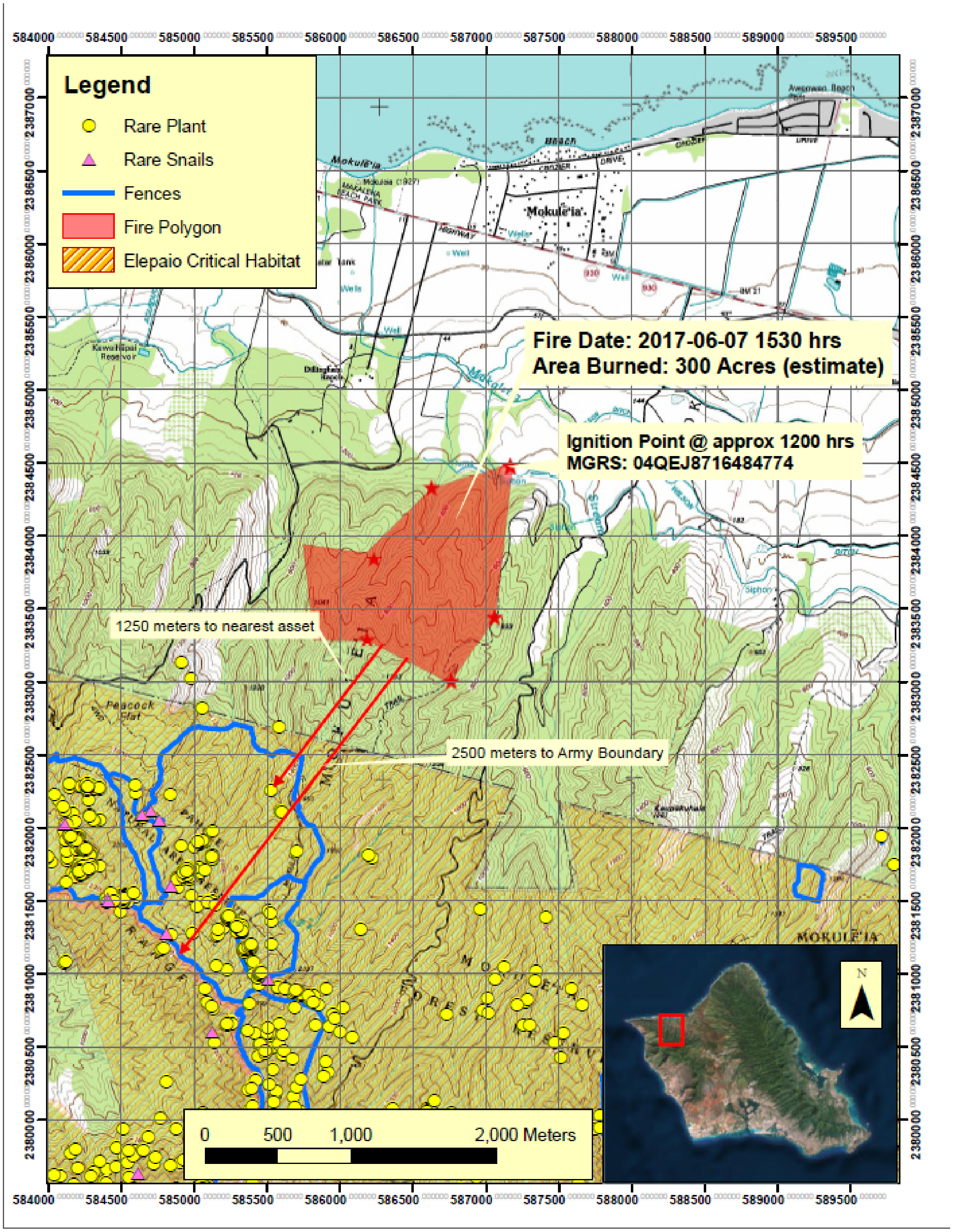

Figure 3: Initial map produce with field points entered on Arc On-line. Map produced at OANRP base and emailed to staff in the field

Spot weather is requested from NWS by Rohrer and reported to DOFAW staff. NWS spot forecasts can be generated by calling NWS (973-5280). In addition a forecast can be requested on line at NWS under the forecasts and fire weather.

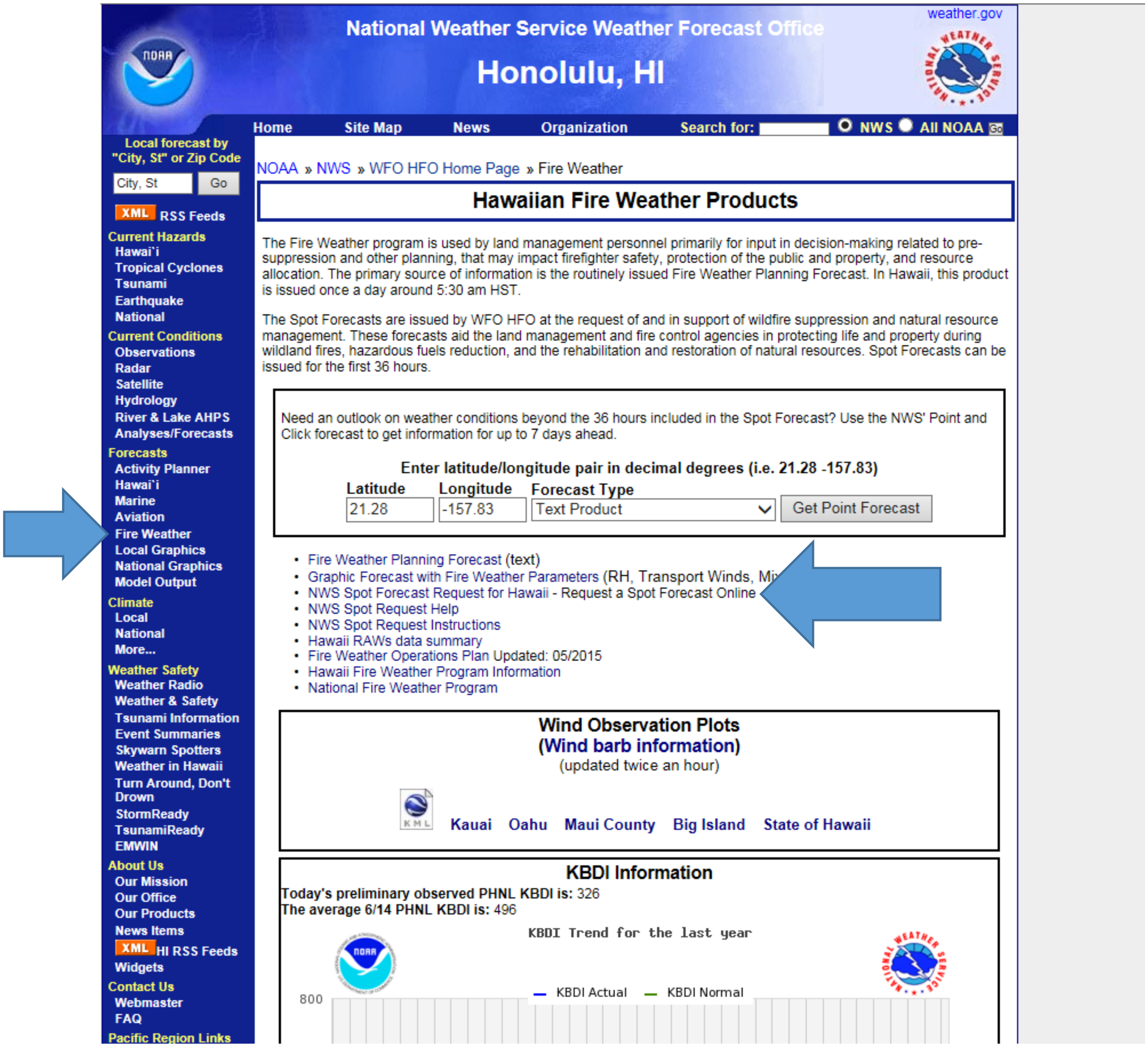

Figure 4: NWS Fire weather spot forecast request.

Figure 5: View from Pahole road gate as fire crests ridges East of Kapuna

At approximately 1600 hrs Kawelo initiates request for military support (via Emergency Operations Center-Pete Woolsey) based on threat to OANRP resources present in the Kapuna fence unit and threat to Army land in Makua (Figure 5 and 6). Kawelo had notified DPW ENV Chief at 1430 hrs to convey fire severity and potential for initiating request. The nearest resources are Nothum and Fluneo. Initial back and forth indicates Military resource may be unable to respond on the 7th. Kawelo, Burt and Schneller stay on until about 1730 hrs reporting spread and mapping.

Figure 6: Ridge East of Kapuna as seen from Dillingham Ranch on the afternoon of June 7

At about 1800 hrs two UH 60 (Blackhawks) arrive on scene. OANRP finds out later that the Military request was facilitated by the mutual aid agreement. Kawelo and Rohrer return to the IC (moved to Dillingham Ranch from Kaala road by HFD) at approximately 1830 hrs and meet with DOFAW staff including IC Misaki. Three Army Wildland fire staff report to IC including Chief Gibbs. Chief Gibbs performs aerial recon with DOFAW staff. Blackhawks continue to work the area until approximately 1945 hrs. OANRP staff, Army Wildland are on site until about 2000 planning operations for the next day and watching fire back-burn toward the Pahole road (Figure 7).

Permission to use the Dole dip ponds is negotiated with Dan Nellis (621-3200 or 479-9321). Coordinating dip pond access is critical to relations.

Kapua, Joby, Wildland fire and chief on site until approximately 2000 hrs. Response set for one Blackhawk & one Chinook for Thursday morning 0800 hrs. Chief Gibbs request one UH60 and a UH 47 to support operations form 0800 hrs June 8.

June 7 Summary

Staff	Time	Total Hours
George Schneller	1100-1730	6.5
Matt Burt	1330-1730	4.0

Kapua Kawelo	1500-2000	5.0
Joby Rohrer	1600-2000	4.0


Figure 7: View from Dillingham IC on the night of June 7 as the fire backed down to the Pahole road south of Kapuna

Key points:
1. OANRP representation at the HFD IC (Kaala road, Schneller) and with DOFAW staff (Burt, Kawelo, Rohrer) greatly facilitated communication and coordination.
2. Mutual Aid Agreement facilitates military response
3. Arc Online tools enabled real time mapping as never before
4. Army Wildland staff at the IC were critical in galvanizing support for operations on June 8. Chief Gibbs overflight enabled him to communicate severity directly to DES and IOC.

June 8, 2017

DOFAW staff stay on site working into early morning of June 8 to ensure that the fire did not jump the Pahole road. Many DOFAW staff spend the night on site. Schneller is on site at 0600 hrs watching behavior and reporting to Rohrer and Kawelo. Rohrer and Kawelo report to the IC at 0700 hrs. Kawelo and DOFAW staff conduct an aerial survey at approximately 0730. Kawelo uses Arc On-line to collect points for a new updated map including LZs (Figure 8). New fire map shows area burned within about

600m of the Kapuna fenceline and a total area of approximately 500 acres. This proximity focuses response on preventing fire from reaching the enclosure. DOFAW objective stated at the morning brief also includes keeping the fire contained within the Kaala and Pahole roads.

Two Army wildland fire fighters are flown in to assist DOFAW staff and direct and observe military ships. Chief Gibbs and Justin Turbo (Wildland Fire Management) are stationed at IC throughout the day facilitating military support.

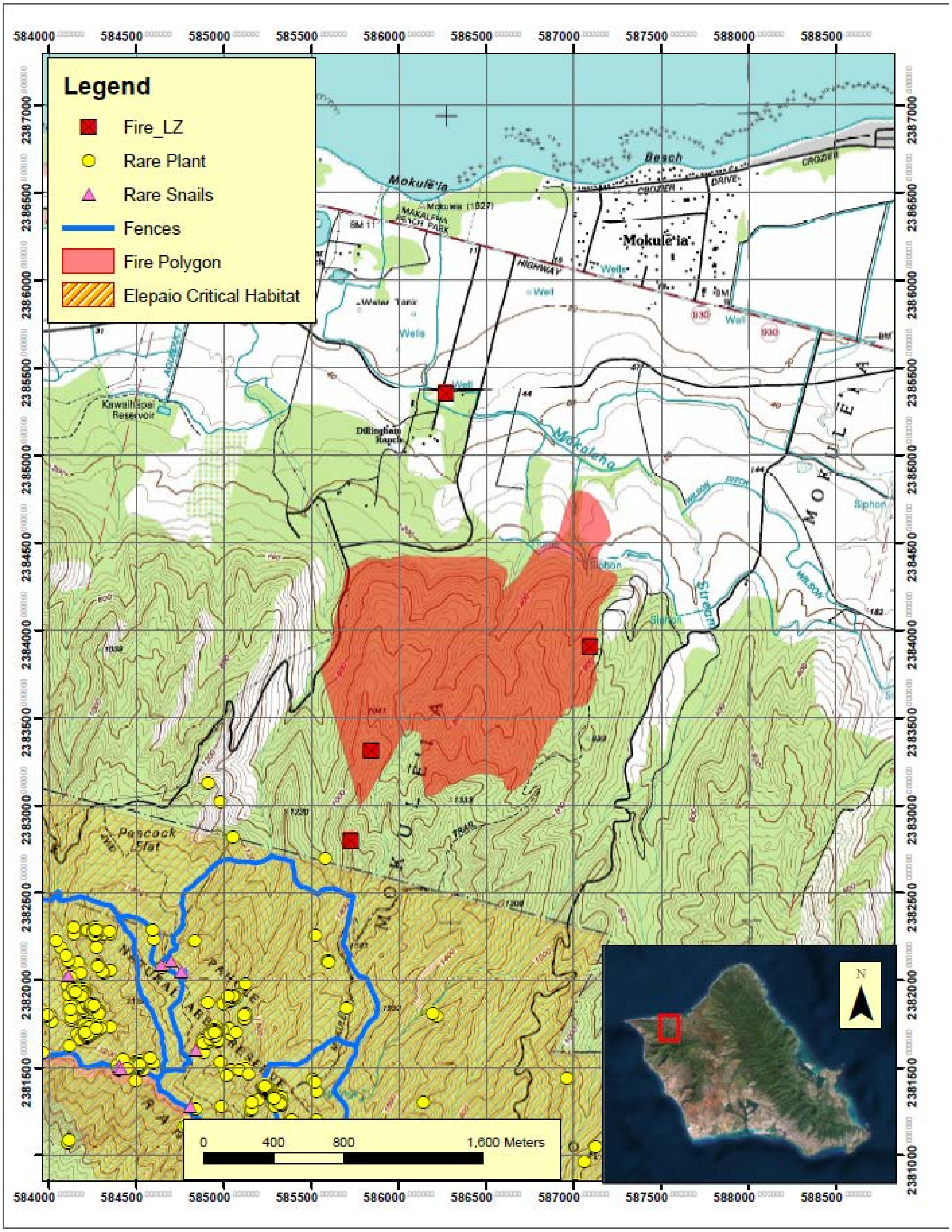

Figure 8: Map revised after aerial survey conducted the morning of June 8. LZ locations taken on the flight provide critical planning and safety information for teams

Pacific Helicopter pilot Steve Aiu is on scene at 0730 hrs and plays a critical role throughout the day directing operations. Aiu functions as air command, in particular directing military ships by indicating drop locations, elevations of the bucket over the site, airspeed and trajectory.

A unique challenge for this fire include the proximity to Dillingham airfield. On the morning of the 8th the airfield was busy, multiple skydiving operations were observed in addition to gliders. This presented a major flight hazard for military ships that had to exit the area to refill water buckets. Wildland Turbo fire indicated that for mainland fires they typically restrict the airspace for a 5 mile radius. As a result DOFAW Zoll work with FAA to institute a TFR thus clearing the airspace. This was a huge benefit and greatly reduce aerial hazards.

Military support includes two UH 60s that report at approximately 0930 hrs and work until about 1300 hrs. UH 47 support is delayed due to bucket issues. Chief Gibbs and Army Wildland work the bucket issue and UH 47 reports at approximately 1300 hrs. UH 60 support returns at approximately 1430 hrs. UH 60 and UH 47 support continue until 1730 hrs. UH 60 are carrying 660 gallon buckets and the UH 47 2000 gallons.

Figure 9: UH 47 dropping 2000 gallons of water on remaining hot spots on June 8

Other aircraft on site includes HFD air one. However they are redirected to a rescue in the middle of the day. In addition HPD reports and works for much of the day.

Water is provided for the MD500s by HFD at a portable tank off the Kaala road and a portable tank at Dillingham Ranch. Military ships unfortunately have to go to Dole for water making their turnaround time about ten minutes. Developing closer dip locations for larger ships could great increase fire fighting effectiveness.

OANRP base continues support through the day getting spot NWS spot forecasts and taking care of miscellaneous items.

Key points:

1. Steve Aiu plays a critical role directing air operations. His many years with of HFD experience makes him a natural leader.
2. Large military ships play a decisive role in delivering massive quantities of water that penetrate deeply and cool remaining hot spots.
3. Dip ponds for the large military ships are distant (Dole land). In future additional dips should be identified. The quarry by the airfield would be an ideal dip site but currently is unavailable due to the aquaponics operation. The pond at Dillingham is over grown and contains endangered water birds. The ocean is not preferred due to bucket corrosion issues. MMR is closer than Dole however would require dropping to the coast on the leeward side.

June 8 Summary

Staff	Time	Total Hours
George Schneller	0600-0700	1.0
Kapua Kawelo	0700-1900	12.0
Joby Rohrer	0700-1900	12.0

<u>June 9, 2017</u>

Burt is on standby to support as needed and goes to the IC in the late morning. Fire behavior is low and DOFAW staff are confident.

<u>June 10-12, 2017</u>

Precipitation on the 10^{th} helps cool remaining hot spots. There is a flare up in the black on the 12^{th} and air one is on scene. DOFAW demobilizes on the morning of June 13.

Updated phone list

CONTACT	**OFFICE**	**CELL**	**RADIO**
East Range baseyard	656-7741		DPW Env. Ch. 6 FM141.101
West Range baseyard	655-9175		
Kapua Kawelo	655-9189	864-1014	
Joby Rohrer	655-6256	295-2556	

Taylor McCarthy	655-6265	381-9585	
Army Wildland Fire			
Jake Faber	653-0201	348-6555	
DPW			
Kapua Kawelo	655-9189	864-1014	
Chief Charles Gibbs	653-0207	907-590-3002	
Manager Justin Turbo	808-798-6579	808-653-0209	
RANGE CONTROL			
KTA Range	497-6660		
Makua Range	655-2533		
Schofield Range	655-1434		
Honolulu Fire Dept.			
Admin/fire operations	831-7774, 834-7773		VHF 123.100
Fire Comm Center	723-7161		
DES (Division of Emergency Services)			
Ken Philips	808-656-6454	808-589-8217	
IOC	808-656-3269/72	808-220-1082	
DPW			
Rhonda Suzuki (Enviro Chief)			
Lisa Graham (Branch Chief)	808-656-3075	808-927-6659	
DLNR			
Wildlife-Ryan Peralta		292-5645	
NARS-Chris Miller	453-6179	286-3868	
Wildlife- Jason Misaki		295-5896	
NARS-Talbert Takahama		295-1115	
Branch Mgr.-Marigold Zoll	973-9787	286-6378	
USFWS			
Dawn Greenlee	792-9400	972-4602	
Patrice Ashfield	792-9400		
Helicopter Support			
Pacific Helicopters	879-9771 (Maui)		
Lincoln Ishii		542-0606	
K&S/Paradise	756-2565 (Oahu) Reservations:293-2570 Kona base mgr:329-6601		
Calvin Dorn (K&S)		895-9615	
Josh Lang (K&S)		741-4354	
Kahekili Kaaa (K&S)		281-2325	
Daniel Spielman (Oahu base mgr)		561-4872	
Windward Aviation	877-3368 (Maui)		
Jim Hobbs		281-4198	
Volcano Helicopters	961-3355 (Big Island)	935-4588 (hanger/fax)	

David Okita		937-3022	
HNL Airport	836-6411		
Dillingham Airport	637-8271		
Snails			
David Cisco	587-0033	559-760-5882	
Dole			
Dan Nellis	621-3200	479-9321	
Monsanto			
Monsanto security		284-7787	

Army Activity Summary

SIR/CCIR # 170540 ADD-ON # 6

REPORTING IOC, EOC, EAC: USAG-HI IOC/ SSG Stevick /TOR: 120945WJUN17

Subject: ADD-ON # 6 to Serious Incident Report # 170540

1. Category: 3-32

2. Type of Incident: Mutual Aid

3. Date and Time:

   a. DTG of Incident: 071838WJUN17
   b. DTG of Receipt: 071838WJUN17

4. Location of Incident: Mokuliea Forest Reserve, 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

Additional Information # 6: At 120945WJUN17 Mr. Chuck Gibbs, Fire Chief reports all Army operations and support were completed on Thursday night. The department of Land and Natural Resources remained on the fire Friday and Saturday to mop up some hot spots and reinforce the fire line. All fire operations were complete at 1430 on Saturday afternoon. DLNR performed firewatch on Sunday between 1100-1600, no other updates were passed on.

Additional Information #5: As of 091430WJUN17 LTC Phillips, Department of Emergency Services Executive Officer (DES XO), reports a total of 450 acres burned and that fire is 75% contained.

SFC Showers, Natalie, 25th CAB LNO reports the following:

1x CH-47F (ACFT 088) from B/3-25 GSAB conducted 14 Bucket drops with 2.0 flight hours

1x UH-60M (ACFT 422) from A/2-25 AHB conducted 12 Bucket drops with 4.7 flight hours.
1x UH-60L (ACFT 574) from A/3-25 GSAB conducted 8 Bucket drops with 4.5 flight hours.

Additional Information #4: LTC Phillips, Department of Emergency Services Executive Officer (DES XO) reports fire is 75% contained.

Stand by request for UH-60 x1 for Friday morning, 0800.

Additional Information #3: LTC Phillips, Department of Emergency Services Executive Officer (DES XO) reports total acreage 450-500 acres with 20-30% containment. The rate of advance is very slow at this time but expected to increase as the day goes on due to increased temperature and winds. The fire has not hit Army Property yet but is less than a quarter mile away and at significant risk due to forecasted winds. There are currently 4 helicopters working the fire (2 UH60s and two non-DoD). One CH47 was requested. Chief Gibbs, Army Wildland Fire, is on scene as the senior DES representative and two personnel from DPW Environmental.

Additional Information #2: At 0843 this morning, UH60x2 launched to join the firefighting effort. Currently personnel from Army Fire and DPW Environmental are on scene.

Additional Information: Total Flight Time and Fire Buckets Dropped: As received from 25th DOC at 072101WJUN17; Total flight time: 2.0 flight hours, Total fire buckets dropped: 14 fire buckets with 1x HH-60M Tail # 20515, returning to home station at approximately 2020.

Summary of Incident: The Honolulu Fire Department, Honolulu Police Department and Department of Natural Resources are engaging a 200 acre fire (Mokuliea Forest Reserve) a kilometer away from an Endangered Species Management Area and three kilometers away from an endangered greenhouse. The Management Area and the Greenhouse are on State property, however the Management Area and the greenhouse belongs to the Army. The fire is moving East to West, towards Army interest.

At 1657, immediate assistance was requested from the Oahu Branch Forestry and Wildlife Manager thru our DPW Natural Resources Branch. At approximately 1820, UH

60x1 launched. Army Fire personnel x2 and Ms. Kapua Kawelo (DPW Natural Resources) is on scene.

Request for CH47x1 and UH60x1 requested to be on standby for tomorrow morning, 0800.

6. Remarks: No

7. Publicity: Yes

8. Next of Kin Notified: N/A

9. Affects International Relationships: No

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

11. Originating Point of Contact: Chuck Gibbs, Fire Chief, Army Fire at 808-656-6455 or charles.e.gibbs14@civ@mail.mil

12. This Report has been Approved for Release by: LTC Kenneth J. Phillips, Department of Emergency Services Executive Officer (DES XO) at 656-6453 or kenneth.j.phillips.mil@mail.mil

13. Was USARPAC CG Informed: No

Summary of progress on <u>Testing the effects of inoculation with beneficial symbiotic fungi on the survivorship of *Phyllostegia kaalaensis*</u>

PI: Prof. Nicole Hynson

Summary
The goal of this project is to test the efficacy of pretreatment with mycorrhizal and endophytic fungal inoculum on increasing the survivorship of the endemic and endangered plant species *Phyllostegia kaalaensis* found only on the island of Oahu, HI. This speicies is currently extirpated from the wild due to the negative impacts of a pathogenic powdery mildew fungus (*Neoerysiphe galeopsidis*).

Progress to date
We have chosen two study sites, one where *P. kaalaensis* was found historically, but is now extirpated and an attempt at reintroduction failed, and a second where the congeneric *P. mollis* has been outplanted by OANRP, and is doing well. The former is located in the Pahole Natural Area Reserve (Kapuna), and the latter is in the Honouliuli Forest Reserve (Kaluaa). We have secured permits from Hawaii Department of Forestry and Wildlife as well as Hawaii Department of Land and Natural Resources to collect soil from these locations that will be used to cultivate the local mycorrhizal fungi. Soil collections were made in November and December 2016 from both sites. These soils were used for a greenhouse trap culture experiment at the University of Hawaii Manoa. Mycorrhizal generalist host plants (*Paspalum notatum*-bahia grass and *Sorghum* × *drummondii*-sudan grass) were grown in replicate in the two field soils to "trap" their arbuscular mycorrhizal fungi. In Summer 2017 we harvested the trap cultures, and after a resting period we extracted the arbuscular mycorrhizal spores in August.

These spore extracts were used to inoculate four different genotypes of *P. kaalaensis* that were propagated axenically by the rare plant lab at the Lyon Arboretum (Figure 1). Replicates of each genotype were inoculated with one of the following treatments: arbuscular mycorrhizal spores (from either Kaluaa or Kapuna), foliar endophytic fungi, arbuscular mycorrhizal spores and foliar endophytic fungi, or no treatment (control; Figure 2). For this experiment we isolated a specific foliar endophytic fungus, *Pseudozyma aphidis*, which is a mycoparasite that occurs naturally in Hawaii and has been shown to combat *N. galeopsidis*. The plants are currently being grown under controlled conditions while they become colonized with these fungal treatments. In two-three months we will introduce *N. galeopsidis*, which kills *P. kaalaensis* in the wild and measure disease severity under our various treatments. We anticipate that plants inoculated with both their above and belowground symbionts will be the most robust, and that these inoculations will lead to increased growth and survivorship of plants in the controlled environment, as well as when any survivors are introduced into the wild sometime in late 2017.

Summary
There are numerous threatened and endangered plant species in Hawaii and elsewhere that in their natural environments rely on beneficial symbiotic microbes for success.

However, current *ex situ* conservation practices rarely incorporate these microbes into their propagation or reintroduction methods. It is our hope that using *P. kaalaensis* as a model species, we can provide evidence of the benefit plant microbiomes to plant health as well as provide recommendations to conservationists and land managers on how to incorporate these microbes into current plant conservation practices.

Figure 1: *Phyllostegia kaalaensis* clones grown axenically from tissue culture.

Figure 2: *Phyllostegia kaalaensis* clones in controlled environment growth chambers post treatment. Treatments include: addition of arbuscular mycorrhizal spores, addition of mycoparasitic endophytic fungus, addition of both spores and endophyte and controls.

Evaluating both the transient and asymptotic dynamics is critical for assessing the efficacy of species reintroductions

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[4] *Department of Community Ecology, UFZ, Helmholtz Centre for Environmental Research, Halle, Germany.*
[5] *Institute of Biology/Geobotany and Botanical Garden, Martin-Luther-University Halle-Wittenberg.*
[6] *German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Leipzig, Germany.*

Under review: Ecological Applications

***Abstract*.**

The reintroduction of species into natural preserves and the suppression of top-down stressors are commonly used restoration strategies to prevent the extinction of critically endangered species. These strategies create new populations that are dominated by a single stage class (e.g., large plants used for outplanting), which can cause the population dynamics to fluctuate in the near-term before it reaches a stable equilibrium. Gaining an understanding of how the dynamics of reintroduced population will fluctuate in the near-term transient phase is critical for developing effective restoration strategies. In this five-year study, we assessed the near-term transient (i.e., 10 year projections) and asymptotic long-term population dynamics of a multi-years reintroduction effort of a critically endangered long-lived shrub, *Delissea waianaeensis*. We found that the near-term transient and the asymptotic long-term growth rates differed. When the probability of high recruitment years was 17%, mimicking the observed field conditions, the population was projected to grow in the near-term but decline in the long-term. The survival of mature plants was the most important vital rate for the long-term growth of the population, whereas seedling recruitment was be most important to the near-term dynamics under some recruitment conditions (i.e., high recruitment years $\geq$ 50%). This research illustrates that when plant reintroductions are established with large vegetative and reproductively mature plants, the population will grow faster in the transient phase than in the long-term (i.e., transient amplification) as the stage structure approaches equilibrium. We suggest that management of additional threats that influence recruitment should be considered for this reintroduction. Our results are relevant to other long-lived

species reintroductions, and suggest short-term signs of recovery should be interpreted with caution when evaluating the likely outcome of population reintroduction efforts.

Keywords: population reintroduction, *Delissea waianaeensis*, stage-structured matrix model, transient analysis, transient elasticity, and stochastic population dynamics.

Introduction

Population reintroduction and the suppression of exotic competitors and predators are commonly used strategies to prevent the extinction of rare species (Maschinski and Haskins 2012, Soorae 2013). The end goals of this management strategy are to establish new populations that will persist in the long-term and promote species recovery (Falk et al. 1996, Pavlik 1996). With an increase in rare and at-risk species (IUCN 2013) and continued anthropogenic change in environmental conditions, population reintroduction has become an integral component of many recovery efforts (Maunder 1992). While many studies have evaluated the initial success of rare species reintroductions by quantifying various measures of fitness, such as the survival of reintroduced individuals and rates of natural regeneration (Menges 2008, Godefroid et al. 2011), few studies have investigated how likely and under what conditions reintroduced populations of rare species will persist over time (but see, Bell et al. 2003, Liu et al. 2004, Maschinski and Duquesnel 2007, Colas et al. 2008, Bell 2013). The limited number of studies that have examined the dynamics of rare species reintroductions is due, in part, to the lack of comprehensive long-term demographic data that quantifies vital rates of reintroduced and naturally recruited individuals in these new populations. Demographic studies that have evaluated the likely outcome or rare species reintroduction efforts have primarily used the long-term asymptotic dynamics as a response metric and yielded mixed results (Bell et al. 2003, Maschinski and Duquesnel 2007, Colas et al. 2008). For some species, reintroduced populations were projected to persist in the long-term (Bell et al. 2003, Maschinski and Duquesnel 2007). In other scenarios, the long-term asymptotic growth rates were <1, indicating the populations would decline over time (Bell et al. 2003, Colas et al. 2008).

To establish reintroduced populations it is a common practice to use large immature individuals (Bell et al. 2003, Maschinski and Duquesnel 2007), a mix of seeds and small immature plants (Bell et al. 2003), and seeds (Colas et al. 2008). However, given reintroduced populations are often started with a cohort of a single life stage (e.g., only seeds or only reproductively mature individuals) and such new populations are likely far from their stable equilibrium, it is expected that the near-term transient and long-term population dynamics will diverge (Fox and Gurevitch 2000, Koons et al. 2005, Haridas and Tuljapurkar 2007). In the near-term transient phase, the population growth rate depends on temporal shifts in plant vital rates and the resulting change in population structure (Haridas and Tuljapurkar 2007). In extreme cases, year-to-year fluctuations in vital rates and the resulting population structure can cause extinction prior to the population reaching equilibrium (Fox and Gurevitch 2000). Therefore, understanding the transient and long-term dynamics of reintroduced populations can aid decision making about management actions that need to be taken to ensure both short and long-term success of reintroduction efforts. There is a growing body of literature that has examined the transient dynamics of natural populations following the removal of environmental stressors that altered the stage structure of the populations, including herbivory pressure (Maron et al. 2010), harvesting (Gaoue 2016), biological invasion (McMahon and Metcalf 2008, Ezard et al. 2010), and habitat disturbance (Ezard et al. 2010, Bialic‐Murphy et al. 2017). However, the near term transient phase of newly established populations is rarely examined (but see, Ezard et al. 2010, Wong and Ticktin 2015).

The Hawaiian Islands are a biodiversity hotspot, with an estimate of over 89% of the flowering plant species being endemic (Wagner et al. 1999). In Hawaii, over 40% of endemic species are listed as critically endangered or threatened (USFWS 2012), 99% of which are threatened by multiple anthropogenic stressors (Wilcove et al. 1998) including habitat conversion and rapid invasion of non-native competitors, predators, and pathogens (Cuddihy and Stone 1990, Wilcove and Chen 1998). Though non-native species are the primary drivers of species endangerment globally, their effects are thought to be more severe for island species. The greater effect of non-native species on islands is due in part to the absence of mammalian predators (and other herbivore and predator functional groups). Given many herbivores and predators were historically absent throughout there range, island plants often have low mechanistic and physiologic tolerance to these consumers (Gillespie & Clague 2009; Whittaker & Fernández-Palacios 2007).

Across oceanic islands, such as Hawaii, rare species reintroduction and suppression of top-down stressors has become a critical component of restoration efforts (Maschinski and Haskins 2012). Some stressors can be removed with little long-term management follow-up. For example, an initial investment in a fence to exclude non-native ungulates can provide long-term removal of this top-down stressor with little ongoing maintenance costs. However, a reduction in the abundance of other biotic stressors, such as invasive competitors, invertebrate predators (e.g., slugs), and small vertebrate predators (e.g., rodents) requires long-term and ongoing maintenance (e.g., annual removal of invasive competitors, frequent trapping of rodents) (Maschinski and Haskins 2012). A pressing question for conservation is whether the removal of the most ubiquitous environmental stressors (e.g., non-native ungulates) and the reintroduction of endangered species are enough to create viable populations, or if other, more difficult to manage, stressors also need to be mitigated.

In this study, we assessed the population dynamics of a multi-year population reintroduction effort of a Hawaiʻi endemic shrub, *Delissea waianaeensis* Lammers (Campanulaceae). This reintroduced population has been actively managed for over two decades, including the suppression of feral pigs (*Sus scrofa*) and non-native ecosystem altering vegetation. At the start of the study, in 2010, the reintroduced population was composed of outplanted mature individuals and first filial plants in all life stages. The objectives of this study were to: (1) quantify how the dynamics of the *D. waianaeensis* reintroduction will change over time as the stage structure approaches a stable equilibrium, (2) identify what part of the life cycle, if improved by management, would have the greatest positive impact on the transient and asymptotic population dynamics, and (3) investigate the influence of temporal variability in seedling recruitment on the transient and asymptotic dynamics.

Methods

Study species

Delissea waianaeensis (Campanulaceae) is a critically endangered tree endemic to the island of O'ahu. The Campanulaceae group is the largest Hawaiian angiosperm family (Givnish et al. 2009) and is also one of the most threatened Hawaiian groups, with over 25% of the endemic Hawaiian species extinct (USFWS 2012). *Delissea waianaeensis* has a single or branched erect stem and is 1–3 meters tall at first reproduction (Wagner et al. 1999). It produces fleshy purple, red, white, and pink berries, which is indicative of frugivorous bird dispersal (Lammers 2005). The floral sugar composition suggest *D. waianaeensis* was historically pollinated by native birds in the honeycreeper (Drepanidinae) and Hawaiian Mohoideae (Mohoidae) groups (Lammers and Freeman 1986, Pender 2013). Following massive extinction of native birds in the Drepanidinae and Mohoidae groups, it is likely that *D. waianaeensis* is dispersal and pollen limited (Lammers and Freeman 1986, Pender 2013). *Delissea waianaeensis* is found between 245–760 m elevation, along the north facing slopes and gulch bottoms of the Waianae Mountain Range (Wagner et al. 1999). In 1996, *D. waianaeensis* was listed as federally endangered (USFWS 1998) and by 2005 it was restricted to seven geographically isolated locations (USFWS 2012).

Study site and reintroduction details

The study site is in the Central Kaluaa gulch of the Honouliuli Forest Reserve, which is located in the northern Wai‘anae Mountains, on the island of O‘ahu (HON; 21° 28' N, -158°6' W). The mean monthly rainfall is 52–171 mm (Giambelluca et al. 2013). The site represents a tropical mesic forest, composed of mixed native and non-native flora and fauna (OANRP 2011). Selection of the reintroduction site was based on similarities of associated species and relatively accessible location in the historic geographical distribution of naturally occurring *D. waianaeensis* (Dan Sailer, personnal communication). In 2001, The Nature Conservancy constructed the Central Kaluaa fence, eradicated feral pigs, and implemented invasive vegetation control for the protection of *D. waianaeensis* and other managed taxa.

In 2002, The Nature Conservancy initiated reintroduction of *D. waianaeensis* into the Central Kaluaa Gulch, starting with the clearing of invasive species across the reintroduction location and the outplanting of 43 mature plants. The founders used for the Kaluaa *D. waianaeensis* reintroduction were from a relictual geographically isolated population of five individuals, located 4,000 m from the outplanting site. Stock from the other six geographically isolated populations was not used for the Kaluaa reintroduction to avoid potential outbreeding depression and the loss of local adaptations (Kawelo et al. 2012). Prior to outplanting, seeds from the five Kaluaa founders were grown in a greenhouse for one growing season. In 2004, the management of the Kaluaa *D. waianaeensis* reintroduction was transferred to the O‘ahu Army Natural Resources Program (OANRP) and incorporated into a larger conservation plan to offset the potential impact of military training operations on 89 rare species. OANRP outplanted an additional 303 plants from 2004–2012. The 2012 outplanting included genetic representation from two additional individuals that were discovered in close proximity to the five original founders used for the Kaluaa reintroduction. The mean plant height at the time of outplanting was 56 cm.

Data collection

From 2010–2015, we collected annual demographic data for a total of 597 permanently tagged plants at the field site. The life cycle of *D. waianaeensis* was categorized into four life stages: reproductively mature (>35 cm and reproductive), large immature (> 35 cm and vegetative), small immature (2 cm – 35 cm), and seedling (< 2 cm). The population stage structure at the start of the study included 74 reproductively mature plants, 131 small and large immature plants, and 217 seedlings. Each year of the study a minimum of 50 plants in the reproductively mature, large immature, and small immature life stages were permanently tagged and vital rate data were collected. All individual seedlings in the population were permanently tagged and vital rate data were collected annually from January to February. For each tagged plant the survival, height to the apical meristem, and fertility (i.e. fruit production) were recorded.

Projection matrix construction

We used the demographic data to construct a Lefkovitch matrix **A** (Caswell 2001) for each transition year 2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015. The 4 x 4 matrix **A** can be decomposed into two matrices: a survival-growth matrix **U** and fertility matrix **F**. Matrix **A** captured the yearly transition probability of survival σ, the probability of growing to the next stage class γ, and seedling recruitment φ_m in the following discrete life stages: reproductively mature (*m*), large immature *(li)*, small immature (*si),* and seedling (*s)*. The term φ_m represents the mean number of seedling produced per mature plant. For the φ_m term, we were able to calculate an additional transition year 2009–2010.

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

The dominant eigenvalue of matrix **A** represents the long-term population growth rate λ, with an associated stable stage distribution *w* and reproductive value *v* (Caswell 2001).

Temporal variability of seedling recruitment φ_m

To model the effect of temporal variability of recruitment as a stochastic process, we first created an array for seedling recruitment that consisted of φ_m values for transition years 2009–2010, 2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015, which are referred to hereafter as years **1–6**. We then classified seedling recruitment φ_{m1-6} in years **1–6** as either *high* (*h*) and *low* (*l*). Seedling recruitment φ_{m1} in year 1 was 3.09 seedlings per mature individual and seedling recruitment φ_{m2-6} in years 2–6 ranged from 0.569 to 0.021 seedlings per mature individual. We classified seedling recruitment φ_{m1} in year 1 as *high* and seedling recruitment φ_{m2-6} in years 2–6 as *low*. To evaluate the influence of temporal variability in seedling recruitment φ_m on population dynamics we created an array of **F** matrices for a total of six scenarios **F1**–**F6**, which are described below, by modifying the probability of high and low recruitment being selected following a temporally stochastic process. Independent of the fertility matrices **F**, we used our survival-growth data 2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015 to create an array of **U** matrices.

Stochastic population dynamics

To project the near-term transient and long-term asymptotic dynamics, we used a stochastic stage-structured model (Caswell 2001):

$$n(t+1) = \mathbf{X}(t)n(t) \quad (1)$$

where $\mathbf{X}(t)$ is equal to the sum of selected **U** and **F** matrices, one from a pool of five **U** matrices (2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015) and the other from a pool of six **F** matrices (2009–2010, 2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015) at a given time *t*. The vector $n(t)$ is the number of individuals in each stage class at a given time t, and $n(t+1)$ is the total number of individuals at time $t+1$. We used this framework to project population dynamics for six scenarios **F1**– **F6**, differing in temporal variability of recruitment. For scenario **F1** the probability of a high seedling recruitment years (h) being selected each time step t was 16.66%. Scenario **F1** mimicked the probability of high seedling recruitment years based on observed field conditions (i.e., 1 in 6 years). For scenarios **F2**– **F6,** we increased the probability that a high seedling recruitment year (h) was selected each time step t in order to simulate an increase in high recruitment by one year for each consecutive scenario. Scenarios **F2**– **F6** ranged from a 33% to a 100% probability of a high seedling recruitment year (h) being selected each time step t (i.e., 2 in 6 years). For all scenarios **F1**– **F6,** matrix **U** was selected with equal probability at each time step t from the pool of **U** matrices.

For scenarios **F1**– **F6,** we calculated the stochastic long-term growth rate λ_s by simulation, using 50,000 iterations following Tuljapurkar *et al* (2003):

$$\log\lambda_s = \lim_{t\to\infty}\left(\frac{1}{t}\right)\log\left[\mathrm{N}(t)/\mathrm{N}(0)\right], \quad (2)$$

where $\mathrm{N}(t)$ is the population size at time t, which is the sum of *n*(t) at a given time t. For each scenario, 95% bootstrap confidence intervals were calculated following methods outlined in Morris and Doak (2002). In addition to projecting the asymptotic stochastic population growth rate for scenarios **F1– F6**, we conducted stochastic elasticity analysis to identify the relative importance of perturbations in vital rates on the stochastic population growth rate λ_s with respect to perturbation of the mean and variance E^s (Tuljapurkar et al. 2003, Haridas and Gerber 2010).

This reintroduced population of *D. waianaeensis* was initiated with all large-sized individuals, and thus the population structure was initially far from its stable stage distribution. To project the stochastic transient population growth rate r_s for scenarios **F1–F6**, we simulated 10,000 independent sample paths of t = 10 years. For each scenario **F1–F6**, we altered the probability of a high (h) seedling recruitment year using the method described above. To mimic a plant reintroduction that is established using only reproductively mature individuals, we set the initial stage structure $n(0)$ to 100% reproductively mature individuals and 0 for the other life stages. Using a cohort of later life stages (e.g. reproductively mature individuals) is particularly relevant from an applied management perspective because reintroduced population are often established with later life stages since these individuals have the highest rate of initial establishment (Maschinski and Haskins 2012). To identify the relative importance of life stages on the stochastic transient population growth rate for scenarios **F1–F6** we conducted stochastic transient elasticity analysis e^s, which is composed of the instantaneous influence of a one time step change in vital rates e^1_{ij} and the long-term influence of perturbations in the stage structure e^2_{ij} (Haridas and Tuljapurkar 2007, Haridas and Gerber 2010).

Results

The long-term stochastic population growth rate λ_s for scenario **F1,** which represents the field recruitment rate (16.66% probability of high recruitment years)**,** was 0.967 (95% CI of 0.963 to 0.972), indicating that the population will decline by 3.3% per year (Figure 1b). A two-fold increase in the probability of high recruitment years from 17% to 33% (scenario **F2**) resulted in a stable population growth rate (λ_s =0.996 [0.995, 1.00]). A three-fold increase in the probability of high recruitment years from 17% (scenario **F1**) to 50% (scenario **F3**) shifted the long-term stochastic population dynamics from a 3.3% decline to a 2% increase in the population size per year ([λ_s =1.020, [1.015, 1.026]; Figure 1b). Similarly, the long-term stochastic population growth rates λ_s were > 1 for scenarios **F4**–**F6** (Figure 1b). Conversely, the reintroduced population of *D. waianaeensis* was projected to grow moderately in the near-term transient phase for all scenarios (Figure 1a).

The survival of mature plants (stasis) was projected to have the greatest impact on the long-term stochastic population growth rate for all scenarios **F1**–**F6** (Figure 2b). Increasing high recruitment years positively influenced the relative importance of the transition from seedling to small immature for the long-term population growth rate. However, this did not change the ranking of which life stage transition had the greatest effect on the population growth rate (Figure 2b). Similar to our results for the long-term stochastic elasticity analysis, survival of mature plants (stasis) had the greatest impact on the near-term population growth rate for scenarios **F1**–**F2** (Figure 2a). Interestingly, when the probability of high seedling recruitment years was ≥ 50% (i.e., scenarios **F3**–**F6**) seedling recruitment had a greater influence than mature plant survival on the near-term dynamics (Figure 2b).

Discussion

Few studies have used a demographic modeling approach to assess the likely outcome of rare species reintroductions (but see, Bell et al. 2003, Maschinski and Duquesnel 2007, Colas et al. 2008), and all of these have focused on the long-term asymptotic dynamics. However, to fully understand the likely outcome of rare species reintroductions it is critical to assess how these populations will fluctuate in the near-term transient phase prior to reaching a stable equilibrium. Previous studies that have examined the transient dynamics of newly established population have yielded mixed results. Plant populations of a culturally important non-timber forest product, *Alyxia stellata*, which was restored by augmentation of immature individuals, were projected to decline faster in the transient phase than over time (Wong and Ticktin 2015). Similarly, newly established populations of invasive species following seed dispersal were found to grow slower early in the invasion process than over time as later life stages filled in and the stages structure approaches equilibrium (Ezard et al. 2010). Conversely, following the exclusion of herbivores, which negatively affected fertility and earlier life stages, plant populations were projected to grow faster in the near term than in the long-term (Bialic - Murphy et al. 2017). In this study, we used five years of demographic data to compare the short and long-term dynamics of a multi-year reintroduction effort of a critically endangered long-lived shrub, *Delissea waianaeensis.*

For *D. waianaeensis*, we found that the population was projected to grow moderately over the next 10 years (Figure 1a). Conversely, the population was projected to slowly decline in the long-term (Figure 1b). This more optimistic short-term projection of plant dynamics is explained by the newly established population, which was dominated by large outplanted individuals. The higher growth rate in the transient phase than in the asymptotic phase can be explained by the high initial reproductive value of the population, which can cause population amplification prior to reaching a stable stage equilibrium (Stott et al. 2011). Since large individuals are more likely to survive and successfully establish a new population, conservation biologists typically use these individuals for reintroduction projects (Maschinski and Haskins 2012). For these reintroductions, our results suggest that short-term estimates of success should be interpreted with caution since transient dynamics will likely be more positive than long-term dynamics. This result is generalizable to other perennial plant reintroductions that are established with large outplanted individuals. Our results also demonstrate that the control of targeted environmental stressors and population reintroduction can lead to an increase in the short-term population growth rate but may not always be enough to establish new populations that will persist over time.

Previous studies have demonstrated that perturbations of earlier life stages are often more important in the transient phase than in the asymptotic phase (Fox and Gurevitch 2000, McMahon and Metcalf 2008, Haridas and Gerber 2010, Miller and Tenhumberg 2010, Bialic‐Murphy et al. 2017). It has also been shown that anthropogenic stressors can have a greater negative effect on the short-term population growth rate under more optimal abiotic conditions than less optimal abiotic conditions (Gaoue 2016). Consistent with previous studies, we found that the short and long-term population growth rates and the elasticity patterns for *D. waianaeensis* diverge and varied based on the probability of years with high recruitment. We also found that in order for

D. waianaeensis to persist over time would require doubling the probability of a high recruitment year from 17% (i.e., the observed field conditions) to 50% (Figure 1b). Additionally, we found that perturbation of the survival of reproductively mature *D. waianaeensis* was projected to have the greatest relative influence on the stochastic population growth rate (Figure 2b). Similarly, changes in the survival of mature plants were projected to have the greatest relative influence on the transient population growth for scenarios **F1**– **F2**. However, when the probability of high recruitment years was ≥ 50% (i.e., scenarios **F3**– **F6)**, perturbation of seedling recruitment, not mature plant survival, was projected to have the greatest influence on the transient population growth rate. These results are consistent with previous research, which illustrate that key vital rates, including survival and fertility, that contribute to asymptotic population growth also have a strong influence on transient dynamics (Stott et al. 2010). Thus, populations that grow faster in the long-term asymptotic phase are more likely to experience greater magnitudes of transient amplification (Stott et al. 2010). Combined, our results and previous studies illustrate that the relative importance of vital rates on the near term population growth rate is dependent, in part, on the level of habitat disturbance and variability of key life processes.

Environmental stochasticity can increase the risk of extinction (Tuljapurkar et al. 2003) and cause the short and long-term population to diverge (Stott et al. 2010). For *D. waianaeensis,* we found that seedling recruitment was temporally variable, with high seedling recruitment in 2009–2010 and low recruitment from 2010–2015 (ranging from 0.02–0.57) (Bialic-Murphy, Gaoue & Knight 2017). Considering the many sources of environmental stochasticity (e.g., changing abiotic conditions, boom-and-bust cycles of seedling herbivores), this variability in seedling recruitment was not surprising. However, our results emphasize the need to understand the mechanisms responsible for this variability in seedling recruitment, as this vital rate has a strong influence on the likely outcome of restoration efforts. As mentioned previously, we found that an increase in the probability of a high recruitment year from 17% to 50% would be required for the population to persist over time (Figure 1b). However, it should be noted that we did not account for potential autocorrelation of stochastic processes, which can strongly influence the dynamics of structured populations (Tuljapurkar and Haridas 2006, Gaoue et al. 2011) and should be a focus of future research.

Implementing conservation recommendations stemming from stochastic perturbation analysis can be challenging (Ehrlén and Groenendael 1998, Mills et al. 1999). Though perspective elasticity analysis is often used to indicate which demographic processes needs to be modified by management to maintain endangered species that will persist over time, these recommendations may not be feasible in a naturally variable environment and conservation biologists must adapt their strategy (Ehrlén and Groenendael 1998, Mills et al. 1999). In this study, we found that for scenarios that were projected to persist over time (scenarios **F3**– **F6**), management efforts aimed at increasing seedling recruitment were the most beneficial to the population when they occur early in the reintroduction process (i.e., while the population is experiencing transient dynamics) (Figure 2a). Conversely, for scenarios that were projected to decline over time (scenarios **F1**– **F2**), maintain high survival of mature plants in the transient phase was projected to be more important (Figure 2a). However, with relatively high *D. waianaeensis* mature plant survival there is little that can be done by management to improve this vital rate. Conversely, there are several potential management options to increase seedling recruitment, including suppression of invasive frugivores and herbivores.

Two of the primary invasive species that negatively influence recruitment of oceanic island species are black ship rat (*Rattus rattus*) and leopard slug (*Limax maximus*) (Joe and Daehler 2007, Shiels et al. 2014). Over the 2015 fruiting season, we found that black ship rats consumed 85% of *D. waianaeensis* mature fruits at the study site (Lalasia Bialic-Murphy, unpublished data). Furthermore, the leopard slug is a known non-native seedling herbivore in Hawaiʻi and has been documented at the study site (Joe and Daehler 2007, Kawelo et al. 2012). In Hawaii natural areas, the density of black ship rats (Shiels 2010) and leopard slugs (Stephanie Joe, personal communication) fluctuate from year-to-year. Thus, it is likely that the variable intensity of frugivory by black ship rats and seedling herbivory by leopard slugs are underpinning mechanisms driving temporal fluctuations in seedling recruitment. Considering the observed boom-and-bust cycles of black ship rats and leopard slugs, it is also likely that the probability of years with high *D. waianaeensis* recruitment would likely increase if conservation biologists prioritize the suppression of top-down stressors in years with high frugivory and herbivory pressure. Previous studies suggest that management actions that reduce boom-and-bust cycles of environmental stressors, such as non-native pests, can reduce the risk of extinction (Tuljapurkar et al. 2003) However, to fully understand the effects of black ship rats and leopard slugs on targeted vital rates and plant dynamics further investigation is needed.

This research has several applied restoration implications. First, our results illustrate that when later life stages are used to establish plant reintroductions, the population will grow faster in the transient phase than in the asymptotic phase as the stage structure reaches equilibrium (i.e., transient amplification) (Stott et al. 2011). Secondly, the effect of management action (e.g., increasing the survival of seedling or mature individuals) on the population growth rate depends on the timescale of interest and is context specific. Globally, this study illustrates that the removal of the most ubiquitous top-down stressors (e.g., non-native pigs) and population augmentation will not always be enough for species in degraded ecosystems to persist over time (i.e., long-term stochastic growth rate $\lambda > 1$). For these species, the suppression of other top down stressors needs to be considered. Furthermore, the results of this research emphasize how critical it is to evaluate both the near-term transient and long-term dynamics of endangered species in order to fully understand the likely outcome of species reintroduction efforts and develop effective restoration strategies.

Data Availability

Matrices used to simulate the transient and asymptotic population dynamics of each scenario 1-6 are deposited in Dryad.

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Figure Legend

Figure 1: Stochastic (a) transient and (b) asymptotic growth rates with 95% confidence intervals, calculated from 1000 bootstrap samples. For scenario **F1** (i.e., field conditions), the probability of high recruitment years was 17% (i.e., once every six years). For scenarios **F2**–**F6,** the probability of high recruitment increased by 17% for each consecutive simulation.

Figure 2: Stochastic (a) transient e^s and (b) asymptotic elasticity E^s to the mean and variance. Seedling (S); small immature > 40cm (SI); large immature, >40cm (LI); and mature signs of reproduction (M). For scenario **F1** (i.e., field conditions), the probability of high recruitment years was 17% (i.e., once every six years). For scenarios **F2**– **F6,** the probability of high recruitment increased by 17% for each consecutive simulation.

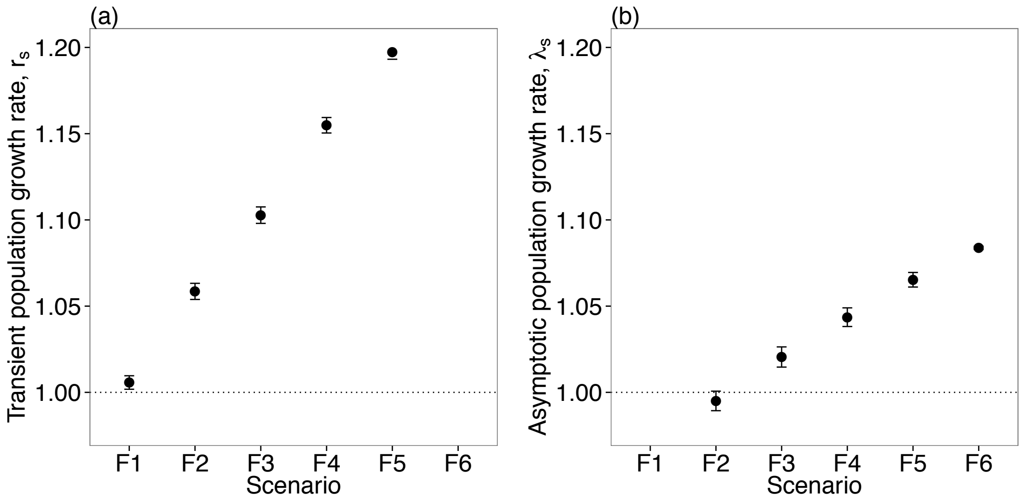
(a)
Transient population growth rate, r_s
1.20
1.15
1.10
1.05
1.00
F1
F2
F3
F4
F5
F6
Scenario
(b)
Asymptotic population growth rate, λ_s
1.20
1.15
1.10
1.05
1.00
F1
F2
F3
F4
F5
F6
Scenario

Figure 1

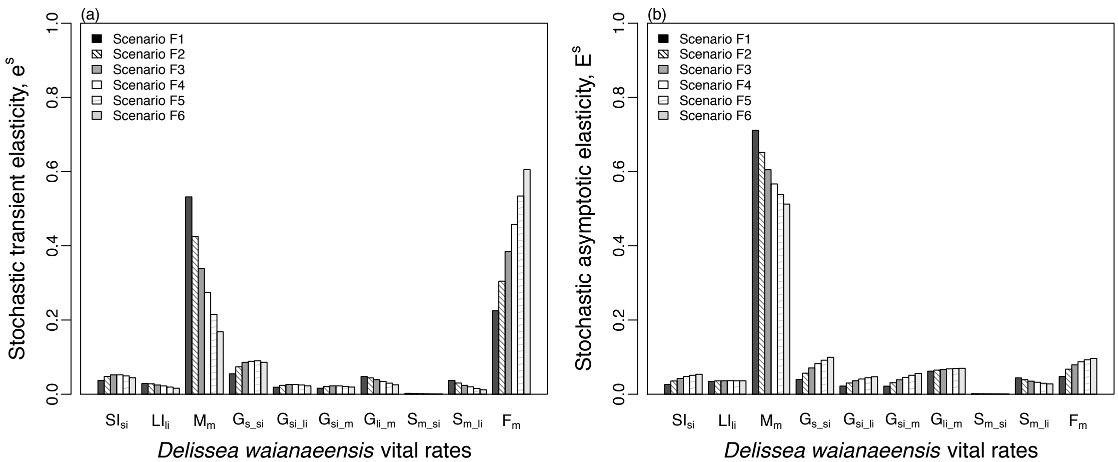
(a)
Scenario F1
Scenario F2
Scenario F3
Scenario F4
Scenario F5
Scenario F6
Stochastic transient elasticity, e^s
0.0
0.2
0.4
0.6
0.8
1.0
SI_si
LI_li
M_m
G_s_si
G_si_li
G_si_m
G_li_m
S_m_si
S_m_li
F_m
Delissea waianaeensis vital rates
(b)
Scenario F1
Scenario F2
Scenario F3
Scenario F4
Scenario F5
Scenario F6
Stochastic asymptotic elasticity, E^s
0.0
0.2
0.4
0.6
0.8
1.0
SI_si
LI_li
M_m
G_s_si
G_si_li
G_si_m
G_li_m
S_m_si
S_m_li
F_m
Delissea waianaeensis vital rates

Figure 2

Using Transfer Function Analysis to develop biologically and economically efficient restoration strategies

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Abstract

Rare species across taxonomic groups and biomes commonly suffer from multiple threats and require intensive restoration, including population reintroduction and threat control. Following reintroduction, it is necessary to identify what level of threat control is needed for species to persist over time. Population reintroduction and threat control are time intensive and costly. Thus, it is pragmatic to develop economically efficient restoration strategies. We combined transfer function analysis and economic cost analysis to evaluate the effects of biologically meaningful increases in demographic processes on the persistence of a reintroduced population of a Hawaii endemic long-lived shrub, *Delissea waianaeensis.* We show that a 41% increase in fertility following the suppression of non-native rodents or an 8% increase in seedling growth following the suppression of invasive molluscs would stabilize the population (i.e., $\lambda = 1$). Though a greater increase in fertility than seedling growth was needed for the reintroduced population to persist over time, increasing fertility by suppressing rodents was the most cost effective restoration strategy. Our study emphasizes the importance of considering the effects of large increases in plant vital rates in population projections and incorporating the economic cost of management actions in demographic models when developing restoration plans for endangered species.

Introduction

For extremely rare species, population reintroduction and the suppression of threats are commonly used restoration strategies to prevent imminent extinction [1]. The ultimate goal of these restoration strategies are to achieve long-term populations that will persistence over time [1]. However, the long-term persistence of reintroduced populations is alarmingly low [2]. Such a low rate of persistence is likely due to the widespread occurrence of threats that are difficult to manage, such as ecosystem disturbance and invasive species. In these altered landscapes, it is essential to identify which threats need to be suppressed, following species reintroduction, to achieve the desired outcome (i.e., population growth rate $\lambda \geq 1$). With limited funding for conservation and the high costs of species reintroduction and threat suppression, it is critically important to identify the most economically efficient restoration strategy.

Demographic population models combined with elasticity analysis are common tools that can identify which vital rate, if improved by management, would have the greatest effect on endangered plant population dynamics [3,4]. This analytical approach is a linear approximation of the relative importance of plant vital rates on population dynamics, and is therefore an appropriate tool for assessing the effect of small changes in vital rates on population growth rate. However, the relative importance of plant vital rates on population dynamics is dependent, in part, on the magnitude of the perturbation and this relationship is often nonlinear [4-6]. Thus, elasticity analysis may lead to suboptimal conclusions when prioritizing conservation actions that have large effects on targeted vital rates. Unlike elasticity analysis, transfer function analysis accounts for the nonlinear relationship between vital rates and population growth rates and is a more appropriate approach to evaluate the influence of changes in vital rates on the population growth rate at the magnitude of interest [7-9]. An additional benefit of transfer function analysis is the possibility of applying simultaneous perturbations on multiple vital rates [9]. For these reasons, transfer function analysis is particularly useful for evaluating conservation strategies for species threatened by multiple environmental factors.

When there are multiple combinations of management actions that would result in the desired outcome, it is also important to identify which strategy is the most cost effective. Some management actions require high upfront fixed costs (e.g., equipment costs) but low variable costs (e.g., continual ongoing maintenance) and others require low upfront costs but high variable costs. Thus, it is not always intuitive which strategy will be the most cost effective in the long-term. Though rarely used, demographic modeling provides an ideal framework to explicitly compare the economic cost of various management actions when developing restoration strategies but see, [10,11].

In a prior study, we evaluated the viability of a reintroduced population of the endangered Hawaiian shrub, *Delissea waianaeensis* Lammers (Campanulaceae) that is threatened by multiple factors including non-native ungulates, plants, rodents and molluscs. Removal of non-native ungulates and invasive plant management increase the population growth rate, but are not enough for this species to persist over time (Bialic-Murphy et al., submitted). In this study, we used transfer function analysis to develop economically efficient restoration strategies and identify which combination of environmental stressors need to be suppressed to ensure population persistence. Specifically, we (1) assessed the effect of changes in seedling growth and fertility on the population growth rate of *D. waianaeensis* across a range of biologically meaningful perturbations, (2) estimated the rate of increase in targeted vital rates that would be enough for *D. waianaeensis* to persist following the reduction in abundance of an invasive rodent and non-native molluscs, and (3) quantified the economic cost and efficiency to suppress the invasive rodent and non-native molluscs.

Results

To assess the ecological and economical effects of invasive rodent and non-native molluscs on the population dynamics, we used a combination of transfer function analysis and economic cost analysis. Our results demonstrate that the effects of vital rate perturbations on *D. waianaeensis* population growth rate were nonlinear across a range of biologically meaningful perturbations (Figure 1). Specifically, the change in population growth rate decreased as the perturbation of fertility, growth of seedlings, and shrinkage of mature plants increased (Figure 1). Conversely, the percent change in population growth rate increased as the perturbation magnitude in the stasis of all life stages and the growth of small vegetative plants increased (Figure 1). Considering only small perturbations, we found that the survival of mature plants would have the greatest effect on population dynamics (Figure 2). However, survival of mature plants in our study population is already high (86%) and cannot be improved further with management (Appendix S1, Figure S1.1). The two vital rates that can be improved by management, fertility and seedling growth, have the same elasticity value (Figure 3). However, a substantially larger increase in fertility (41%) than seedling growth (8%) was required to shift the population growth rate from declining to stable (i.e., $\lambda = 1$, Figure 3). There were also multiple combinations of increases in seedling growth and fertility that could achieve this desired outcome (Figure 3). Using transfer function analysis, we found that increases in fertility and seedling growth following threat control translated to an increase in population growth rate from 0.97 to 1.01 and from 0.97 to 1.05, respectfully. The relative marginal efficiency x of increasing fertility ϵ_f and seedling growth ϵ_s on population growth rate was 1.20 (*i.e.,* $x = \epsilon_f / \epsilon_s$), which indicates the suppression of *R. rattus* is more economically efficient than the suppression of molluscs.

Discussion

The long-term persistence of reintroduced populations is alarmingly low [2]. Thus, more threat management is necessary post-reintroduction to ensure the long-term persistence of most reintroduced species. In this context, it is critical that conservation biologists identify cost-effective combinations of restoration actions. Managing rare plant species native to oceanic islands is particularly challenging, as these species are typically threatened by numerous factors, some of which are more difficult to manage than others [12]. In this study, we used transfer function analysis and relative marginal efficiency to establish biologically meaningful and economically efficient post-reintroduction strategies for a long-lived shrub in Hawaii. This study contributes to a growing literature that finds that large perturbations in fertility and earlier life stages can have smaller effects on population growth rate than would be expected based on elasticity analysis, which considers small perturbations in vital rates [9].

Ignoring the biological limits in targeted vital rates when prioritizing restoration actions can also lead to ineffective management [13]. For example, Lubben, et al. [13] found that management recommendations based solely on elasticity analysis, which ignores biological limits, would indicate conservation biologists should focus on increasing the survival of adult Serengeti cheetah. However, when the magnitude of change in targeted vital rates were considered they found that multiple vital rates needed to be increased in order for Serengeti cheetah to persist, including the survival of adult and newborn cubs. For *D. waianaeensis,* it was critical to consider biological limits of vital rates perturbations to identify what part of the life cycle would have the greatest impact on population dynamics. Specifically, a greater increase in fertility (41%) than in seedling growth (8%) was needed to stabilize this reintroduced population (Figure 3). Thus, considering only the magnitude of change in vital rates needed to achieve a population growth rate λ=1 (i.e., cost negligent model), our results would suggest management should focus on improving seedling growth.

Seed consumption by rodents is an important threat to many rare species, especially for systems in which rodents are introduced [14-16], or occur at unnaturally high densities due to human modification of landscapes [17,18]. Similarly, seedling herbivory by molluscs poses a significant threat to native oceanic island plants, especially Campanulaceae species such as *D. waianaeensis* [12,19]. In this study, we found that management recommendations based on the results of cost-negligent model would suggest conservation biologists should focus on increasing seedling growth by suppressing molluscs. However, improving fertility by reducing fruit consumption by *R. rattus* would be more cost effective and should therefore be prioritized. There are several reasons for the higher economic efficiency of *R. rattus* control than mollusc control. First, there are large differences in management-induced changes in targeted vital rate follow threat control. While fertility can increase by up to 83% following the suppression of *R rattus*, seedling growth can only increase by up to 33% following the suppression of molluscs [12]. Secondly, it is less expensive to suppress rodents than it is to suppress molluscs. The lower cost of rodent suppression than mollusc suppression is due, in part, to the shorter duration of time that rodents need to be suppressed. While rodents only need to be suppressed during the *D. waianaeensis* fruiting season, molluscs need to be suppressed year round. Furthermore, technological advancements, such as the development of the self-resetting Goodnature A24 rodent traps, have improved the efficiency and reduced the labor hours needed to suppress rodents [20]. Similar technological advancements in mollusc control have not been achieved and should be a focus of future applied research and policy considerations. For *D. waianaeensis,* additional research is also needed to explicitly measure demography in other environments and the realized effects of managing both rodents and molluscs, since the response in vital rates used for our economic models were based on field experiments for related species [12,21]. Due to the extreme rarity of this species, we were limited in our ability to measure demography across space and to experimentally manipulate threats.

Numerous studies examined the effects of invasive pests on the demography of rare species [22]. Surprisingly, to our knowledge, only two other studies have directly linked the economic cost of targeted threat control actions to changes in the population growth rate of managed species [10,11]. These studies also found that incorporating the costs of targeted restoration explicitly in demographic models resulted in optimal management recommendations that diverged from the cost-negligent managed recommendations. For example, Baxter, et al. [10] found that elasticity analysis would focus on increasing the survival of the endangered Australian Helmeted Honeyeater, whereas cost-efficient management recommends would focus on increasing fecundity by reducing nest predation. The time is ripe for more demographic analyses that explicitly incorporate the cost of management actions for conservation planning. Many rare plant and animal populations have detailed demographic data and face multiple threats. Typically, approximate estimates for the economic costs of management are also readily available.

This study provides an example of how to develop efficient and effective management strategies for declining populations. Specifically, our study demonstrates the usefulness of transfer function analysis to set biologically meaningful increases in targeted vital rates that would be needed to reach a predefined restoration goal (e.g., population growth rate $\lambda \geq 1$). Further, when multiple management strategies could be used to reach the desired restoration outcome, our results illustrate the importance of incorporating the cost of targeted threat control actions in demographic models in order to optimize management efficiency. Considering the limited financial resources allocated to conservation and the continual increase in the listing of rare and at-risk species [23], using demographic models to identify the most economically efficient restoration strategy is becoming increasing desirable.

Methods

Study system

Delissea waianaeensis is a single or branched O'ahu endemic shrub typically reaching 1–3 m in height [24]. The fleshy fruit is an ovoid berry, with seeds that are 1.0–1.2 mm long and 0.4–0.6 mm wide [25]. Seed viability is relatively high, with a 95% mean germination rate [26]. The fleshy fruit is indicative of frugivorous bird dispersal [27].

We studied the demography of *D. waianaeensis* in the Central Kaluaa gulch of the Honouliuli Forest Reserve, in the northern Wai'anae Mountains of O'ahu (HON; 21° 28' N, -158°6' W). This *D. waianaeensis* population is a multi-year reintroduction effort, which has been actively managed for over a decade by the Nature Conservancy and the O'ahu Army Natural Resources Program (OANRP). Prior to plant reintroduction, an ecosystem level fence was constructed and feral ungulates were removed. At the site, there is also an ongoing suppression of invasive vegetation (for details see Bialic-Murphy et al., submitted). The two remaining biotic stressors faced by *D. waianaeensis* population are fruit-consuming black ship rat (*Rattus rattus*) and seedling-consuming non-native molluscs (Appendix S1, A). Both of these stressors are extremely disruptive to oceanic island ecosystems and are drivers of species decline and extinction [14,19].

Data collection and matrix construction

The life cycle of *D. waianaeensis* was categorized into four life stages based on height to the apical meristem: reproductively mature individuals (>35 cm), large immature (> 35 cm and non-reproductive), small immature (2 cm–35 cm), and seedling (< 2 cm). From 2010–2015, a total of 597 plants were permanently tagged and demographic data were collected annually in January–February. For each tagged plant we recorded survival, growth to the apical meristem, and reproduction (i.e., vegetative, flowering, or fruiting). Using these demographic data from 2010–2015, we constructed a mean 4x4 Lefkovitch transition matrix **A** (Caswell 2001):

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

The transition matrix **A** captures the probability of survival σ, the probability of growing to the next life stage γ, and seedling recruitment φ_m in the following discrete life stages: reproductively mature (*m*), large immature *(li*), small immature (*si*)*,* and seedling (*s*). The term φ_m is the mean total number of seedlings produced at time $t+1$ by the total number of reproductively mature plants at time t. Since we had an additional year of data for fertility, the φ_m term of matrix **A** is the mean fertility over six consecutive years (2009–2015). We calculated the population growth rate of *D. waianaeensis* as the dominant eigenvalue, λ, of matrix **A**. We analyzed the sensitivity of λ to perturbations in matrix elements, and elasticity analysis (i.e., proportional sensitivity) following equations in [28].

Transfer function analysis

The exact relationship between the magnitude of change (δ) in vital rates and the population growth rate λ is given by [29]:

$$\delta^{-1} = \mathbf{c}^{\mathrm{T}}(\lambda\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{d} \qquad \text{eqn 1}$$

where **A** represents the transition matrix and **I** is an identity matrix**.** The terms **c** and **d** represent row and column vectors that determine the specific vital rates that will be perturbed. The term δ denotes the magnitude of the perturbation. We used eqn 1 to quantify the response of population growth rate λ to a range in biologically meaningful perturbations δ [30], using the *popdemo* package (Stott et al. 2012b) in R version 3.1.0. We specifically tested the effects of biologically meaningful (a) increases in fertility φ_m following the suppression of $R.$ $rattus$, and (b) increases in seedling growth γ_s following the suppression of non-native molluscs on λ. We also identified the magnitude of perturbation δ for fertility φ_m and seedling growth γ_s that is needed to reach a stable population growth rate, $\lambda_{pert} = 1$ [29]. The range of biologically meaningful increases in fertility and seedling growth following threat control were determined using a combination of field experiments and the results of previous studies (Appendix S1, B).

Relative marginal efficiency

We calculated the marginal efficiency to suppress non-native molluscs or *R. rattus*, following [10]:

$$\epsilon_k = \frac{\partial \lambda}{\partial C_k} \qquad \text{eqn 2}$$

where $\partial C_k$is the change in cost for achieving a management action k (i.e., increase in targeted vital rate) and $\partial \lambda$ represents the change in the population growth rate following investment in management k. The later was calculated using eqn 1. The efficiency of two management actions, *n* and *m*, can be estimated by calculating the relative marginal efficiency $x = \epsilon_n/\epsilon_m$. If the relative marginal efficiency x is >1, then management action *n* is more efficient than *m*.

The costs to suppress *R. rattus* C_f and molluscs C_s were derived from the OANRP database and represent the average cost to suppress *R. rattus* and molluscs at other managed sites of comparable size to the *D. waianaeensis* site (Appendix S1, C). The suppression of *R. rattus* and molluscs both require an investment in variable costs (e.g., wages). The suppression of *R. rattus* also requires an upfront investment in fixed costs (e.g., equipment). To incorporate the cost of equipment needed to suppress *R. rattus* on a yearly basis, the fixed costs (e.g., equipment) were amortized over the lifespan of the equipment [31]. The total cost to suppress *R. rattus* C_f was calculated as the sum of the fixed and variable annual costs (Appendix S1, C).

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Data availability

Matrices used to simulate short and long-term population dynamics of each scenario are deposited on Dryad.

Supplementary information

1. Supp Appendix S1

2. Supp Figure S1.1

3. Suppl Figure S1.2

Figure captions

Figure 1: Transfer function analysis, where the black line illustrates the change in population growth rate across a range of biologically meaningful perturbations in the vital rates. The red line represents the slope of λ predicted from sensitivity. The vital rates are fertility (φ), survival (σ), growth (γ), and shrinkage (ε) and the life stages are seedling (S), small immature (SI), large immature (LI), and mature (M).

Figure 2: Elasticity analysis, which measures proportional sensitivity and is commonly used to assess how small perturbations in vital rates influence population growth rate. The vital rates are fertility (φ), survival (σ), growth (γ), and shrinkage (ε). The life stages are life stages are seedling (S), small immature (SI), large immature (LI), and mature (M).

Figure 3: Transfer function analysis, which was used to identify the combinations of increases in fertility and seedling growth that would shift the population growth rate from declining to stable. The red line represents a population growth rate $\lambda = 1$.

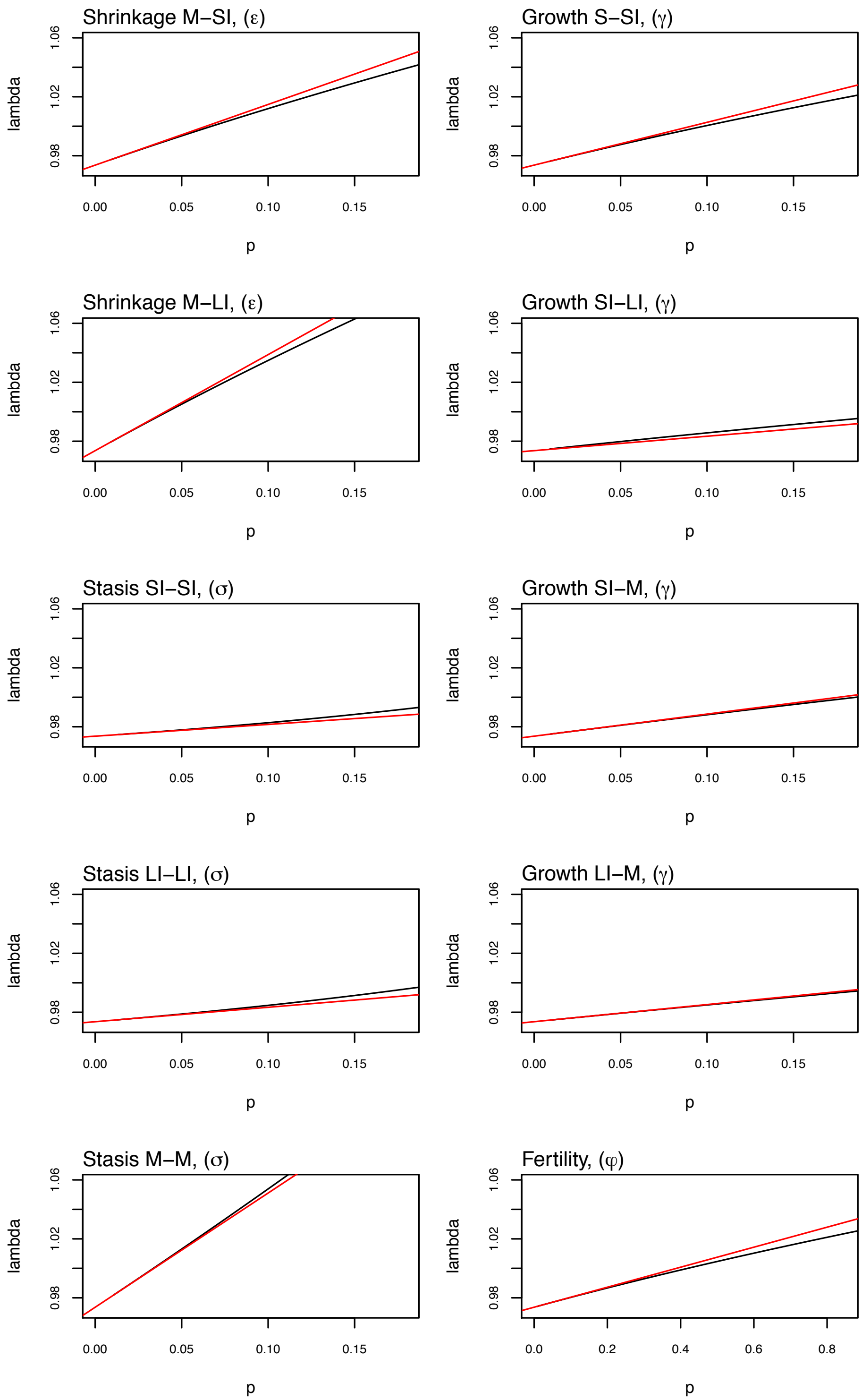
Shrinkage M–SI, (ε)
Growth S–SI, (γ)
Shrinkage M–LI, (ε)
Growth SI–LI, (γ)
Stasis SI–SI, (σ)
Growth SI–M, (γ)
Stasis LI–LI, (σ)
Growth LI–M, (γ)
Stasis M–M, (σ)
Fertility, (φ)
lambda
p
0.98
1.02
1.06
0.00
0.05
0.10
0.15
0.0
0.2
0.4
0.6
0.8

Figure 1

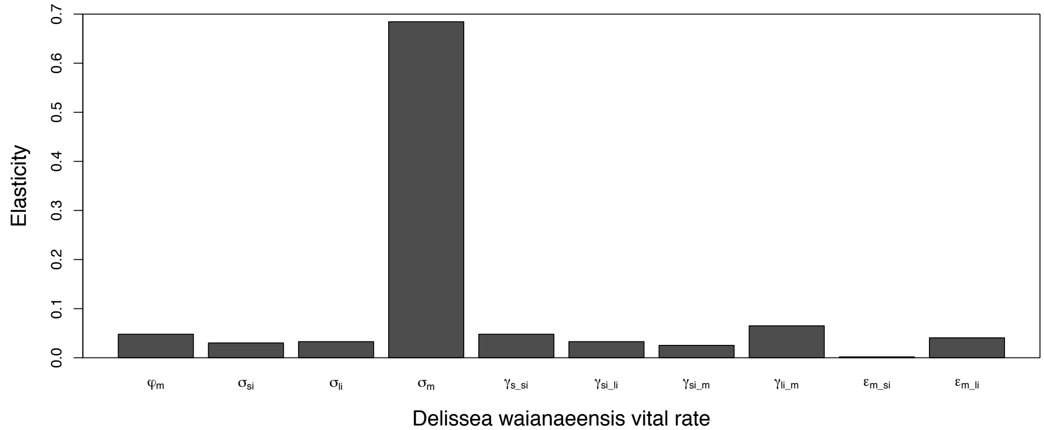
Elasticity
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
φm
σsi
σli
σm
γs_si
γsi_li
γsi_m
γli_m
εm_si
εm_li
Delissea waianaeensis vital rate

Figure 2

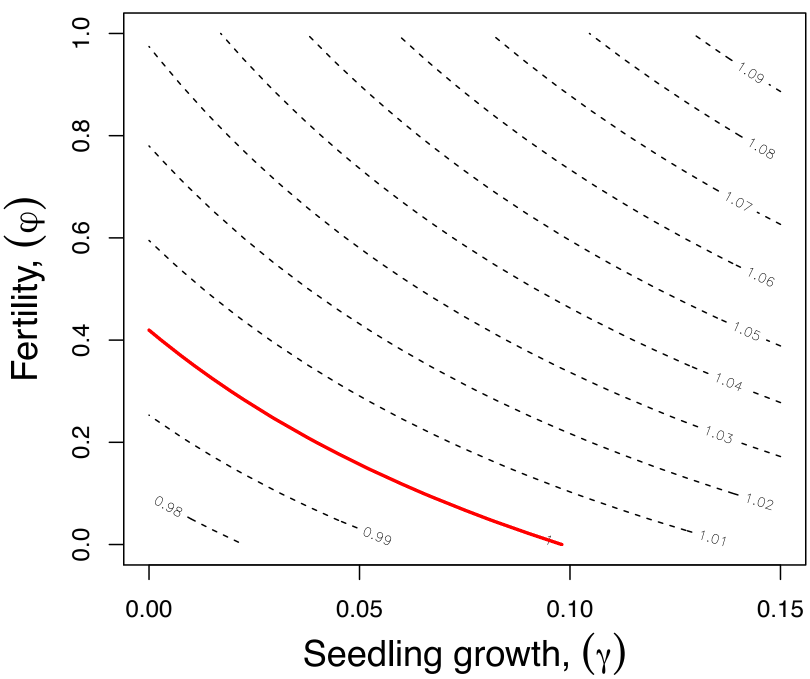

Figure 3

Supporting information for

Using Transfer Function Analysis to develop biologically and economically efficient reintroduction strategies

Appendix S1

A: Background information for *Rattus rattus* and non-native molluscs

Rattus rattus (black ship rat) is one of the most disruptive vertebrates to invade oceanic islands and often listed as a primary driver of population decline and extinction of native plants (Shiels et al. 2014; Towns et al. 2006). The estimated home range of *R. rattus* is 4 ha (Shiels 2010).When foraging, *R. rattus* are the most active in areas with thick understory vegetation cover 10–30 cm in height (Shiels 2010). *Rattus rattus* dens are often below ground in soil and fractured rock substrate, under logs, in thick understory vegetation, and inside partially dead trees (Shiels 2010). Thought *R. rattus* are omnivores, seeds and fruits are the dominant portion of their diet (Shiels et al. 2014). Following consumption and digestion by *R. rattus*, small seeds (0.5–1.2 mm) remain intact and viable (Shiels & Drake 2011). The relatively small size of *D. waianaeensis* seeds (1.0–1.2 mm) suggests that *R. rattus* do not alter seed viability of this taxon following consumption and digestion. However, the large home range, den characteristics, and foraging behavior of *R. rattus* imply *D. waianaeensis* seeds consumed by *R. rattus* are deposited in unsuitable habitat for seedling establishment.

The establishment of non-native molluscs (Mollusca: Gastropoda) is often implicated in the decline of oceanic island species (Cowie et al. 2009; Joe & Daehler 2007). Molluscs are generalist herbivores, primarily consuming foliage on the forest floor. In Hawaii, a total of 12 different non-native mollusc species have established throughout natural areas (Cowie 1999; Cowie 1997). In mesic to wet forest communities in Hawaii, terrestrial molluscs significantly reduce the density of numerous native seedlings and thus, the suppression of non-native molluscs is often incorporated as part of the recovery strategy for endangered species (Joe & Daehler 2007; Kawelo et al. 2012).

B: Range of biologically meaningful perturbations in targeted vital rates

The range of biologically meaningful perturbations that we used for this study was determined using a combination of field experiments and the results of previous studies. To set a realistic range of increases in fertility φ_m following the suppression of *R. rattus*, we quantified the percent of fruits consumed and the identity of the consumer using a modified version of the methods developed by Pender et al. (2013). Given there are other potential frugivores that may consume *D. waianaeensis* fruits, including native and non-native birds, tracking tunnels were used to isolate the effects of *R. rattus* on fertility. Specifically, we installed 24 tracking tunnels at equal distance along four transects (50 cm x 10 cm x 10 cm; Connovation Limited, Auckland, New Zealand), with tracking cards inserted (The Black Trakka Gotcha Traps LTD, Warkworth, New Zealand) (Figure S1.1). The four transects spanned the length of the *D. waianaeensis* population; capturing intrapopulation habitat heterogeneity. Each tracking tunnel was baiting with one mature fruit and checked at a two-day interval. On each visit, fruit consumption was recorded and the tracking tunnels were re-baited. The footprints left on the tracking cards each visit were used to identify the frugivore consuming *D. waianaeensis* fruits (Figure S1.1). In total, the tracking tunnels were baited five times during the 2015 fruiting season. In this field experiment, we found that the mean *R. rattus* frugivory rate was 83%. To mimic the impact of *R. rattus* on fertility and population dynamics, we used the mean number of *D. waianaeensis* fruits consumed at our field site to set the range of biologically feasible increases in φ_m (i.e., 1%–83%) that could be achieved by suppressing *R. rattus.* The proportion of fruits consumed by *R. rattus* at the *D. waianaeensis* population was consistent with previous studies that have examined the effect of *R. rattus* on the fertility of a related taxon in the Campanulaceae group, *Cyanea superba* ssp. *superba* (Pender et al. 2013).

To set a range of biologically meaningful increases in seedling growth γ_s following the suppression of non-native molluscs, we used the results of a previous field experiment (Kawelo et al. 2012). In this experiment, 200 seeds of three localized Hawaiian endemic species (*Cyanea superba* ssp. *superba, Cyrtandra dentata, and Schiedea obovata*) were sown on the top layer of soil in 12 plots, 15m x 15m in diameter. Six plots were treated with a molluscicide, Sluggo (Neudorff Co., Fresno, California), and the other six plots were left exposed to normal herbivory intensity at the field site. The density of seedlings in each plot was recorded on a weekly basis for six weeks. This study illustrated that non-native molluscs significantly reduced seedling density of localized endemic plants by up to 33% (Kawelo et al. 2012). The range of biologically feasible increases in γ_s following the suppression of non-native molluscs that we used in our study was 1%–33%.

C: Cost of management actions

To suppress *R. rattus* at the *D. waianaeensis* field site would require 20 Goodnature A24 self-resetting multi-species kill traps (Tyler Bogardus, personal communication). The per unit cost of the Goodnature A24 self-resetting multi-species kill trap was $125 and the lifespan of the traps was 10–15 years (Tyler Bogardus, personal communication). The total field time needed to setup the *R. rattus* trap grid and maintain it over one *D. waianaeensis* fruiting season was 60 hours ($25.92 per hour x 60 hours = $1,555.2; Oahu Army Natural Resources Program, unpublished data). The total yearly field time needed to suppress molluscs was 176 hours ($25.92 per hour x 176 hours = $4,562; Oahu Army Natural Resources Program, unpublished data). The lower total field time needed to suppress *R. rattus* than to suppress molluscs is due, in part, to the shorter duration of time that *R. rattus* needs to be suppresses. While *R. rattus* only needs to be suppressed during the *D. waianaeensis* fruiting season, molluscs need to be suppressed year round. The fixed cost of equipment to suppress *R. rattus* was $2,500 (i.e., 20 Goodnature A24 rodent traps x $125 per trap). However, when amortized over the lifetime of the equipment (i.e., 10 years), the yearly equipment cost to suppress *R. rattus* was $250. Including labor costs, the total yearly cost to suppress *R. rattus* (i.e., yearly fixed cost of equipment and labor costs) was $1,805. For mollusc suppression, there is no upfront fixed cost of equipment and the total yearly labor cost was $4,562.

Figures

Figure S1.1: The image to the left is a photo of the tracking tunnels (50 cm x 10 cm x 10 cm; Connovation Limited, Auckland, New Zealand) used to quantify fruit consumption by *Rattus rattus*. The image to the right is a tracking card (The Black Trakka Gotcha Traps LTD, Warkworth, New Zealand) with footprints of *Rattus rattus* following fruit consumption.

	S	SI	LI	M
S	0.000	0.000	0.000	0.687
SI	0.161	0.368	0.000	0.004
LI	0.000	0.188	0.326	0.061
M	0.000	0.163	0.544	0.860

Figure S1.2: Mean yearly transition matrix for of *Delissea waianaeensis.* The life stages are life stages are seedling (S); small immature > 40cm (SI); large immature, >40cm (LI), and mature signs of reproduction (M).

Appendix ES-8
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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 (σ_i), growth to the next stage class (γ_i), and fecundity (φ_m). Fecundity (φ_m) was calculated by dividing the number of seedlings counted in a given year by the number of mature plants the

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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 (σ_m = 47%) was lower than to the other transition years (σ_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 σ_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 φ_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 φ_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 φ_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 φ_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 λ_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 λ_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 λ_s of each scenario (**A**, **B**, **C**, and **D**). To identify the relative importance of different life stages on the stochastic population growth rate λ_s for each scenario, we calculated the elasticity $E^{\mu S}$ of λ_s to perturbation of mean matrix elements μ_{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.

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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 (λ_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% (λ_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 (λ_s = 0·968, 95% CI [0·964–0·971]). The combined influence of both stressors (scenario **D**) decreased the stochastic population growth rate (λ_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

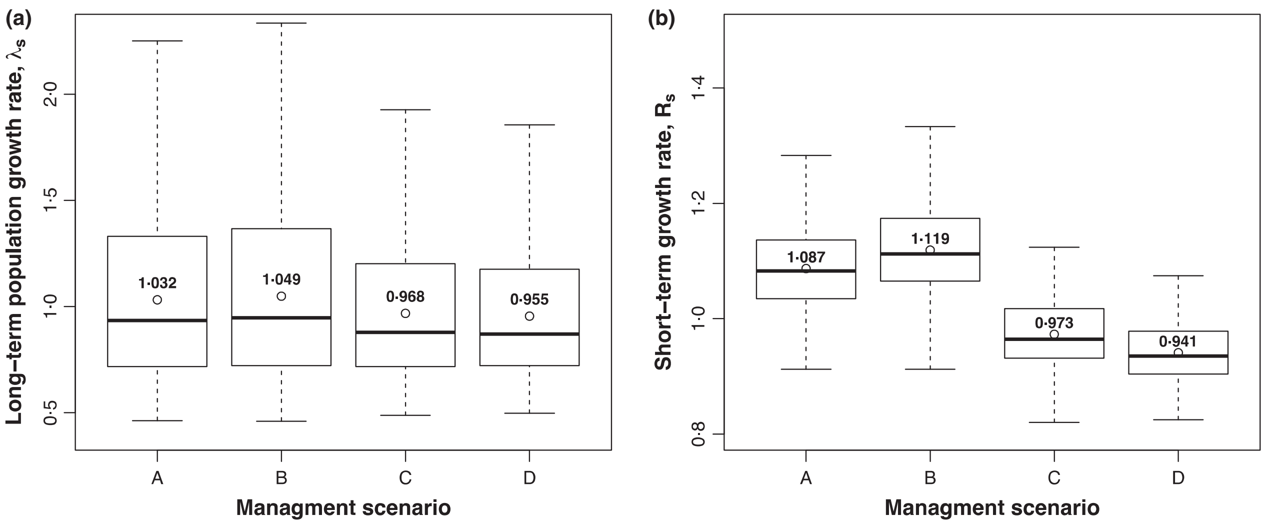

Fig. 1. Stochastic short (R_s) and long-term (λ_s) population growth rates of *Cyrtandra dentata*. The black bar is the median and the boxes represent the inter-quartile range. The limits of the whiskers are 1·5× the inter-quartile range. The open circle is the mean of each management scenario. Scenario **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.

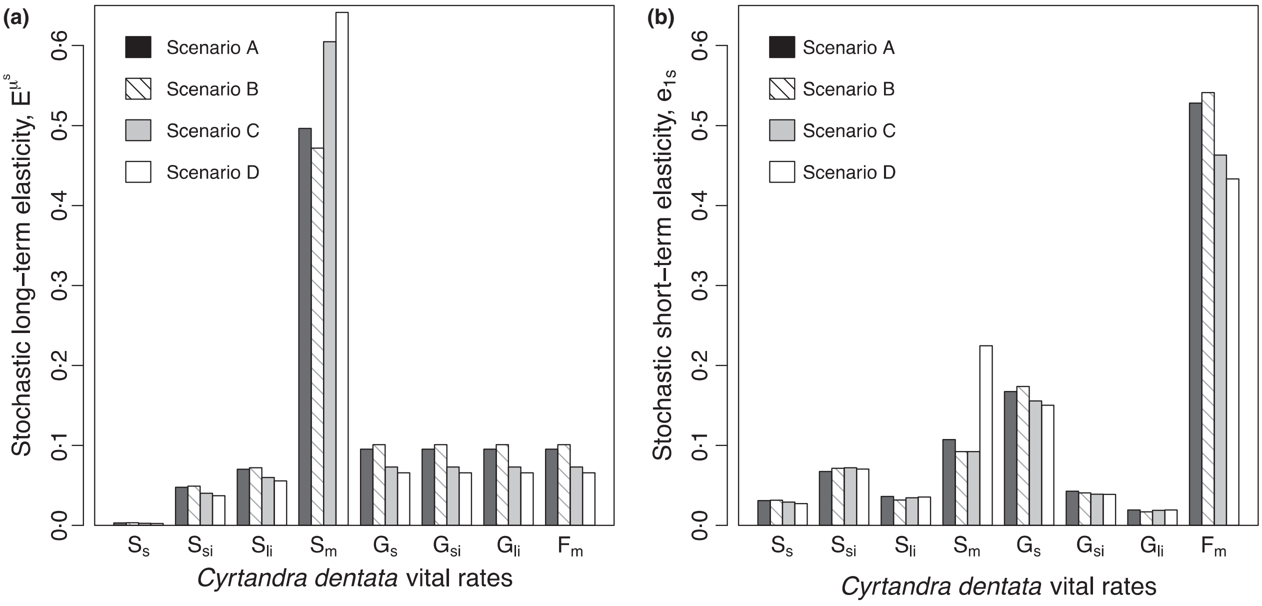

Fig. 2. Stochastic elasticities of *Cyrtandra dentata* (a) long- and (b) short-term growth rates to perturbation of mean vital rates. The vital rates are survival (S), growth (G), and fertility (F) and the life stages are seedling (*s*), small immature (*si*), large immature (*li*), and mature (*m*). 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

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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).

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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.

Introduction

Recent evolutionary radiations on island chains such as the Hawaiian Islands can provide insight into evolutionary processes, such as genetic drift and adaptation (Wallace 1880, Grant and Grant 1994, Losos and Ricklefs 2009). For limited mobility species, colonization processes hold important evolutionary stories not just among islands, but within islands as well (Holland and Hadfield 2002, Parent 2012). One such radiation produced at least 91 species of Hawaiian tree snails in the endemic subfamily Achatinellinae, on at least five of the six main Hawaiian Islands: Oʻahu, Maui, Lanaʻi, Molokaʻi, and Hawaiʻi (Pilsbry and Cooke 1912–1914, Holland and Hadfield 2007). As simultaneous hermaphrodites with the ability to self-fertilize, colonization events among islands may have occurred via the accidental transfer of a single individual by birds (Pilsbry and Cooke 1912–1914), or via land bridges that connected Maui, Molokai, and Lanai at various points in geologic history (Price and Elliot-Fisk 2004). Early naturalists attributed speciation solely to genetic drift, noting that this subfamily was "still a youthful group in the full flower of their evolution" (Pilsbry and Cooke 1912–1914). However, as these species evolved over dramatic precipitation and temperature gradients, natural selection and adaptation may have been quite rapid as species expanded to fill unexploited niches along environmental gradients, early in this subfamily's history. As such, species in the subfamily Achatinellinae provide an excellent system for examining both neutral and adaptive processes of evolution.

Habitat loss, predation by introduced species, and over-harvesting by collectors led to the extinction of more than 50 species in the subfamily Achatinellinae, and resulted in the declaration of all remaining species in the genus *Achatinella* as Endangered (Hadfield and Mountain 1980; U.S. Fish and Wildlife Service 1981; Hadfield 1986). Of these, *Achatinella mustelina* (Mighels 1845) is the most abundant and locally widespread, with at least 2000 individuals remaining in the wild.

A study of *A. mustelina* based on a single barcoding gene, cytochrome oxidase I (COI), synonymized many of the subspecies that had been characterized based on shell morphology, and identified six evolutionarily significant units (ESUs) whose distribution generally correlated with geographic features such as ridgelines (Holland and Hadfield 2002). In the last twenty years the field of genetics has transitioned from this type of single or multi-gene study to genomic methods (Stapley et al. 2010), but many researchers working on non-model organisms have been left out of this revolution (Garvin et al. 2010). Reduced-representation sequencing has made genomic approaches more affordable for those working on non-model organisms (Helyar et al. 2011, Toonen et al. 2013). This total information approach includes thousands of sites from across the genome, and may generate better-resolved phylogenies (Rokas et al. 2003), improving the management of endangered species that previously lacked this high-resolution information (Harrison and Kidner 2011).

In this study we had several goals. First, we examined whether the relationships uncovered utilizing a single barcoding gene, cytochrome oxidase I (Holland and Hadfield 2002), were consistent with relationships identified using whole mitochondrial genome comparisons. Next, we asked whether mitochondrial relationships were consistent with those that were found utilizing a genome-wide approach in which thousands of variable sites (single-nucleotide polymorphisms, or SNPs) were examined across the genome (Toonen et al. 2013). We asked whether these relationships among populations of *A. mustelina* were consistent with population-level or species-level relationships, by constructing mitochondrial and SNPs-based phylogenies that included species in all four genera within the subfamily Achatinellinae (*Achatinella, Newcombia, Partulina, Perdicella*), as well as from two genera within the family, but outside of the subfamily Achatinellinae (*Auriculella*, *Tornatellides*).

Methods

Field Sites, Sample Collection, and Preparation. The current range of *Achatinella mustelina* extends about 25 kilometers north to south in the Waianae Mountain Range along elevational clines of 450–

1200 m (Holland and Hadfield 2007). These elevational clines correlate with rainfall and temperature, with a rainshadow effect between the windward and leeward sides of the mountain range.

Sample collection and DNA extraction. Between October 2014 and June 2016 small tissue samples were collected in a nonlethal manner from 4–50 individuals per population and individually preserved in 100% ethanol until DNA extraction (Thacker and Hadfield 2000). DNA was individually extracted from tissue samples using a DNeasy Blood and Tissue Kit (Qiagen) according to the manufacturer's protocol. Extracted DNA was quantified using the Biotium AccuClear Ultra High Sensitivity dsDNA quantitation kit with 7 standards. Equal quantities of DNA from each individual within a population were pooled to a total of 1 µg. From these pools, libraries were prepared for genome scanning using the ezRAD protocol (Toonen et al. 2013) version 2.0 (Knapp et al. 2016). Samples were digested with the frequent cutter restriction enzyme DpnII from New England Biolabs®. They were then prepared for sequencing on the Illumina® MiSeq using the Kapa Biosystems Hyper Prep kit following the manufacturers guidelines with the exception of the size selection, which was modified to select for DNA fragments between 350–700 bp. All samples were amplified after size selection for the recommended cycles to generate 1 µg of adapter-ligated DNA. Once complete, all libraries were run on a bioanalyzer and with qPCR to validate and quantify them to ensure equal pooling on the MiSeq flow cell. Quality control checks and sequencing were performed by the Hawaii Institute of Marine Biology Genetics Core Facility.

After cleaning and pairing forward and reverse reads we obtained a total of 301,350,630 sequences from 22 populations of *A. mustelina*, as well as between one and six populations of 24 other species from five genera (Table 1).

Table 1. Populations and species sequenced in this project (*Achatinella mustelina*) and in a concurrent project funded through the Hawaii Division of Forestry and Wildlife (DOFAW; all other species).

Subfamily	Genus	Species	Code	ESU	Population
Achatinellinae	*Achatinella*	*apexfulva*	AAP1		
Achatinellinae	*Achatinella*	*bulimoides*	ABU1		
Achatinellinae	*Achatinella*	*concavospira*	ACO1		
Achatinellinae	*Achatinella*	*decipiens*	ADE1		
Achatinellinae	*Achatinella*	*fulgens*	AFUL1		
Achatinellinae	*Achatinella*	*fulgens*	AFUL2		
Achatinellinae	*Achatinella*	*fuscobasis*	AFUS1		
Achatinellinae	*Achatinella*	*lila*	ALI2		
Achatinellinae	*Achatinella*	*lila*	ALI1		
Achatinellinae	*Achatinella*	*lila*	ALI3		
Achatinellinae	*Achatinella*	*mustelina*	AMU1	ESUA	Kahanahaiki
Achatinellinae	*Achatinella*	*mustelina*	AMU2	ESUA	Pahole
Achatinellinae	*Achatinella*	*mustelina*	AMU3	ESUB	Koiahi
Achatinellinae	*Achatinella*	*mustelina*	AMU4	ESUB	Ohikilolo
Achatinellinae	*Achatinella*	*mustelina*	AMU5	ESUB	Culvert 39
Achatinellinae	*Achatinella*	*mustelina*	AMU6	ESUB	Culvert 56/57
Achatinellinae	*Achatinella*	*mustelina*	AMU7	ESUC	Skeet Pass
Achatinellinae	*Achatinella*	*mustelina*	AMU8	ESUC	Haleauau
Achatinellinae	*Achatinella*	*mustelina*	AMU9	ESUD	SBW-R
Achatinellinae	*Achatinella*	*mustelina*	AMU10	ESUD	Makaha
Achatinellinae	*Achatinella*	*mustelina*	AMU11	ESUD	Puu Hapapa
Achatinellinae	*Achatinella*	*mustelina*	AMU12	ESUD	Puu Kalena
Achatinellinae	*Achatinella*	*mustelina*	AMU13	ESUD	Puu Kumakalii
Achatinellinae	*Achatinella*	*mustelina*	AMU14	ESUE	Ekahanui
Achatinellinae	*Achatinella*	*mustelina*	AMU15	ESUF	Palikea
Achatinellinae	*Achatinella*	*mustelina*	AMU16	ESUE	H1-H4 Huliwai
Achatinellinae	*Achatinella*	*mustelina*	AMU17	ESUE	NH1-NH4
Achatinellinae	*Achatinella*	*mustelina*	AMU18	ESUD	K1-K6
Achatinellinae	*Achatinella*	*mustelina*	AMU19	ESUD	S1-S6
Achatinellinae	*Achatinella*	*mustelina*	AMU20	ESUB	Kaawa 1-13
Achatinellinae	*Achatinella*	*mustelina*	AMU21	ESUD	MAK-G 1-15
Achatinellinae	*Achatinella*	*mustelina*	AMU22	ESUD	MAK-F 1-7
Achatinellinae	*Achatinella*	*sowerbyana*	ASO1		
Achatinellinae	*Achatinella*	*sowerbyana*	ASO2		
Achatinellinae	*Achatinella*	*sowerbyana*	ASO3		
Achatinellinae	*Achatinella*	*sowerbyana*	ASO4		
Achatinellinae	*Achatinella*	*sowerbyana*	ASO5		
Achatinellinae	*Achatinella*	*sowerbyana*	ASO6		
Achatinellinae	*Achatinella*	*sp. Oahu*	AUN1		
Achatinellinae	*Newcombia*	*cumingi*	NCU1		
Achatinellinae	*Partulina*	*mighelsiana*	PMI1		

Subfamily	Genus	Species	Code
Achatinellinae	*Partulina*	*perdix*	PPE1
Achatinellinae	*Partulina*	*perdix*	PPE2
Achatinellinae	*Partulina*	*physa*	PPH1
Achatinellinae	*Partulina*	*proxima*	PPR1
Achatinellinae	*Partulina*	*proxima*	PPR2
Achatinellinae	*Partulina*	*proxima*	PPR3
Achatinellinae	*Partulina*	*redfieldii*	PRE1
Achatinellinae	*Partulina*	*redfieldii*	PRE2
Achatinellinae	*Partulina*	*redfieldii*	PRE3
Achatinellinae	*Partulina*	*redfieldii*	PRE4
Achatinellinae	*Partulina*	*semicarinata*	PSE1
Achatinellinae	*Partulina*	*terebra*	PTER1
Achatinellinae	*Partulina*	*tesselata*	PTE1
Achatinellinae	*Partulina*	*variabilis*	PVA1
Achatinellinae	*Perdicella*	*helena*	PHE1
Achatinellinae	*Perdicella*	*helena*	PHE2
Achatinellinae	*Perdicella*	*sp.* Maui	PER1
Auricullelinae	*Auriculella*	*sp.*	AUR1
Auricullelinae	*Auriculella*	*sp.*	ACR1
Tornatellidinae	*Tornatellides*	*iridescens*	TIR1

Mitochondrial Genomes. Utilizing the data from 15 populations of *A. mustelina*, we assembled the complete mitochondrial genome of *A. mustelina* (GenBank accession number KU525108). Reads (69,178,116 sequences) were initially mapped to the reference mitogenome of *Albinuria coerulea* (Hatzoglou et al. 1995). The alignment of mapped sequences was inspected, and a consensus sequence was generated. This consensus sequence was used as a reference for the next iteration, in which all ~69 million sequences from a given population were mapped against the consensus sequence achieved in the previous round of alignment. This process was repeated until the complete mitochondrial genome was obtained. In total, 30,695 reads mapped to the complete mitochondrial genome, with coverage ranging from 10x to 4409x per site (256 ± 50). Annotation of mitochondrial elements was carried out with DOGMA (Wyman et al. 2004) and MITOS (Bernt et al 2013).

Once the *Achatinella mustelina* mitogenome was obtained, reads for populations of other species were mapped to the reference mitogenome of *Achatinella mustelina* (Price et al. 2016).

Through an iterative process, whole and partial mitogenomes of all populations were constructed. In total, 969–7474 reads per population mapped to the complete mitochondrial genome, with coverage ranging from 1X to 1030X per site (46.3 ± 73.6). Annotation of mitochondrial elements was carried out with DOGMA (Wyman et al. 2004) and MITOS (Bernt et al 2013). Multiple sequence alignments were performed with MUSCLE v3.8.31 (Edgar 2004) under default parameters, visual inspection of the alignment found no regions that appeared to be poorly aligned. Maximum likelihood trees were generated with RAxML v. 8.1.16 (Stamatkis 2014) with the GTRGAMMA model and optimization of rate parameters and bootstrap support values based on 500 replicates.

Genome-wide Analyses. Initial trials were conducted with the programs pyRAD or ipyRAD, however these large ezRAD libraries (~6 million reads up to 300bp long) were slow to process due to the high number of loci (a single library took up to a month to process on a high-end work station). The dDocent pipeline v. 2.2.19 was used to process raw reads with several steps modified in order to quickly process a large number of libraries (n=59), and to account for pooled populations. *De-novo* assembly was first performed on members of the *Achatinella* genus (n=39) in order to construct a reference sequence for reference mapping against the total dataset. The *de-novo* assembly options were: Clustering_Similarity% = 0.85, Mapping_Reads? = Yes; Mapping_Match_Value = 1; Mapping_MisMatch_Value = 4; Mapping_GapOpen_Penalty = 6. All libraries were mapped to the *Achatinella* reference using mapping parameters as above. The program Freebayes v1.0.2-29 was used to call variants from the merged bam file produced by the dDocent pipeline, with stringent filters, ignoring multi-nucleotide polymorphisms and complex events, under the pooled continuous model with a minimum coverage of 5 reads (i.e. -0 -E 3 -z .1 -X -u -n 4 -K --min-coverage 5 --min-repeat-entropy 1 -V). The resulting vcf file was examined in R (R Development Core Team 2011), using the heatmap.bp function in the package vcfR (Knaus and Grunwald 2017) in order to evaluate coverage across libraries and loci (Figure S1), which was fairly even with the exception of the outgroups and few libraries with very low coverage that were dropped from further analysis using VCFtools (Danacek et al. 2011). VCFtools which was also used to determine depth and heterozygosity information of the libraries. For phylogenetic analysis, the SNPhylo (Lee et al. 2014) was used in order to generate a fasta formatted file containing variable positions. The number of sites was higher than allowed by the automated pipeline, and subsets of the data were analyzed under a broad array of program settings; however these trees generally resulted in low support values and odd placements of taxa (results not shown) therefore, trees were generated with RAxML v. 8.1.16 with the GTRGAMMA model and optimization of rate parameters and bootstrap support values based on 500 replicates.

Results

Mitochondrial genomes. The *Achatinella mustelina* mitogenome is similar to those of other Pulmonates (White et al. 2011), with 13 protein-coding genes, two rRNA genes, and 22 tRNA genes. The total length is 16,323 bp, slightly larger than other Pulmonates (White et al. 2011). The base composition of the genome is: A (34.7%), T (42.6%), C (12.7%), and G (10.0%). This is the first mitochondrial genome sequenced within the Achatinelloidea superfamily (Price et al. 2016).

When whole and partial mitochondrial genomes were compared across populations within *A. mustelina*, for the most part, the same patterns were observed as in previous studies using only one mitochondrial gene (Fig. 1ab). However, some of the populations near previously identified ESU boundaries grouped in slightly different ways. For example, samples from several populations thought to be ESU D clustered with the samples from Ekahanui (ESU E). When analyses of mitochondrial genomes included all species, the differentiation among populations in ABC and those in DEF appeared to be consistent with species-level differences among other species (Fig. 1a). Overall, populations grouped into five or six clusters, consistent with ESUs ABCDEF. Populations in ESUs ABC grouped together, and populations in ESUs DEF grouped together, with strong support values (Fig. 1b).

Total information approach. When thousands of sites from across the genome were used to examine relationships, patterns generally followed ESU patterns, with a few exceptions. The Makaha population ("AMU10") grouped with ESU B populations, rather than ESU D populations (Figure 2). When all 59 samples were analyzed using the total information approach, patterns were similar over all, but there were low support values on multiple branches within *A. mustelina* (Figure 3).

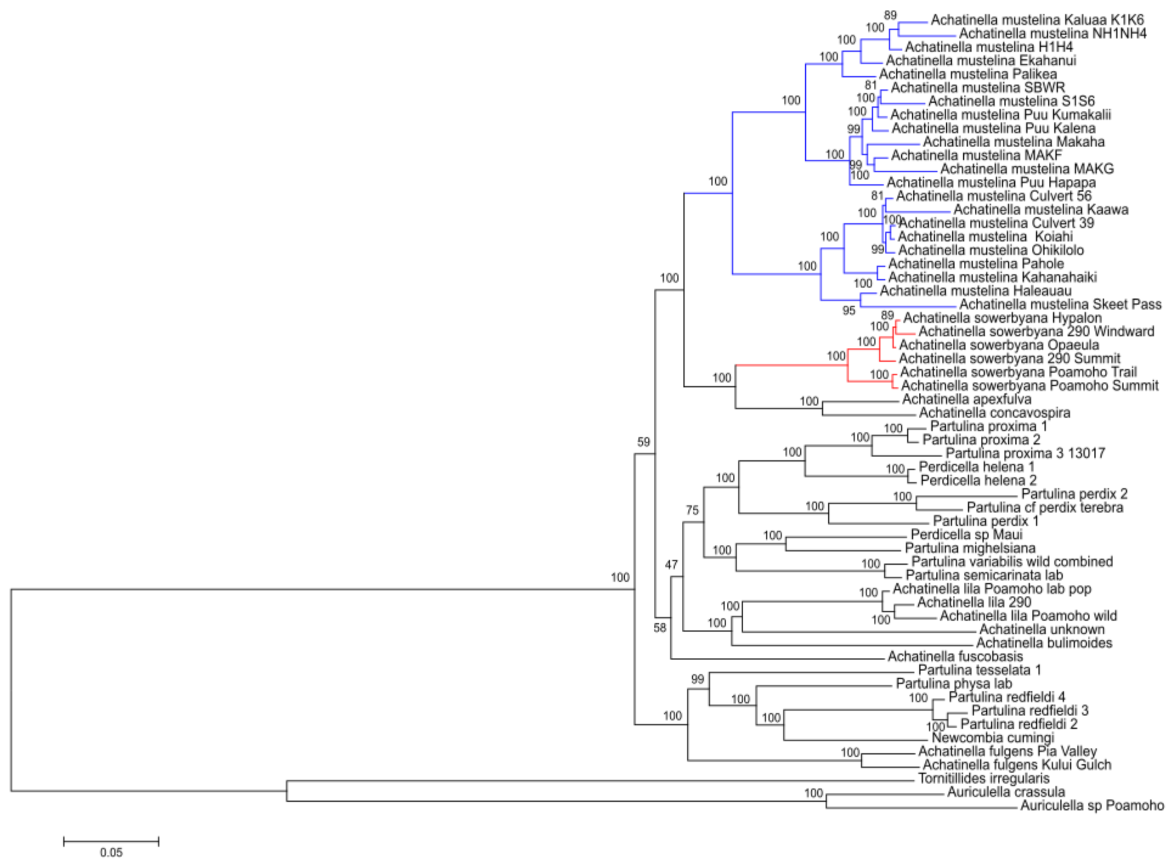


Figure 1a. Mitochondrial tree with all populations and species sequenced, including 22 populations of *Achatinella mustelina* and 37 populations representing 24 additional species.

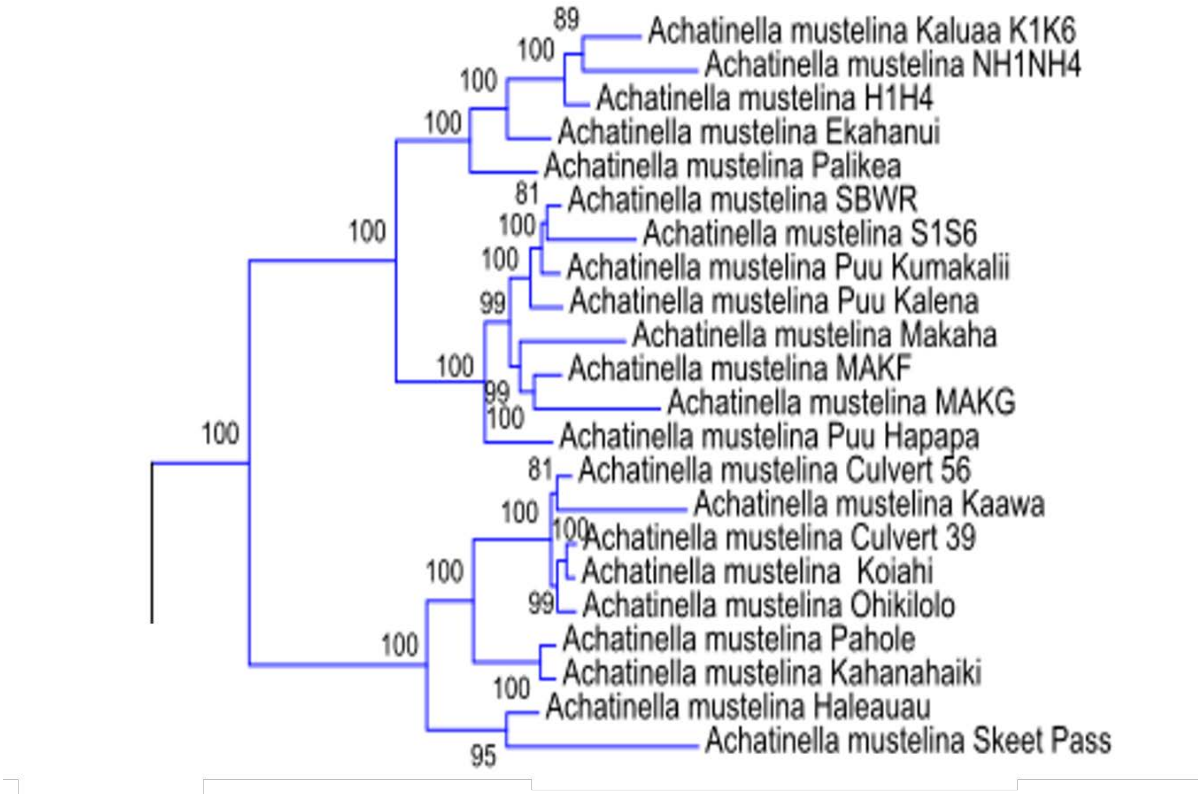


Figure 1b. Only populations of *Achatinella mustelina*, from figure 1a, for viewing convenience.

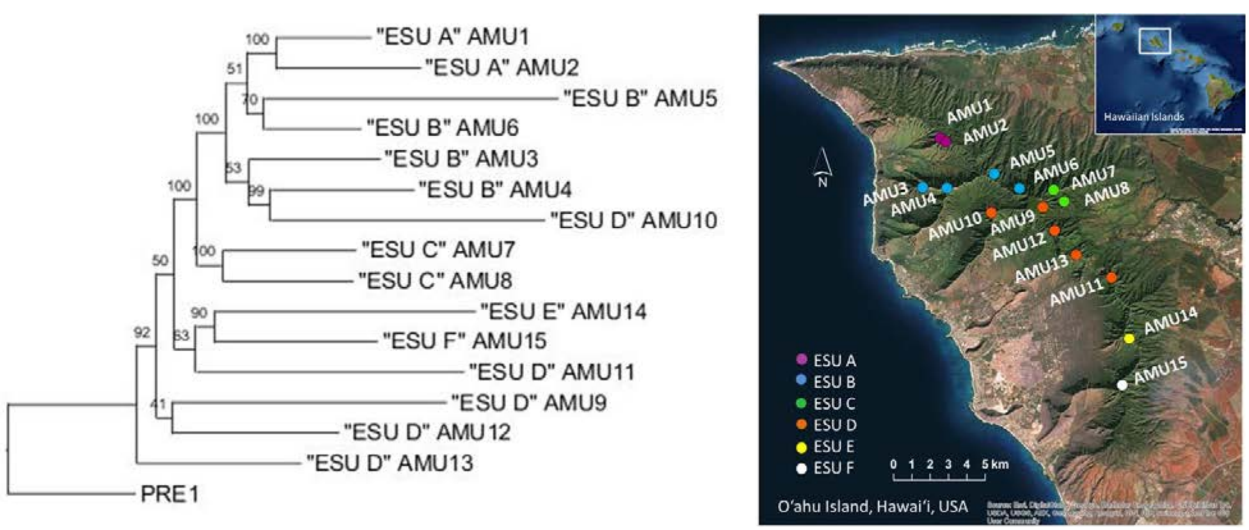
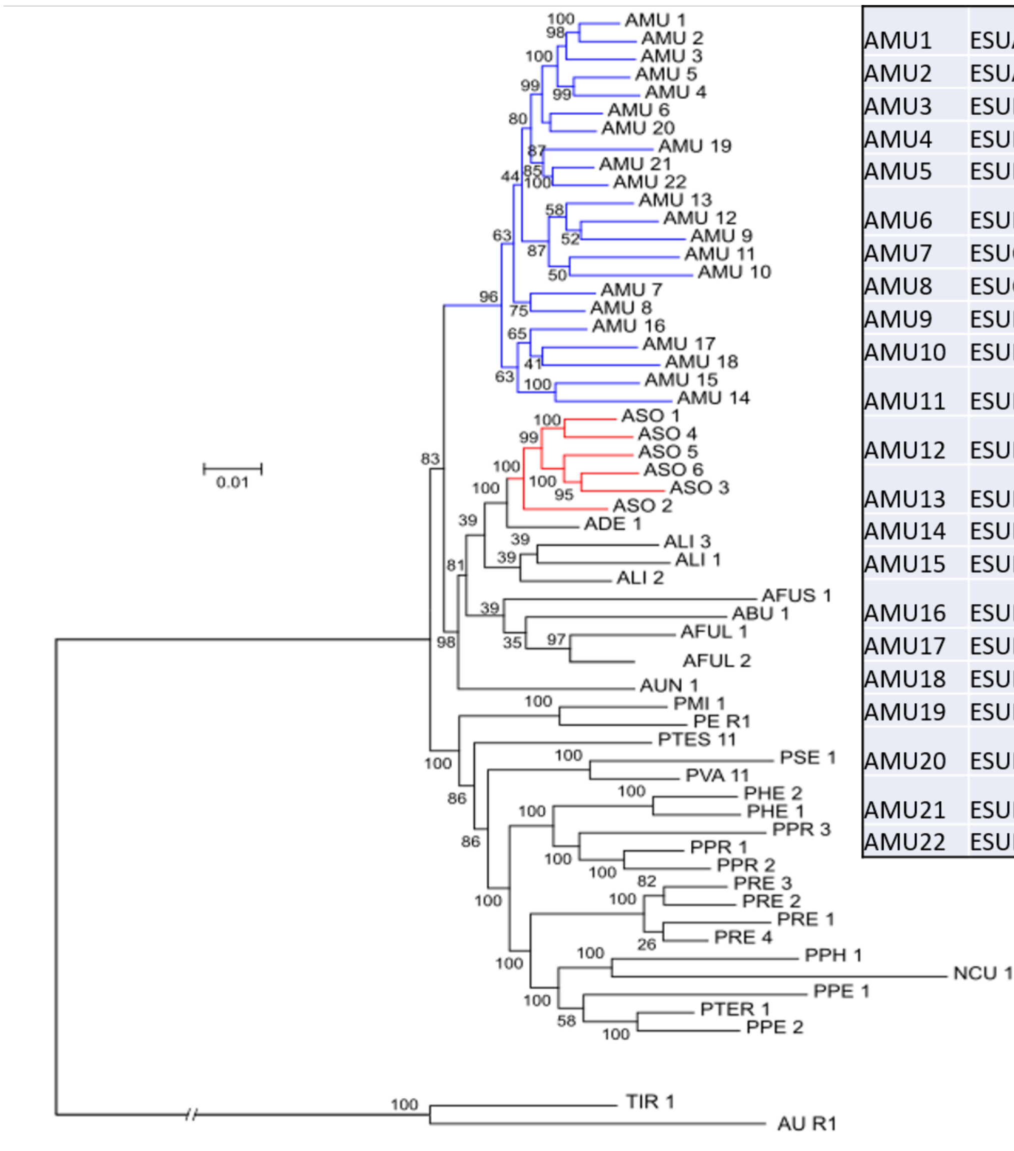


Figure 2. Phylogenetic tree generated using a total information approach using the program iPyrad, with geographic locations shown for each population.



AMU1	ESUA	Kahanahaiki
AMU2	ESUA	Pahole
AMU3	ESUB	Koiahi
AMU4	ESUB	Ohikilolo
AMU5	ESUB	Culvert 39
AMU6	ESUB	Culvert 56/57
AMU7	ESUC	Skeet Pass
AMU8	ESUC	Haleauau
AMU9	ESUD	SBW-R
AMU10	ESUD	Makaha
AMU11	ESUD	Puu Hapapa
AMU12	ESUD	Puu Kalena
AMU13	ESUD	Puu Kumakalii
AMU14	ESUE	Ekahanui
AMU15	ESUF	Palikea
AMU16	ESUE	H1-H4 Huliwai
AMU17	ESUE	NH1-NH4
AMU18	ESUD	K1-K6
AMU19	ESUD	S1-S6
AMU20	ESUB	Kaawa 1-13
AMU21	ESUD	MAK-G 1-15
AMU22	ESUD	MAK-F 1-7

Figure 3. All populations and species analyzed using a total information approach (both nuclear and mitochondrial variable sites).

Discussion

Populations within *A. mustelina* are now managed to maintain the genetic distinctiveness of the ESUs, by only "mixing" snails within, but not among, ESUs. Management efforts for the remaining populations include four *in situ* predator-free enclosures (two in ESU A, one in ESU D, and one in ESU F), and rat removal in large populations outside of predator-free enclosures, along with other habitat management efforts. There is general agreement that predator-free enclosures are the only way to protect tree snails from all three invasive predators, since there is, as yet, no effective method for removing the predatory snail *Euglandina rosea* or Jackson's chameleons, which have both devastated native mollusks and other invertebrates in habitats where they are present. However, enclosures are expensive to build and require accessible land with a minimal incline, which is scarce in the high elevations of the Waianae Mountain Range. ESUs B, C, and E do not yet have enclosures due to these constraints, and many populations within these ESUs are declining due to high rates of predation from *E. rosea* and Jackson's Chameleons. However, current policy, based on the existing understanding of genetic structure in this species, prevents the movement of vulnerable populations into existing enclosures that contain tree snails belonging to a different ESU.

Our methods have captured 50-90% of mitochondrial genomes for each population examined. Whole mitochondrial genomes have been compared across the range of Achatinella mustelina, and for all species sequenced as part of this study. These results suggest the same management approach as COI alone (Holland and Hadfield's 2002 paper), with no change to the current management approach of 5 or 6 discrete ESUs, with populations grouping along the Waianae ridgelines.

However, when nuclear evidence was considered (a scan/survey of thousands of sites across the entire genome), we observed a more nuanced picture. For example, Makaha (ESU D) always groups with Koiahi and Ohikilolo (ESU B). Puu Hapapa (ESU D) groups with Ekahanui (ESU E) about 50% of the time. On the other hand, some populations are very much the same for both nuclear and mitochondrial markers. Populations in ESU C (Haleauau and Skeet Pass) always group together, separate from the others. The populations on the three ridges that meet on top of Mt. Kaala (from ESUs B, C, D) separate out from one another with both mitochondrial and whole-genome approaches.

Another result consistent across both mitochondrial and genome-wide approaches is that the differences among some ESUs are similar to species-level differences across the subfamily. Evaluations of morphology and further examination of genetic data are needed before any major conclusions may be drawn, but these results are highly suggestive that major differences exist among two groups if ESUs (ABC, DEF), and outcrossing depression could result if geographically distant populations, particularly from different ESUs, are combined. The location of the divide between the two groups (ABC, DEF) is roughly consistent with a faultline near the top of Mt. Kaala, which correlates with historical, but not current, geological features that may have formed geographic barriers to gene flow in the past (Figure 4). However, we lack modern geographic features to explain the lack of gene flow between ABC and DEF.

Balancing concerns regarding predators, inbreeding, and climate change. Given concerns regarding high predation on tree snail populations, and our limited ability to remove two out of three predators, protection of declining tree snail populations remains a priority. Over the past few years a number of other concerns have been raised, including the potential for inbreeding depression in small, isolated populations, as well as impacts of climate change, such as an increasing number of drought events leading to high juvenile mortality. When translocating snails into enclosures or into areas with rat-trapping grids to protect them from predation, potential impacts of inbreeding or outbreeding depression, as well as potential impacts from climate change, must be considered.

Overall, there are four conditions under which translocations are currently being considered. In the majority of situations, translocation is being considered because of drastic population declines caused by high predation by rats, Jackson chameleons, or *E. rosea*. Translocation may also be important when genetic rescue is needed due to low heterozygosity and inbreeding depression. In this case, diversity may be increased by combining populations or simply translocating a few individuals into an enclosure. Third, in the case of assisted evolution, we may wish to combine populations to add genetic diversity that increases the likelihood of critical populations adapting to climate change. Finally, we may wish to move a critical population that is not predicted to survive climate change in its current location, to a location where it is more likely to survive climate change, a process called assisted colonization.

Unsurprisingly, total DNA evidence suggests that snail populations that are closer together geographically are more closely related genetically, and snail populations that are farther apart are less related. Pulling snails from nearby populations (< 1 km) into enclosures should be enough to combat inbreeding. Outbreeding depression may be a concern if tree snails from more distant populations are combined. Phylogenetic trees generated in this study may be used as general guidelines, particularly for branches with high bootstrap values (>70), but consultation is strongly encouraged in cases where snails will be moved > 1 km. In light of climate change, we still recommend moving snails to wetter, cooler locations, and never to locations that are warmer or drier than source locations. Also based on projections of shifts in suitable climate under likely climate change scenarios (A. Vorsino, in prep), we recommend moving snails in ESUs D, E, and F north (toward Mt. Kaala), but not south.

For populations in the southern Waianae Mountains, in particular (ESUs DEF), that are adapted to hotter, drier, conditions, populations must be carefully monitored for response to droughts and high-temperature conditions. In consultation with the Snail Extinction Prevention Program and USFWS, OANRP may wish to consider trials in which tree snails from ESUs E and F are crossed under lab conditions, to determine whether outbreeding depression is a concern. These trials should be undertaken before the population size of ESU E declines further.

Moving forward, actions should be taken and populations prioritized based on whether the loss of the population would likely mean the loss of an entire ESU, whether the population has unique genetic characteristics that contribute to ESU or species-level diversity, and whether the population is predicted to survive through the end of the century under hotter, drier conditions.

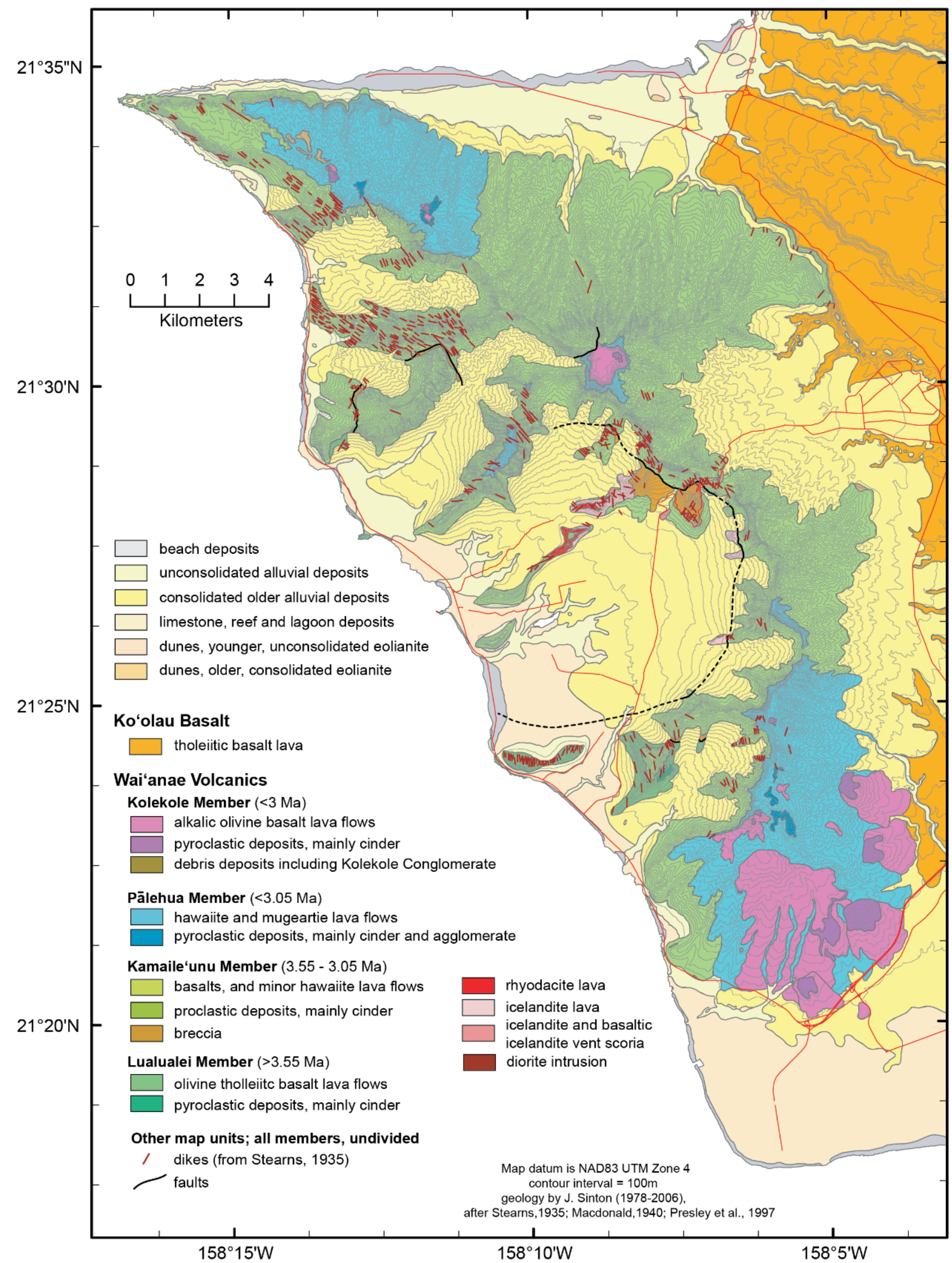


Figure 4. Geology of the Waianae Mountains (from Presley et al. 1997, updated by J. Sinton 2016).

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ASSESSMENT OF EFFECTS OF *SOLENOPSIS PAPUANA* ON ARTHROPODS IN OAHU FORESTS

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Background

Solenopsis papuana is the most widespread and abundant invasive ant species in the upland forests of both mountain ranges on Oahu. While other more conspicuous ant species often occur in exposed, drier microsites such as ridgetops with short-statured vegetation, *S. papuana* is the most common species that can be found under the canopy in the interior of mesic to wet forests, and appears to be nearly ubiquitous above elevations of roughly 1000 ft. Although concern about the ecological effects of this species has been raised for many years, almost no research has been done on any aspect of its biology or ecology. We are conducting a study of the ecological effects of *S. papuana* on the ground arthropod communities in forests under conservation management. A secondary goal is to attempt to measure effects of *S. papuana* on reproduction in native *Drosophila* flies in the field.

FY17 progress and results

During fiscal year 2017, graduate student Sumiko Ogura-Yamada completed the remainder of the field and lab work planned for the project. This included work in two areas: conducting a field experiment to assess effects of *S. papuana* on arthropod communities, and conducting a field experiment to assess the effects of *S. papuana* on native *Drosophila* reproduction.

A. Effects of *S. papuana* on arthropod communities

This aspect of the project is essentially complete. All of the samples have been sorted and databased, and the data have been analyzed. Sumiko Ogura-Yamada is currently in the process of writing up these results for the second chapter of her thesis. A draft of this chapter is not currently ready for distribution, but in general, the study found relatively weak effects emanating from the year-long suppression of *S. papuana* in the six pairs of field plots. Analysis of relative changes in abundance and diversity among the soil and leaf litter arthropod communities found relatively few statistically significant changes. None of the groups of native arthropods examined significantly increased in abundance or diversity after *S. papuana* was controlled. However, there was some compelling evidence for an overall release of the arthropod community from ant predation, because several groups did respond positively and statistically significantly, and nearly all of the non-significant changes were in the direction of increasing abundance and/or diversity following ant control.

There are therefore several potential reasons to explain why arthropod communities did not respond more strongly to ant suppression. First, the consistent pattern of (non-significant) increasing abundance and/or diversity among nearly all groups assessed suggests that some of these changes may have become stronger, and statistically significant, if tracked for a longer period of time. A second reason may stem from the fact that *S. papuana* has likely now been widespread in these forests for at least several decades: most of the species that are more vulnerable to predation by this ant may now be largely extirpated from areas where the ant is abundant. If this is the case, it would be very unlikely that these species would be capable of colonizing the ant-suppressed plots during the year-long experiment, and thereby contribute to an increase in native arthropod diversity. Those species remaining in areas with high densities of ants are likely to be more resilient to ant predation, and therefore less likely to respond as strongly when ants are suppressed. This is an unfortunate weakness of this type of study design (even though the randomized treatment experiment is often advocated as having the greatest inferential power). The second explanation is supported by the example of the positive response of picture-winged *Drosophila* flies to ant suppression, which was only revealed with a specialized experiment that introduced these flies into the field plots. The latter results are detailed below.

B. Effects of *S. papuana* on native *Drosophila* reproduction

As mentioned above, we conducted an experiment in which immature stages of picture-winged *Drosophila crucigera* flies were placed in randomized field plots in which *S. papuana* were either suppressed or left untreated. This experiment revealed that suppressing these ants increased the egg to adult survival rate of these flies by 2.4-fold, on average. Equivalently, ambient densities of these ants reduce this survival rate by 58%. This indicates that *S. papuana* is likely having a substantial impact on populations of picture-winged *Drosophila*, including listed species, in mesic to wet forests where it occurs. It suggests that developing safe methods to control this ant, in conjunction with host plant augmentation, may be an important aspect of the recovery of listed *Drosophila* species. It also suggests that more complete mapping of distributions of *S. papuana* and other ant species may be highly useful. This should 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. The results of this experiment are detailed more fully in the appended manuscript below, which is currently under review for publication.

Title**:** 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 Oʻahu. 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.

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, Hawaiʻi 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 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 been observed foraging up to a height of at least two meters on tree trunks. More commonly, it attains high densities 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 Oʻahu, 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 Hawaiʻi, and clarify the magnitude of the threat posed by ants to picture-winged fly recovery.

Materials and Methods

Field plots

Twenty-eight 5 x 5 m plots were established in November of 2016 across three mesic forest sites in the central to northern Waiʻanae Mountain range of Oʻahu: eight plots at Puʻu Hāpapa (810 m elevation, 1185 mm annual rainfall), eight plots at ʻĒkahanui (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 x 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 minutes, 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 Figure 1. Ant numbers in both suppressed and control plots were also monitored every four to six weeks (Fig. 1), using the bait card methods described above.

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 hr 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).

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 x 18 x 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.

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 hrs, 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 x 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 9-12 December 2016; the same triplets were then used again for the eight ʻĒkahanui branch pieces from 15-18 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 26-29 December 2016, for the Pahole site.

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 (Puʻu Hāpapa, ʻĒkahanui, Pahole). Statistical analyses were performed using JMP Pro Version 13.

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 Puʻu Hāpapa oviposition period and 4.2% (1 of 24) during the ʻĒkahanui 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 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 ʻĒkahanui 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, attracted to the baited trap inside. However, we re-ran 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.

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) species 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 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 (see also Gaigher et al. 2012). Broadcasting the granular ant bait at such 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.

Acknowledgements

We thank the O‘ahu Army Natural Resources Program for funding and logistical support, the Hawai‘i Department of Land and Natural Resources Division of Forestry and Wildlife and Natural Area Reserve System for permits and land access, and Mark Wright and anonymous reviewers for comments on the manuscript.

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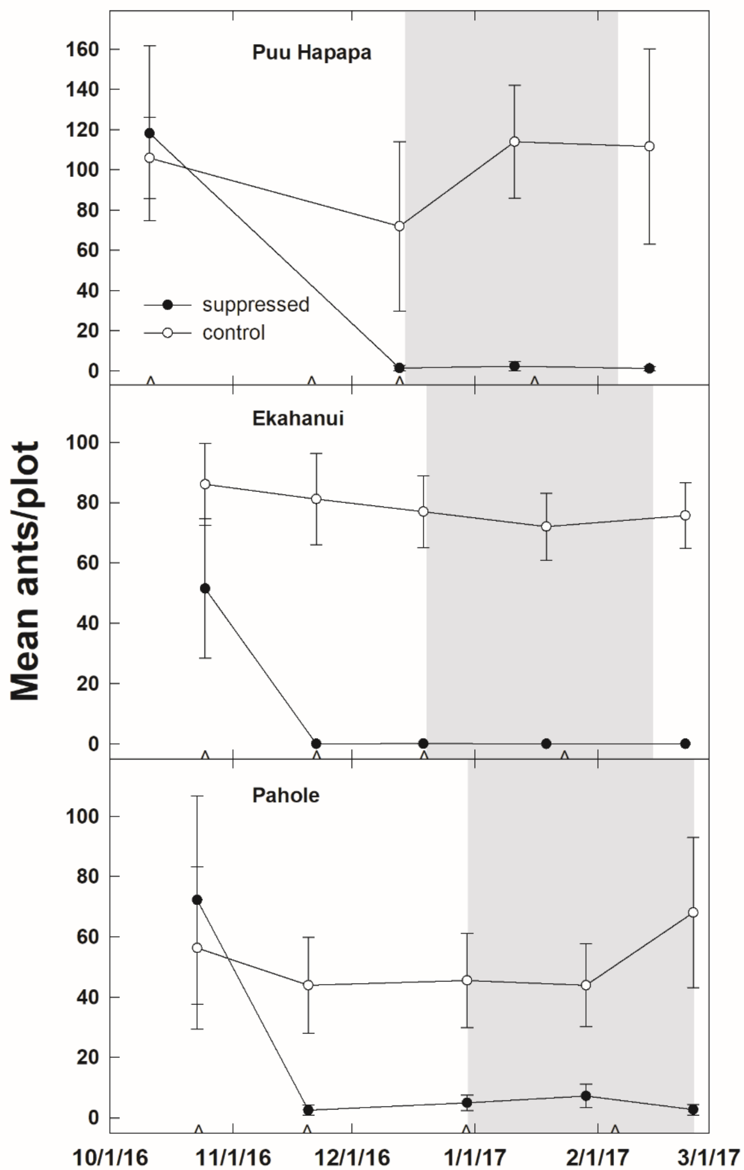

Figure 1. Mean number of ants (± SE) at bait monitoring cards in ant-suppressed and control plots at the three field sites over the course of the experiment. First date in each panel is prior to ant suppression using bait stations; timing of ant bait placement/replacement within stations is shown with 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.

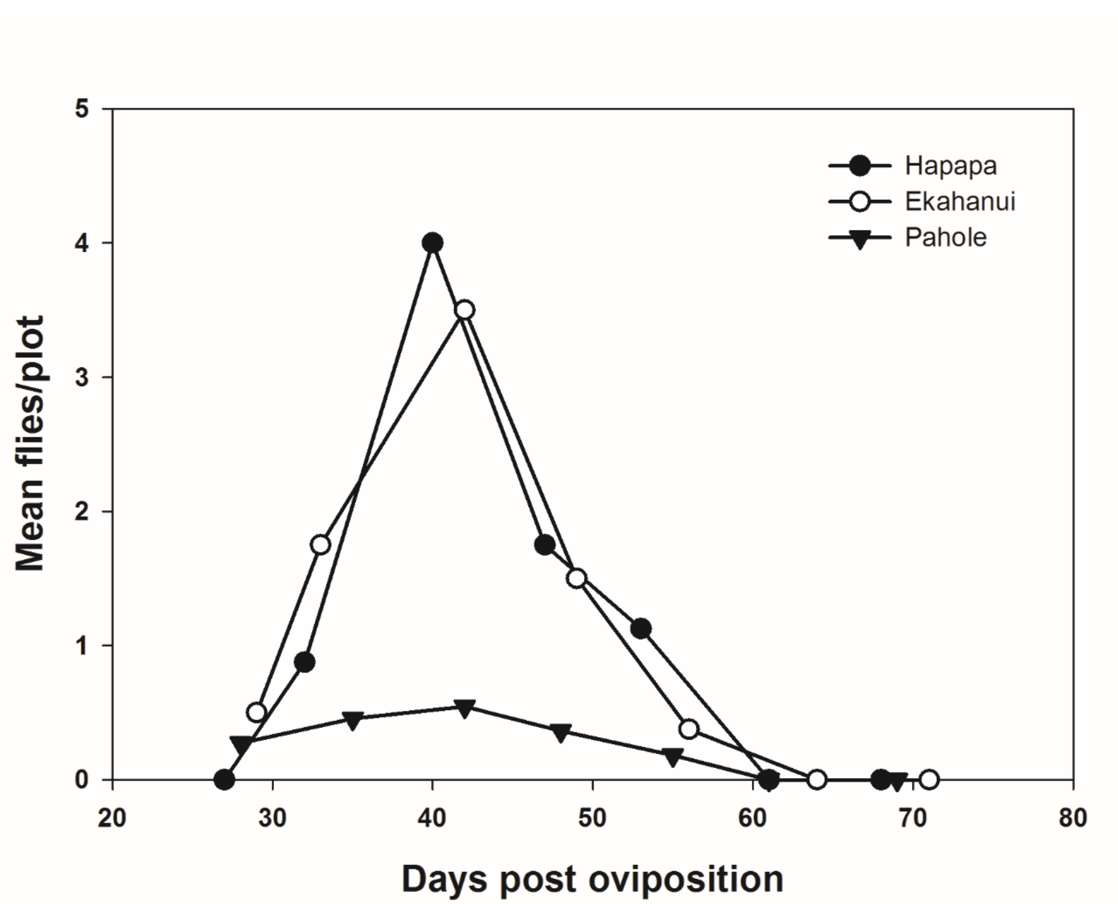

Figure 2. Temporal pattern of adult fly emergence at each site over the course of the experiment, as measured by captures in field cages monitored approximately weekly.

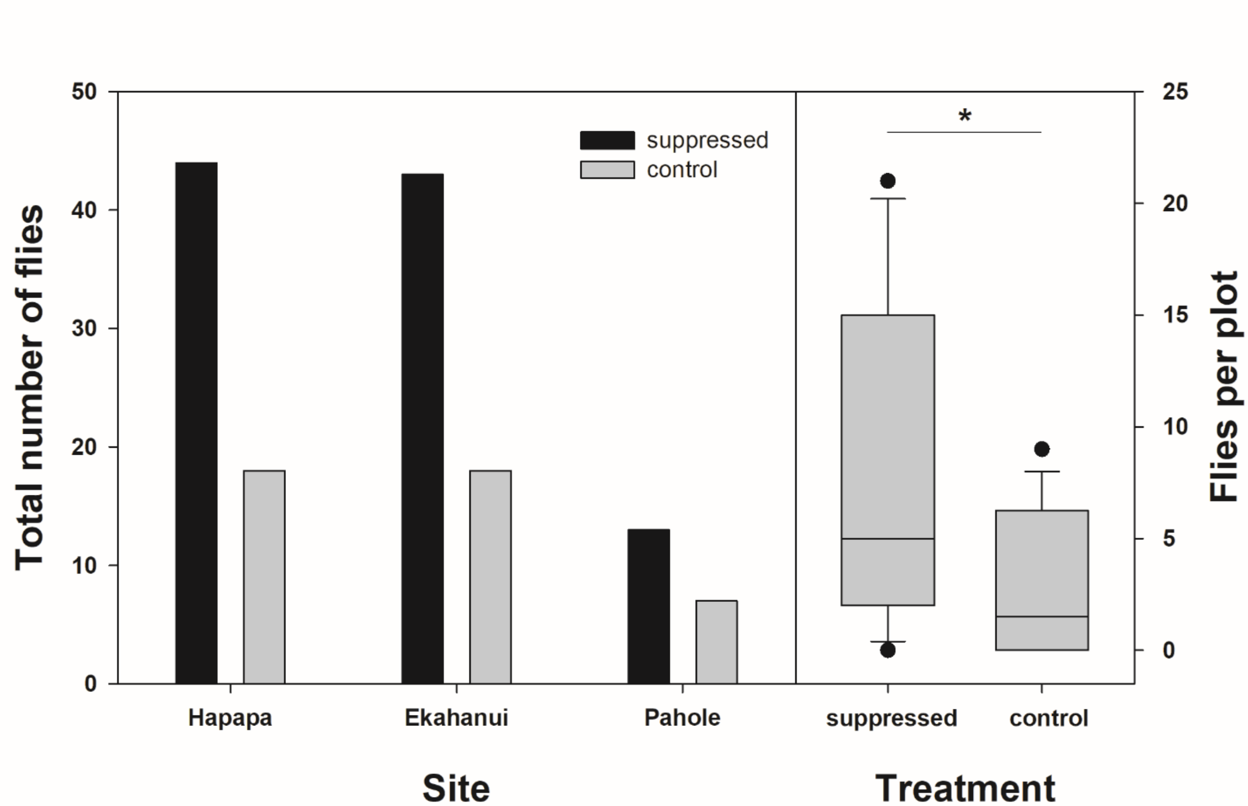

Figure 3. Left panel: Total number of flies emerged in ant-suppressed and control plots at each site. Right panel: Box plots of numbers of emerged flies per plot for ant-suppressed and control treatments across all sites. Box forms first and third quartiles, with median line inside; whiskers show 5% 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).

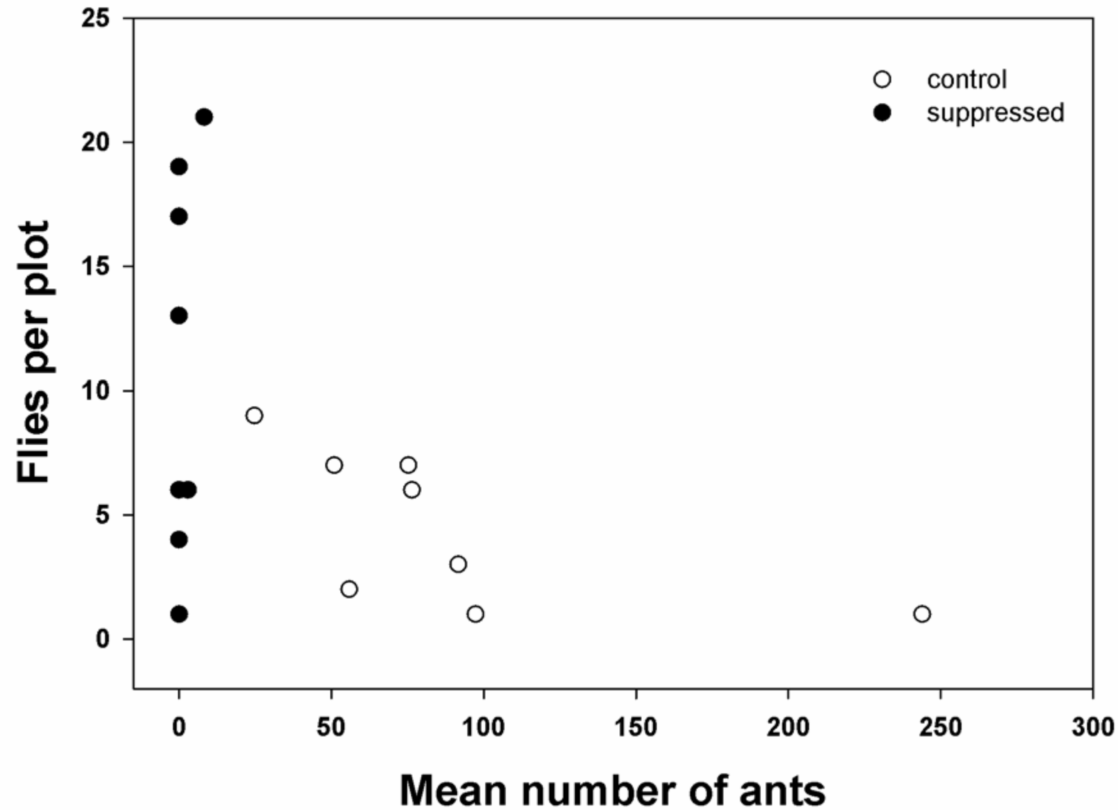

Figure 4. Relationship between ant abundance and the total number of adult flies that emerged in the 16 Puʻu Hāpapa and ʻĒkahanui plots. Ant numbers are the means of the central five bait cards placed around the emergence cage in each plot, and averaged over the final three monitoring events when flies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

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

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U.S. Army Garrison Hawaii, Environmental Division, O'ahu Army Natural Resources Program

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: Non-native frugivorous birds on the Island of O'ahu exhibit behavioral responses to prerecorded conspecific and heterospecific vocalizations with a stronger response exhibited towards conspecific tracks

H_2: Interactions of non-native frugivorous birds with fruits, including direct fruit consumption, are increased near fruiting plants where conspecific and heterospecific vocalizations are broadcasted

H_3: Non-native frugivorous birds exhibit stronger responses to vocalizations during the non-breeding season (Sept – Jan) due to increased gregariousness and flocking outside of the breeding season (Feb-Aug)

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
- >40% of Hawaiian plants are threatened with extinction while a concurrent invasion of exotic plants has led to drastically modified plant communities with only small patches of native plants remaining
- **Attracting frugivorous birds into areas with high-densities of native species may help restore eroding seed dispersal networks**

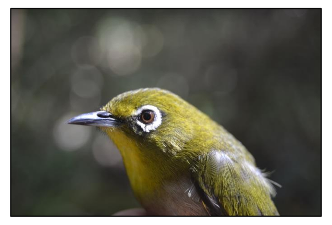
- Birds select habitat based upon a combination of direct resource cues (i.e. food abundance) and indirect social cues (i.e. conspecifics)
- Conspecific attraction (CA) is the tendency for individuals of the same species to settle near one another and often improves their ability to locate food or reduce 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
- **'Assisted migration' has been proposed, but not implemented, as a possible solution to the growing, global, seed dispersal crisis**

Methods

Study Species

<u>Red-billed leiothrix *(Leiothrix lutea)*</u>

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

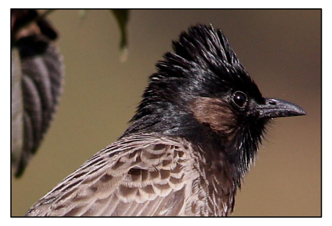


<u>Japanese white-eye (*Zosterops japonicus*)</u>

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

<u>Red-whiskered bulbul (*Pycnonotus jocosus*)</u>

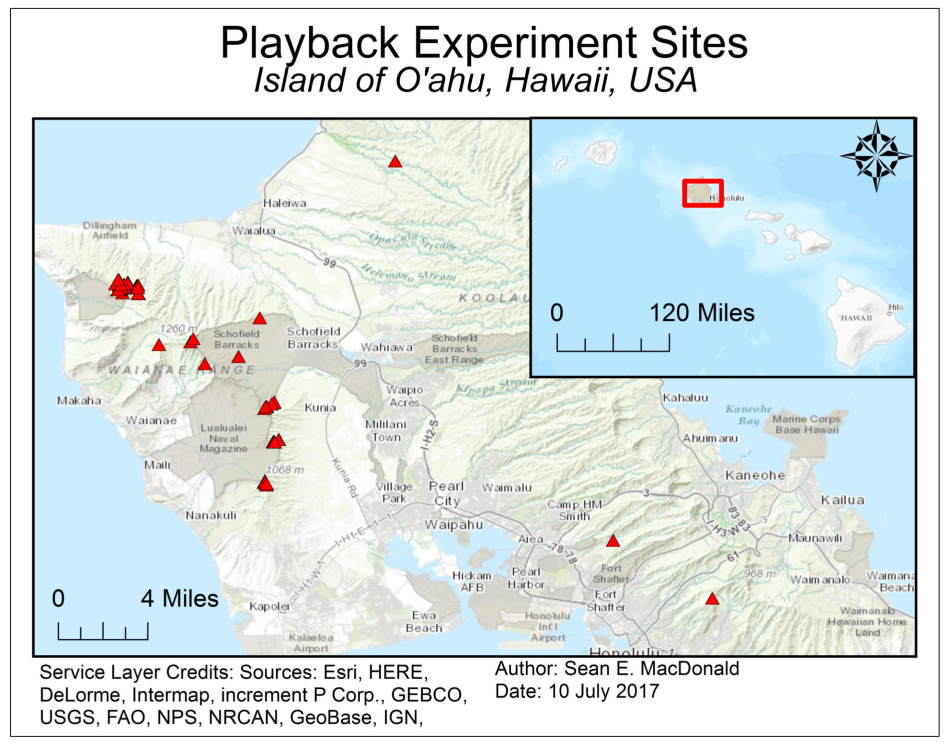
- Introduced 1965 from SE Asia
- Rapid population growth and range expansion
- Habitat: Upper canopy in forested highlands
- Behavior: cautious, but highly gregarious



<u>Red-vented bulbul (*Pycnonotus cafer*)</u>

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

Study Sites

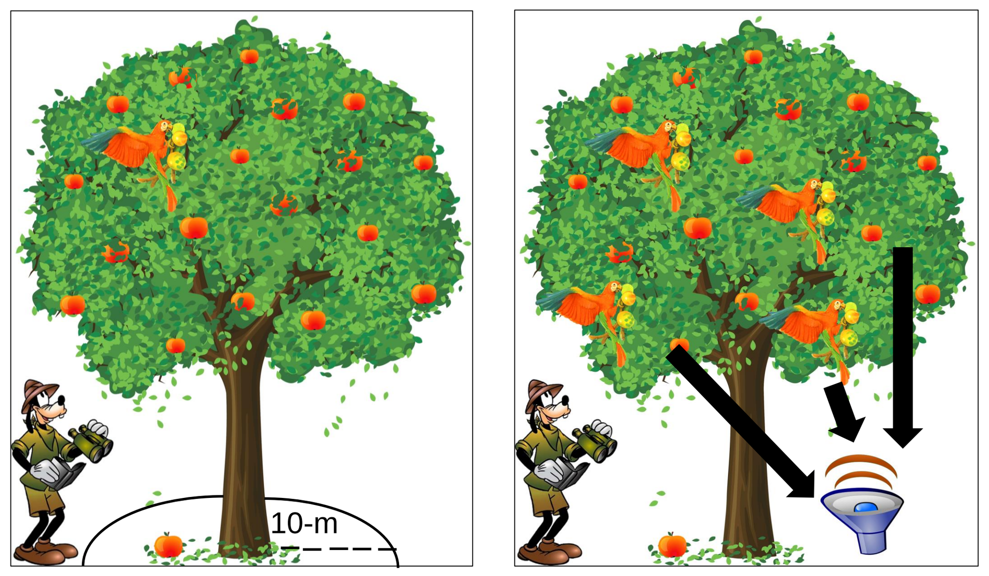


Study Design

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

<u>Control – Hour 1</u> <u>Treatment – Hour 2</u>



Results

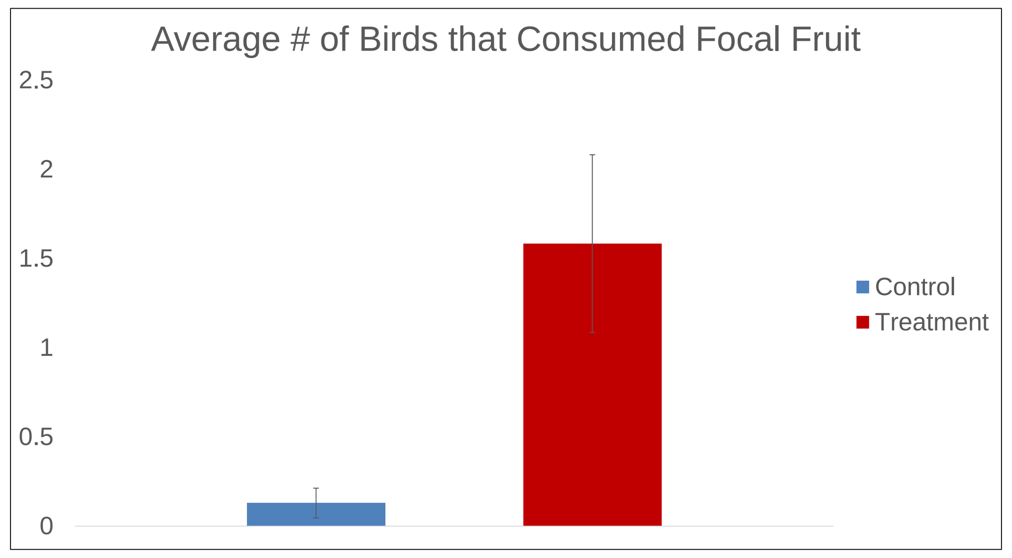


Figure 1. Average number of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye that consumed the focal fruit during the control and treatment periods across 77 conspecific attraction experiments conducted from summer 2016 – summer 2017 on the Island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

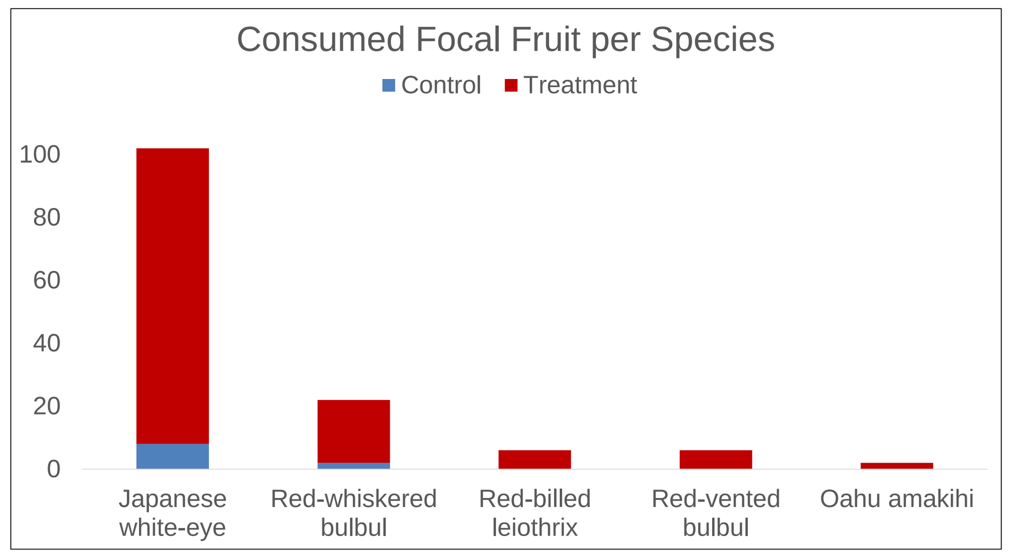


Figure 2. Sum of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye that consumed focal fruit during control and treatment periods across 77 conspecific attraction experiments conducted from summer 2016 – summer 2017 on the Island of O'ahu, HI, USA.

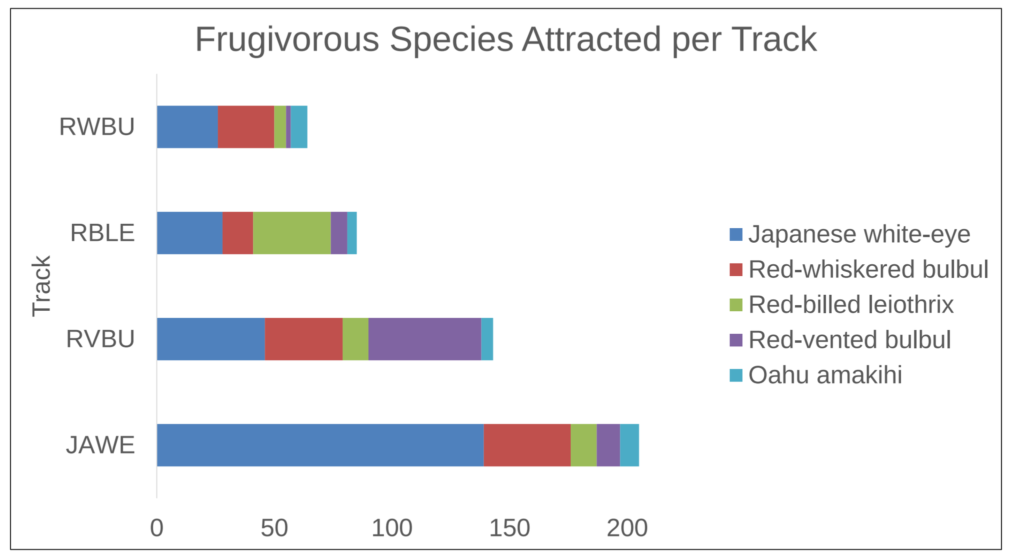


Figure 3. Sum of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye attracted to Red-vented bulbul (RVBU), Red-whiskered bulbul (RWBU), Red-billed leiothrix (RBLE), and Japanese white-eye (JAWE) playback tracks broadcasted during treatment periods across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

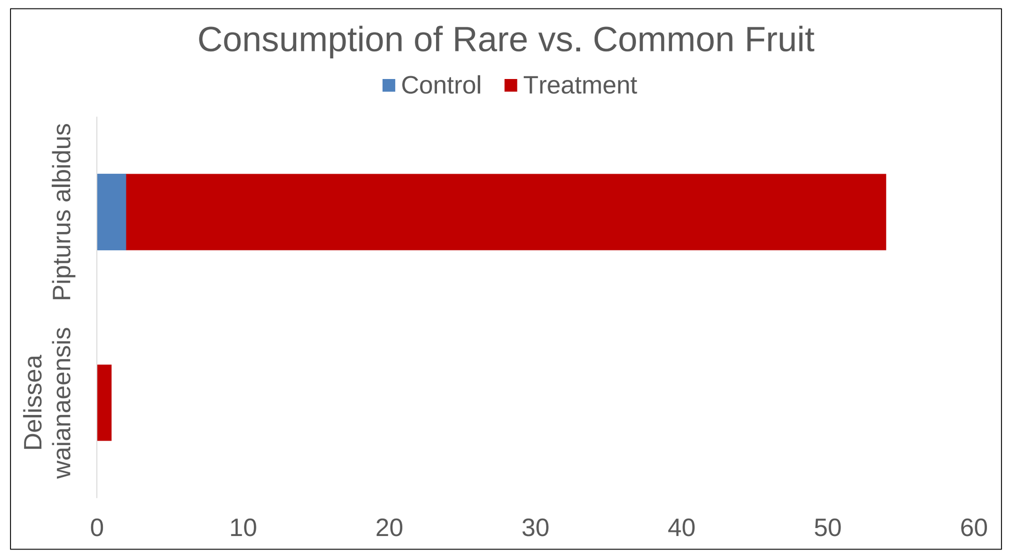


Figure 4. Sum of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye that consumed focal fruit of rare Delissea waianaeensis and common Pipturus albidus fruit during control and treatment periods across 20 conspecific attraction experiments from summer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

Discussion

Summary

- The focal species' response to the stimulus was extremely variable with the Japanese white-eye comprising some 540 of the 996 fruit-eating birds attracted, suggesting that efficacy may be bird species-dependent
- Birds consumed focal fruit in 5% of control periods, which grew to almost 30% during treatment periods, indicating that birds may rely heavily on social info when making foraging decisions
- Māmaki (*Pipturus albidus*) comprised more than half of all observed frugivory events, suggesting that fruit familiarity may be a driver of frugivory
- There is very little difference in behavioral response between breeding and non-breeding seasons, demonstrating that fruiting phenology may be the only temporal limitations for this tool

Management Implications

This experiment was designed to establish proof of concept and is narrow in scope. More research is needed to determine feasibility in other systems. **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.**

Results

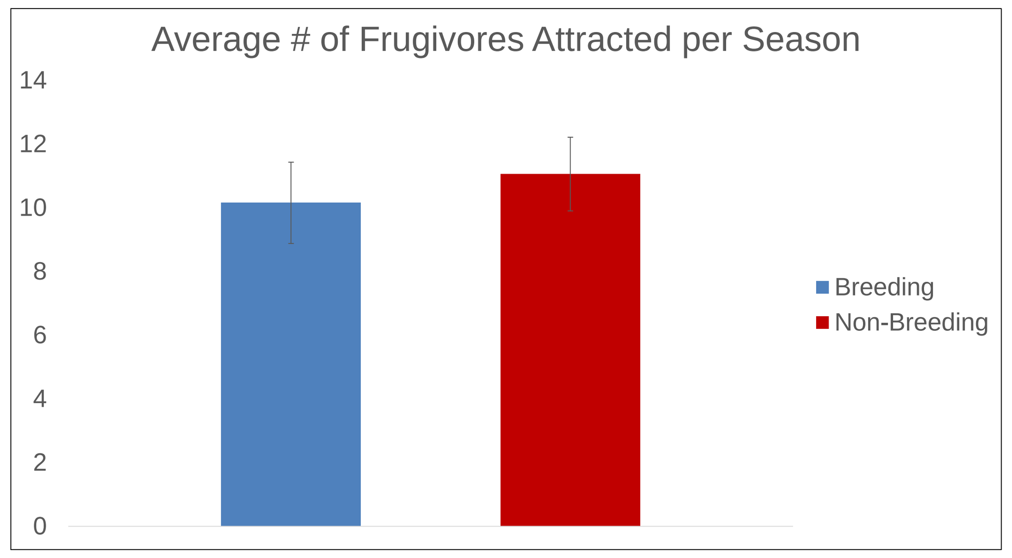


Figure 5. The average number of O'ahu 'amakihi, Red-vented bulbul, Red-whiskered bulbul, Red-billed leiothrix, and Japanese white-eye attracted during the breeding (February – August) and non-breeding (September – January) seasons across 77 conspecific attraction experiments conducted from summer 2016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

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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 14-18, Oct. 2017 – Sept. 2022
OIP Year 11-16, Oct. 2017 – Sept. 2022

MU: Ekahanui, Ekahanui No MU, Huliwai, Huliwai no MU

Overall MIP Management Goals:

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

Background Information

Location: Southern Waianae Mountains

Land Owner: State of Hawaii

Land Managers: DOFAW (State Forest Reserve)

Acreage: 216-acres

Elevation Range: 1800-3127 ft.

Description: Ekahanui MU is in the Southern Windward Waianae Mountains. Puu Kaua is at the apex of many sub drainages that make up Ekahanui. The summit of Puu Kaua is 3127 ft. high. Three major drainages are encompassed in the MU. Overall the area is characterized by steep vegetated slopes and cliffs, especially at higher elevations. Much of the MU is dominated by alien vegetation. There are only small pockets of native vegetation at the back of the gulches and at higher elevation worth of intensive management. The alien dominated areas were included in the MU boundary to ensure management options for the Oahu Elepaio, *Chasiempis sandwichensis ibidis*. Most of this alien dominated area fenced for Elepaio management falls into the Subunit II fence. The MU is accessed via the Kunia road through the Kunia Loa development in the South.

Huliwai MU is also located in the Southern Windward Waianae Mountains, just 1 mile north of Ekahanui by way of the contour trail. While Huliwai gulch is a relatively large drainage made up of several small sub drainages with the summit of Puu Kanehoa (2728 ft.) at its apex. The Huliwai MU is just a small fraction of this area because of the poor quality of the native habitat that remains. The MU consists of a small fence (0.3-acres) enclosing a population of *Abutilon sandwicense.* The fence includes a small stand of *Sapindus oahuensis* and a mix of native and alien canopy and understory species. The surrounding area is mostly invaded by alien species, but there is a volunteer group "Friends of Honouliuli" that have been working in the nearby areas to restore native plants and help control targeted invasive species. The MU is most easily accessed from the Wili Wili Ridge Trail head via the Monsanto Farm Gate.

Native Vegetation Types

Waianae Vegetation Types	
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.*, Sapindus oahuensis*, and *Santalum freycinetianum*. Understory includes: *Alyxia stellata, Bidens torta, Coprosma* spp., and *Microlepia strigosa*

Mesic-Wet forest	Canopy includes: *Metrosideros polymorpha polymorpha*. Typical to see *Cheirodendron trigynum*, *Cibotium spp.*, *Melicope spp.*, *Antidesma platyphyllum*, and *Ilex anomala*. Understory includes: *Cibotium chamissoi*, *Broussasia arguta*, *Dianella sandwicensis*, *and Dubautia spp.* Less common subcanopy components of this zone include *Clermontia spp.* and *Cyanea spp*.
NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted.	

Vegetation Types at Ekahanui

Mesic Mixed Forest

Mesic-Wet Forest

MIP/OIP Rare Resources at Ekahanui

Organism Type	Species	Pop. Ref. Code	Population Units	Management Designation	Wild/ Reintroduction
Plant	*Abutilon sandwicense*	EKA-A, B, C, HUL-A	Ekahanui and Huliwai	MFS (OIP)	Both
Plant	*Alectryon macrococcus* var *macrococcus*	EKA-A*, B, C, D*, E*, F	Ekahanui	Genetic Storage and MFS (MIP)	Wild
Plant	*Cenchrus agrimonioides* var. *agrimonioides*	EKA-A, B, C, D	Central Ekahanui	MFS (MIP)	Both
Plant	*Cyanea grimesiana* subsp. *obatae*	EKA-A*, B, C	North Branch of South Ekahanui	Genetic Storage and MFS (MIP)	Both
Plant	*Delissea waianaeensis*	EKA-A, B*, C*, D	Ekahanui	MFS (MIP)	Both
Plant	*Kadua parvula*	EKA-A	Ekahanui	MFS (MIP)	Reintroduction
Plant	*Phyllostegia mollis*	EKA-A*, B*, C*	Ekahanui	MFS (OIP)	Both
Plant	*Plantago princeps* var *princeps*	EKA-A, B, C, D	Ekahanui	MFS (OIP)	Both
Plant	*Schiedea kaalae*	EKA-A, B, C*,D,E#	Ekahanui	MFS (MIP)	Both
Snail	*Achatinella mustelina*	EKA-A, B, C,D,E,F,G	ESU-E	MFS (MIP)	Wild
Bird	*Chasiempis sandwichensis ibidis*	N/A	Ekahanui	MFS	Wild
Arthropod	*Drosophila montgomeryi*	N/A	Ekahanui	None	Wild

MFS= Manage for Stability *= Population Dead #=not an IP population
GSC= Genetic Storage Collection †=Reintroduction not yet done

Other Rare Taxa at Ekahanui

Organism Type	Species	Status
Plant	*Asplenium dielfalcatum*	Endangered
Plant	*Asplenium unisorum**	Endangered
Plant	*Chrysodracon forbesii*	Endangered
Plant	*Cyanea pinnatifida*	Endangered
Plant	*Cyanea calycina*	Endangered
Plant	*Dissochondrus biflorus*	Species of Concern
Plant	*Euphorbia herbstii**	Endangered
Plant	*Phyllostegia hirsuta*	Endangered
Plant	*Phyllostegia kaalaensis**	Extirpated
Plant	*Platydesma cornuta* var *decurrens*	Endangered
Plant	*Schiedea hookeri*	Endangered
Plant	*Schiedea pentandra*	Candidate
Plant	*Urera kaalae*	Endangered
Plant	*Tetramolopium lepidotum var. lepidotum*	Endangered
Plant	*Zanthoxylum dipetalum var. dipetalum*	Endangered
Plant	*Solanum sandwicense*	Endangered
Snail	*Philonesia sp.*	Species of Concern
Snail	*Amastra spirizona*	Species of Concern

*= Population Dead

Rare Resources at Ekahanui

Mature *Cyanea grimesiana subsp. obatae* at reintroduction

D. waianaeensis recruitment around reintroduced plants.

Abutilon sandwicense flower

Wild *Schiedea kaalae* patch

Plantago princeps var. princeps with infructescense

Locations of Rare Resources at Ekahanui

Map removed to protect rare resources

MU Threats to MIP/OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2017
Pigs	All	Across MU	No animals within fence
Rats	All	Across MU	MU-wide snap trap grid currently running
Predatory snails *Euglandina rosea*	*Achatinella mustelina*	Predator-proof snail enclosure offsite (Palikea)	Limited to hand-removal. Majority of the A. *mustelina* have been placed in SEPP rearing laboratory. All *A. mustelina* in MU will be moved into Palikea North enclosure, which will be completed by the end of 2017.
Slugs	*C. grimesiana* subsp. *obatae, D. subcordata, S. kaalae, P. mollis,* seedlings of several other species may be affected	Affected rare taxa sites only	Slug control toxicant (FerroxxAQ®) applied every 6 weeks.
Ants	Potential threat to *Drosophila montgomeryi*	Fly breeding sites	Ants known to harm *Drosophila* are present throughout this MU, however research is needed to find fly breeding sites and to identify insecticides that will control ants without harming the flies.

Weeds	All	Rare taxa sites primarily, across MU secondarily	Regular maintenance required several times per year
Fire	All	Target *Urochloa maxima*	Regular grass control within the MU and along fence line as needed.
Black Twig Borer *Xylosandrus compactus*	*Alectryon macrococcus* var. *micrococcus,*	None	These remain a threat and damage to plants will be noted, however no control methods are available
Jackson's Chameleons	*A. mustelina*	None	Limited to hand-removal and the physical barriers (enclosures), to protect *Achatinella* from predators under construction.

Management History

- 1860s-80s: Area 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 established for watershed protection purposes.
- 1930s-50s: Division of Forestry and Civilian Conservation Corps builds roads, trails and fences and continue removal of feral goats and cattle; plants 1.5 million trees in the Honouliuli Forest Reserve mainly below the 1800' elevation.
- 1970's: *Clidemia* first introduced to the Waianae Mountains in North Honoulililuli.
- 1990-2009: Honouliuli Preserve managed by The Nature Conservancy.
- 1998-2002: Biological surveys by TNC staff and Joel Lau.
- 1996-1998: TNC staff conducts *Schinus terebinthifolius* trials to determine the most effective control method using girdling and herbicide (Garlon4) application techniques.
- 1999: Elepaio management begins with banding and rodent control around approximately 6 pairs by TNC. By 2006, the number of territories protected is about 20. By 2009, over 25 pairs are known and protected by rat control efforts.
- 2000: Subunit I fence completed by TNC (40-acres). TNC eradicated the last pigs through the use of volunteer and staff hunters.
- 2001-2002: OANRP begins collaboration with TNC by helping to build fence around *Amastra spirizona* and to create rat control grids with bait boxes and victor traps to protect *Achatinella mustelina* and *Plantago princeps* var. *princeps*.
- 2001-2006: Catchment tanks and field nursery installed by TNC staff. Other common native restoration efforts done by TNC/Army staff.
- 2002: *Achatinella mustelina* surveys by Army Staff and Joel Lau.
- 2003: TNC outplanted *Cyanea grimesiana* subsp. *obatae* plants (EKA- B) into Palai Gulch.
- 2003: *Delissea waianaeensis* plants (EKA-D) reintroduced into Subunit I fence by TNC.
- 2003: *Schiedea kaalae* plants (EKA-D) were outplanted by TNC in the S. Ekahanui gulch.
- 2004: OANRP builds additional population unit (PU) fences outside of Subunit I.
- 2005: A 120-acre fire burns into the forest, well into the adjacent gulch to the south of Ekahanui as well as into the lower reaches of Ekahanui Gulch itself.
- 2005: *Cenchrus agrimonioides* var. *agrimonioides* (EKA-B) plants reintroduced along fenceline (Subunit I/II) on ridge.
- 2006: *C. grimesiana* subsp. *obatae* (EKA-C) plants reintroduced into the S. Ekahanui gulch "2D" site.
- 2007: Active management by TNC stops due state wide realignment of priorities.
- 2008: Subunit II/III fence completed by OANRP. Fence was vandalized not long after completion.

- 2008: *C. agrimonioides* var. *agrimonioides* (EKA-C) plants introduced on the North ridge on B-line.
- 2008 Ant surveys implemented.
- 2009: James Campbell Co. sells Honouliuli Preserve to the State of Hawaii and TNC transfers lease. TNC ends their involvement and operations in MU.
- 2010 last pig removed from Subunit II fence.
- 2010-2011: Large-scale rodent trapping grid system installed using 512 Victor snap traps throughout the whole MU. However, only the Victor traps surrounding the *Plantago princeps var. princeps* and the *A. mustelina* populations along the crest line are monitored year-round, whereas the rest of the Victor traps are checked during the Elepaio breeding season.
- 2011: Stream in airplane gulch breaches fence and is later repaired.
- 2011: *Abutilon sandwicense* plants (EKA-B) reintroduced into the Subunit I fence.
- 2011: *C. agrimonioides* var. *agrimonioides* (EKA-D) into the “Bump-out”/Subunit IV.
- 2011: One hundred and two Victor snap traps are added to existing rodent trapping grid. Total of 667 traps.
- 2012: Subunit IV fence completed. Pigs ingress Subunit I; ungulates removed via hunting.
- 2012: *Phyllostegia mollis* plants (EKA-D) reintroduced in the PlaPriPri/PhyMol gulch.
- 2013: Thirty-four Goodnature A24 Rat Trap- Automatic & Self-Resetting are added to trapping grid to assist rodent control surrounding the *Achatinella mustelina* and *Plantago princeps var. princeps* populations at the top crest line of MU.
- 2013: *A. sandwicense* plants (EKA-C) reintroduced intro the Subunit III fence.
- 2013-2015: OANRP *Drosophila* fly surveys begin around *Urera* sites. None were observed.
- 2014: *P. princeps var. princeps* plants (EKA-D) were outplanted.
- 2014: Huliwai fence completed to protect *A. sandwicense* (HUL-A).
- 2014: Pig ingress in Ekahanui subunit II; ungulates removed via hunting.
- 2016: Eleven pigs reported in Subunit I fence by OANRP staff; one pig caught in a snare. Further ungulate sign was observed.
- 2016: *Kadua parvula* plants (EKA-A) reintroduced along the top crest line above *P. princeps var. princeps* population.
- 2016: Strategic area above Subunit I enclosed, mauka line of Subunit I repaired, no further ungulate sign detected.
- 2016: Two temporary enclosures for *A. mustelina* were built near populations that were rapidly declining in order to protect the remaining *A. mustelina* until the Palikea North enclosure is complete. Unfortunately, the exclosures EKA-M on Mamane ridge south and EKA-S located north near the *Amastra spirizona* both failed to help the snails survive and they were discontinued.
- 2016: All but one individual *P. mollis* (EKA-D) reintroduction confirmed dead.
- 2017: One hundred and two *A. mustelina* were collected and brought to the Snail Extinction Prevention Program’s housing and rearing facility.

<u>Future goals</u>

- 2017: All Victor snap traps will be replaced with The Goodnature A24 Rat Traps. A total of 350 A24 traps will be added.
- 2018: All ESU-E *A. mustelina* will be translocated to the Palikea North enclosure.

Ungulate Control

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

Threat Level:

- *Sus scrofa:* High
- *Capra hircus*: Low level (but are present in gulches and ridges on the leeward side and to the south)

Management Objectives:

- Maintain fenced Subunits I-IV as ungulate free.

Strategy and Control Methods:

- Exclusion of all ungulates from MU via large-scale fencing.
    - Subunit I completed by TNC contractor in 2000
    - Four PU fences completed by OANRP staff in 2004
    - Subunit II/III completed by OANRP in 2008
    - Subunit IV completed by OANRP in 2011
- Conduct quarterly perimeter fence checks.
- Conduct yearly Subunit and interior fence checks.
- Note any pig sign while conducting day to day actions within fenced MU.
- If any pig activity is detected, work with Ungulate Management/Elepaio Stabilization Coordinator to implement hunting or snaring.

Discussion: There is a perimeter fence around the entire MU. The major threats to the perimeter fence include fallen trees, vandalism, rock fall, and high water events. There are no “major” gulch crossings but rather three smaller crossings that have potential to carry a large amount of debris. Special emphasis will be placed on checking the fence after extreme weather events, such as in when 2011 when a stream breached the unit II part of the perimeter. There have been relatively few incidences of vandalism to the fence in the past.

For Ungulate Management Map, please see Weed Survey Map for existing fence lines.

Weed Control

Weed Control actions are divided into 4 subcategories:

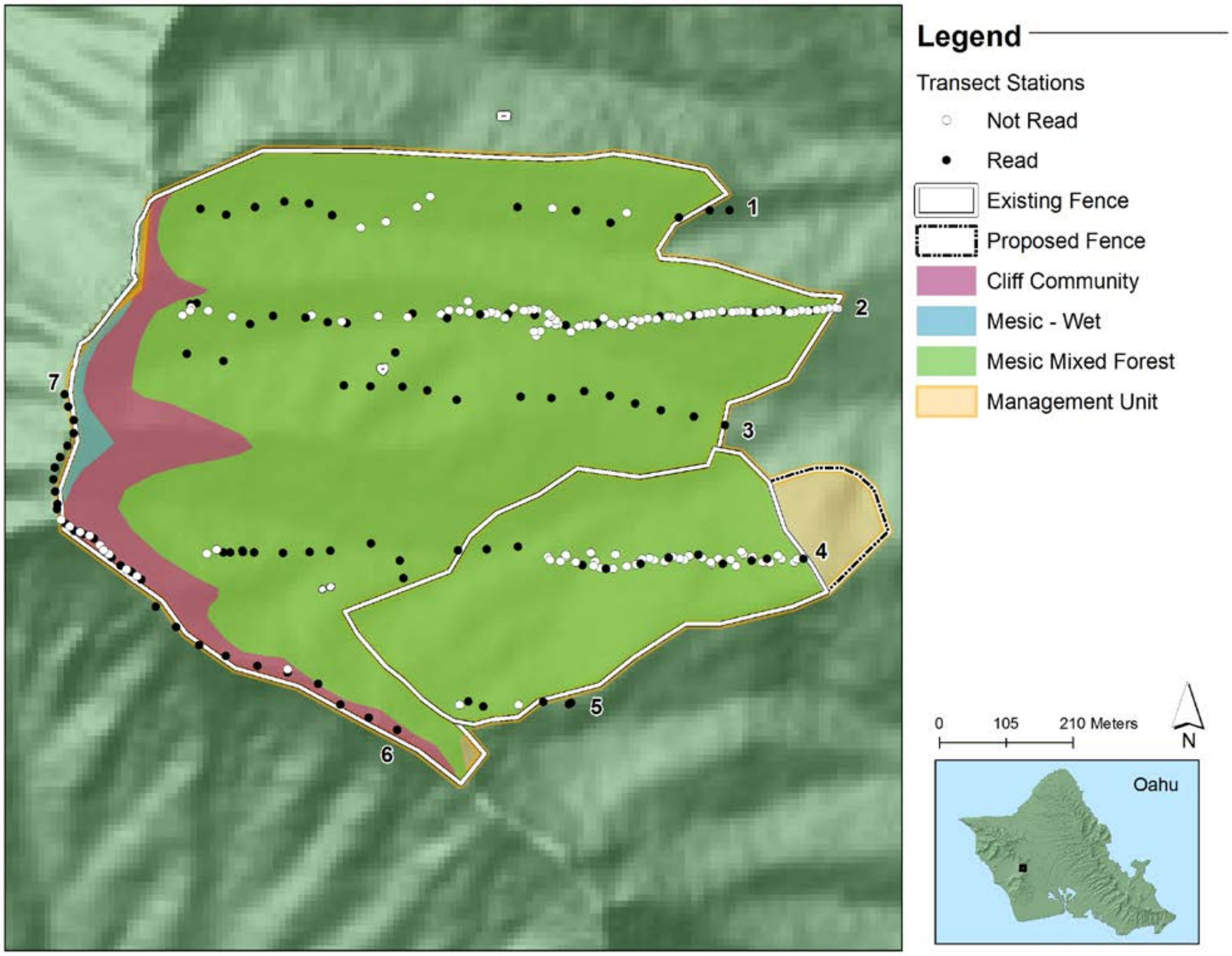
1) Vegetation Monitoring
2) Surveys
3) Incipient Taxa Control (Incipient Control Area - ICAs)
4) Ecosystem Management Weed Control and Restoration Actions (Weed Control Areas - WCAs)

These designations facilitate different aspects of MIP/OIP requirements.

Vegetation Monitoring

From October to November of 2008, a total of 115 bell plots in 7 transects were monitored for the Ekahanui management unit (MU). MU monitoring will be conducted every ten years and will provide OANRP with trend analyses on vegetation cover and species diversity. Results from the 2008 monitoring are included in the 2009 annual report (map of the locations of MU monitoring transects below reflects Ekahanui MU from the 2008 monitoring). Plots measuring 5 x 10 m were generally located every 20 m along transects. Transects were located in accessible areas (as the majority of the MU is too steep to access), spaced approximately 50 m apart. Understory (0 – 2 m 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. Based on MIP 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 and Friedman's tests with Bonferroni adjusted post-hoc pairwise comparisons for cover data, paired t tests and repeated measures ANOVA for species richness data, and McNemar's tests for frequency data.

Locations of MU Monitoring Transects



Vegetation Monitoring Analyses

The mean alien vegetation cover in the understory was 33% across the MU. The 90% confidence interval for the mean was 28% to 37%. This percentage meets the management goal of 50% or less non-native cover in the understory. The mean alien canopy cover was 56% with 90% confidence that the mean was 50% to 62% (refer to MU Vegetation Monitoring table).

Pimenta dioica and *Fraxinus uhdei* are non-native species which OANRP is interested in tracking over time in order to learn more about the potential threat of these species. From the data collected for the 2008 MU vegetation monitoring, *P. dioica* occurred in one out of 115 plots and *F. uhdei* in six.

A large portion of the MU was fenced for the protection of Elepaio and has been weeded on a gradual basis. In areas around rare plant taxa, OANRP has been taking a more aggressive approach to weed management (refer to Ecosystem Management Weed Control section) to meet the IP goals for each OIP/MIP managed plant taxon. In addition, OANRP has plans to restore native habitat for rare taxa and decrease weeding efforts in areas where staff has spent large amounts of time weeding via native common outplanting. Possible restoration efforts in Ekahanui MU is discussed in the Ecosystem Weed Control section below.

MU Vegetation Monitoring Analyses

Variable	Count	Mean	StDev	*lower limit	*upper limit
NF	115	5.4	15.4	3.1	7.8
NS	115	9.5	15.6	7.1	11.9
NG	115	1.6	4.4	1	2.3
XF	115	3.8	12.4	1.9	5.7
XS	115	18.8	21.1	15.5	22
XG	115	11.2	21.1	8	14.5
NoVegUS	115	53.6	34.5	48.3	59
NativeUS	115	15.2	21.7	11.8	18.5
AlienUS	115	32.9	29.3	28.4	37.4
NativeCanopy	115	15.9	25.3	12	19.9
AlienCanopy	115	56.3	38.1	50.5	62.2
TotalCanopy	115	68	31	63.2	72.8
*90% probability interval					

NF=Native ferns NS=Native shrubs NG=Native grasses XF=Alien ferns XS=Alien shrubs XG=Alien grasses
NoVegUS=Total Non-vegetative (bare ground) understory NativeUS= Total Native understory AlienUS= Total alien understory

With the exclusion of the cliff and wet-mesic communities Ekahanui is a mixed mesic forest. The majority of management falls within this vegetation type and was analyzed separately to aid in setting WCA vegetation percent cover goals. A large portion of the mesic forest was dominated by established monotypic *Psidium cattleianum* stands. This is the main reason for the low percentage of alien vegetation cover and low species diversity in the understory. The mixed mesic vegetation community's mean alien cover in the understory was 33% and 75% in the canopy. The mean native vegetation cover for the understory was 7.2% and 9.4% for the canopy (refer to the Mixed Mesic Vegetation Type Monitoring Analysis table).

Mixed Mesic Vegetation Type Monitoring Analysis

Variable	Count	Mean	StDev	*lower limit	*upper limit
Native US	86	7.2	12	5	9.3
Alien US	86	33.3	30.2	27.8	38.7
Nonveg	86	63.1	32.4	57.3	68.9
Native canopy	86	9.4	17.4	6.3	12.5
Alien canopy	86	74.8	24	70.5	79.1
*90% Confidence Level					

NonVeg=Total Non-vegetative (bare ground) understory NativeUS= Total Native understory AlienUS= Total alien understory

For the MU the alien species mean in the understory was 6.5 and 1.9 in the canopy. The native understory species mean was 6.2 and 1.5 in the canopy (Refer to MU Species Count Table). For the mixed mesic vegetation type the alien species mean in the understory was 4.7 and 2.3 in the canopy. The native understory species mean was 3.7 and 1.2 in the canopy (refer to the Mixed Mesic Vegetation Type Species Count table). This baseline data will be used to track species diversity of the MU over time.

MU Species Count

Variable	Count	Mean	StDev	*lower limit	*upper limit
Native US	115	6.2	6.3	5.2	7.1
Alien US	115	6.5	4.4	5.8	7.2
Native Canopy	115	1.5	2	1.2	1.8
Alien Canopy	115	1.9	1.3	1.7	2.1
*90% Confidence Level					

NativeUS= Total Native understory AlienUS= Total alien understory

Mixed Mesic Vegetation Type Species Count

Variable	Count	Mean	StDev	*lower limit	*upper limit
Native US	86	3.7	3.8	3	4
Alien US	86	4.7	2.9	4.1	5.2
Native canopy	86	1.2	1.4	0.9	1.4
Alien canopy	86	2.3	1.17	2.1	2.5
*90% Confidence Level					

NativeUS= Total Native understory AlienUS= Total alien understory

Vegetation Monitoring Response:

- Increase weeding efforts if the non-native vegetation goals are not being met in the MU.

Surveys

Potential Vectors: OANRP activity, hikers/hunters, pigs/goats, 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:

- Note unusual, significant, or incipient alien taxa during the course of regular field work. Map and complete Target Species form to document sighting.
- Survey LZs quarterly (if used) and Campsites used in the course of field work, not to exceed once per quarter.

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.

At Ekahanui, landing zones are checked when used (not exceeding once per quarter). LZs within the MU include the following: 132 EKA Summit, 106 Ekahanui Crestline, and 136 Ekahanui North. LZ 132 is used increasingly less due to the ingress of *Melinis minutiflora* grass that obstructs the landing zone. This LZ will be cleared to use in case of emergencies. The Ekahanui Trailhead LZ (99) is no longer in existence as it was on private, fallow agricultural land which has been sold and developed. Establishment of another LZ in the area was proposed but has been determined unnecessary since the re-establishment of the SBS LZ. There is a weed transect along the access trail from the trailhead to the fence. There are currently no road surveys for the MU as the access road now goes through private, agricultural land.

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.

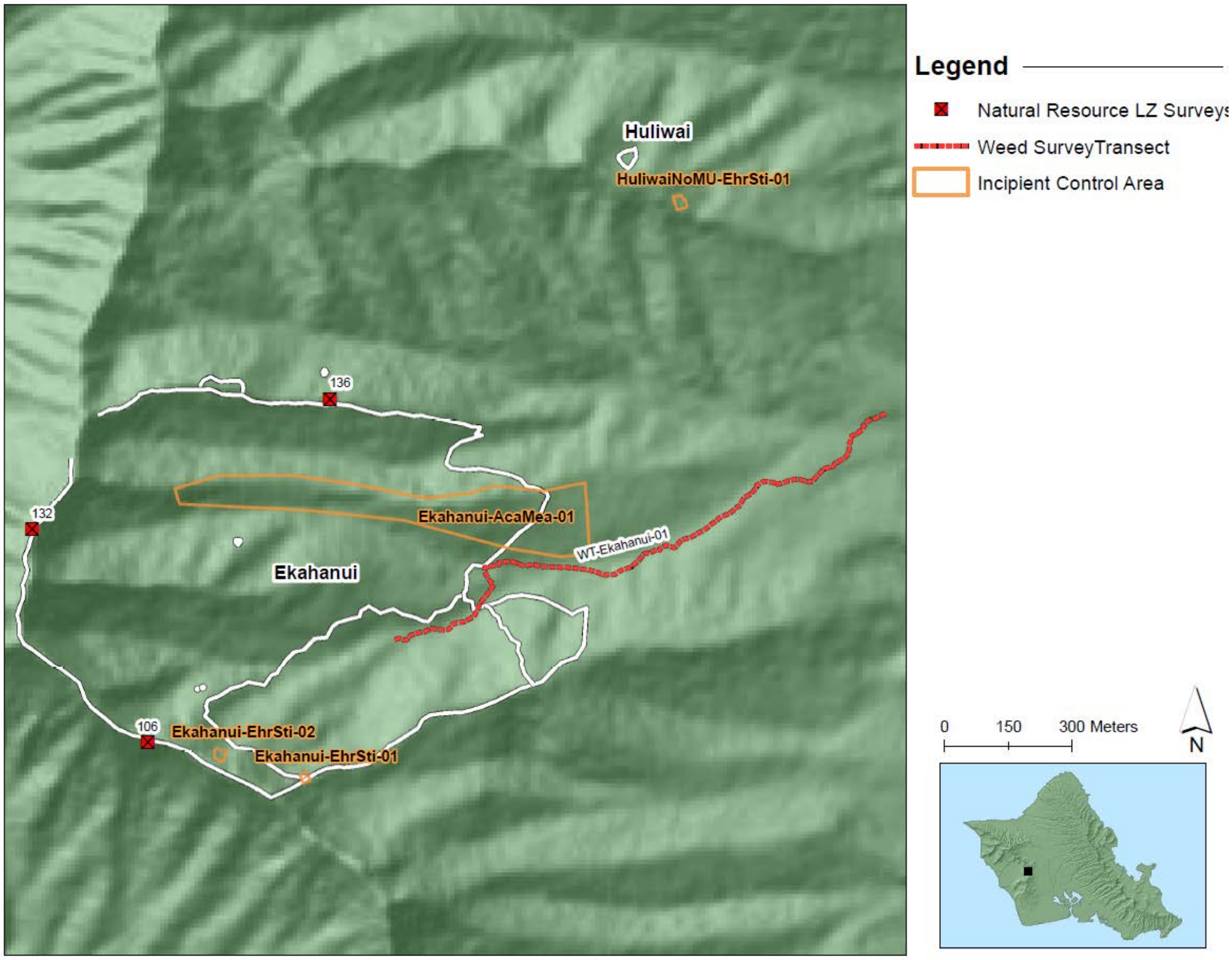
Management Objectives:

- 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, locations, 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.

Incipient Control Area and Survey Locations Map

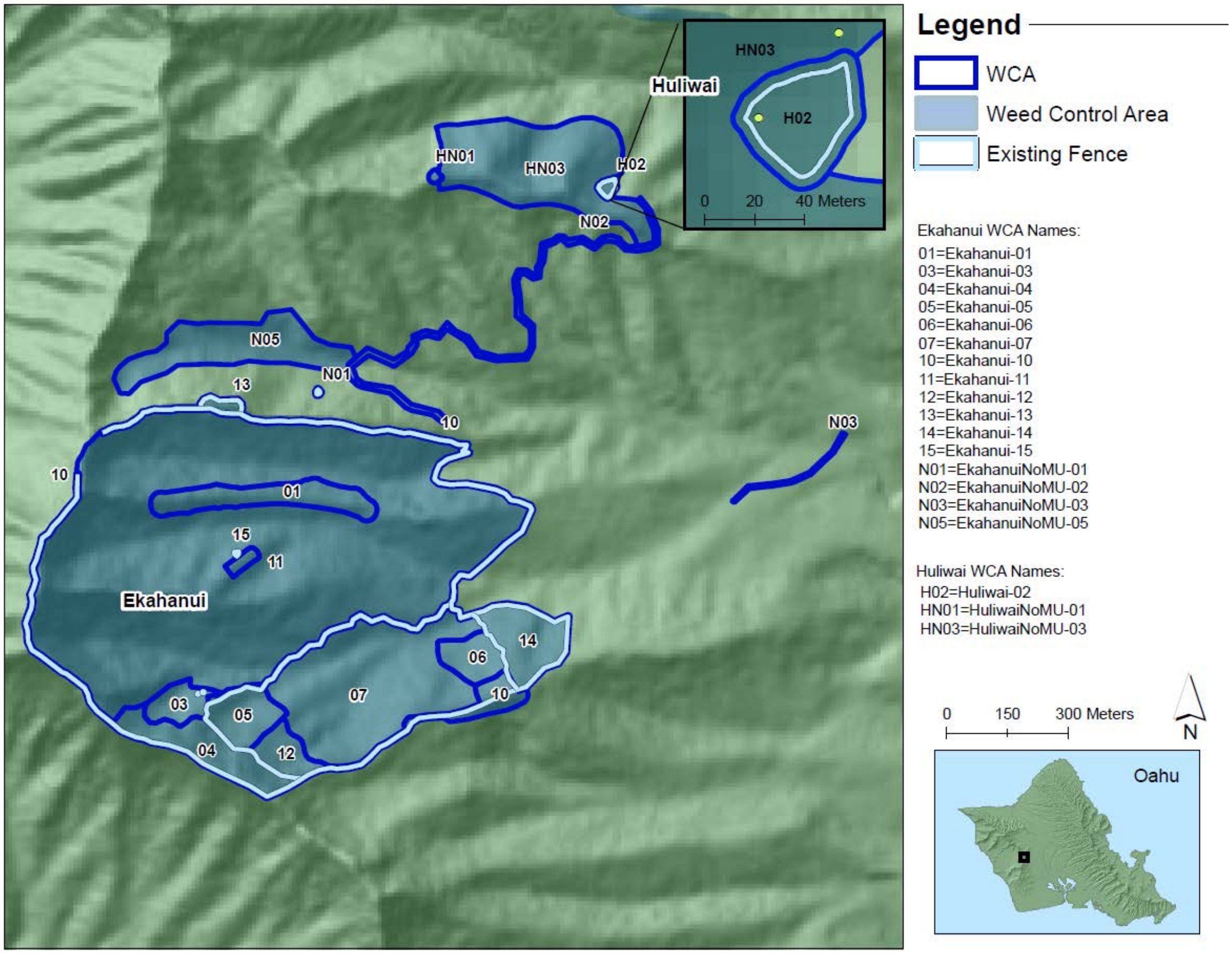


Two incipient species have been identified by OANRP in the MU: *Ehrharta stipoides* and *Acacia mearnsii*. *E. stipoides* ICAs were first reported in 2012 and 2015, which may have been introduced by Pono Pacific staff while monitoring Palikea, where *E. stipoides* is well-established, and Ekahanui rodent trapping grids. Return visits will be scheduled to prevent immature individuals from reaching maturity and to eradicate these species from the MU.

Summary of ICAs

Taxon	ICA Code	Control Discussion
Acacia mearnsii	Ekahanui-AcaMea-01	Known from one location within MU. ICA formed, control ongoing annually. Ekahanui MU is mauka of forestry plantings of *A. mearnsii*. Seeds persist in seed bank. Need wider surveys to better define ICA boundary. Identify any hotspots.
Ehrharta stipoides	Ekahanui-EhrSti-01 Ekahanui-EhrSti-02 HuliwaiNoMU-EhrSti-01	All sites checked at least once per quarter. Targeted for eradication, which can be successfully done due to short-lived seed bank (2 yrs.). Pick and remove from field any potentially mature fruit. Use pre-emergent herbicide. This species is cryptic and can be difficult to ID.

Weed Control Areas Map



Ecosystem Management Weed Control

MIP Goals:

- Within 2m of rare taxa: 0% alien vegetation cover except where removal of weeds 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:

- In WCAs within 50m of rare taxa, work towards achieving 25% or less alien vegetation cover in understory and canopy.

Discussion: Weed control began in Ekahanui with the efforts of TNC. Most of this effort has taken place within the Subunit I fence. *Passiflora suberosa*, which is pervasive throughout the MU, was cleared out of the many *Pisonia* dominated gulches, and *Psidium cattleianum* was thinned from areas with native canopy. Hundreds of endangered plants were planted in this MU by TNC, and many more followed by OANRP. Reintroductions of common natives were also used by TNC to restore habitat within the MU. Much of the weed control conducted by staff in Subunit I follows the actions set forth by TNC staff.

The Ekahanui Subunit II and III fences were completed in 2009. There are a few WCAs within these subunits, and for the most part they are small and are for weed control only as needed around rare plant sites. The entire Subunit II and III was not be broken up into WCAs as is the case with some other MUs, due to the fact that most of Subunit II and III are highly degraded. Subunit III was constructed mainly to protect a wild population and of *Abutilon sandwichensis*. Later this site was augmented with reintroduction *A. sandwichensis* in 2013. The weeding of the WCA in Subunit III is primarily focused on improving the habitat for this species and providing more space for managing reintroduction.

A large concern with weed control in Ekahanui MU is its potential impacts on Oahu Elepaio. The MU has one of the largest breeding populations of Elepaio on the island, and impacts of weed control during breeding season are not well understood. It is reasonable to assume that killing potential foraging and nest trees during breeding season has the potential to be at the very least disruptive to the endangered bird. It is also reasonable to assume that Elepaio have evolved with native forest components and would persist better within restored habitat. No or limited weed control is proposed for the weed-dominated areas of Subunit II. Elepaio territories are surveyed and mapped each year and within these territories canopy weed control is prohibited during breeding. Restricted canopy control may be conducted during 'off' season, with the guidance of the Elepaio specialists.

Weed control in the WCAs of Huliwai are very limited. Weeding is focused around a two IP species (*A. sandwichensis* and *Cenchrus agrimonioides* var. *agrimonioides*). *A. sandwichensis* sites was enclosed by a 0.5 acre fence in 2014. Overall, Huliwai is heavily degraded with alien vegetation and is of low priority for OANRP to manage. Fortunately, a volunteer group named "Friends of Honouliuli" help manage this area with native plant restoration and incipient control.

The table below summarizes invasive weeds found at Ekahanui, 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

Taxon	Distribution	Notes
Araucaria columnaris	Restricted	Found in gulch to the North of Ekahanui fence. Plants are localized and new locations of this taxa found outside of this gulch in the MU will be noted. *A. columnaris* grow large, thus becoming a dominate canopy species. Additionally, *A. columnaris* produces large amounts of leaf litter, which can inhibit native plant recruitment.
Chrysophyllum oliviforme	Scattered	In HuliwaiNoMU-03. Targeted for control within WCAs by the Senior Day care.
Clidemia hirta	Widespread	First observed in the 1970's. High priority to control around rare plant taxa. *Clidemia* is bird dispersed and can become a dominant understory species. *Clidemia* is best treated by using the clip-and-drip method (cutting stump and applying Garlon4 herbicide).
Ficus macrophylla	Widespread	Targeted for control within WCAs. Map individuals/groups of plants within the MU.
Grevilia robusta	Widespread	Widespread throughout the MU. Trees shade out rare plant taxa. Selectively control trees as part of WCA efforts. IPA method using Aminopyralid (Milestone) is effective in

		controlling *Grevilia*.
Heliocarpus popayanensis	Widespread	Targeted for control within WCAs. Effective IPA control method known.
Kalanchoe pinnata	Widespread	Targeted for control within WCAs, especially around rare taxa sites. *K. pinnata* competes with native plant recruitment in inhabiting an area. *Kalanchoe* reproduces vegetatively from cut leaves and stems. It sometimes forms dense stands. It should not be controlled via clip-and-drip treatments, as cut material may regrow. Plants should be treated with a foliar spray of glyphosate or foliar drizzle of Garlon 4.
Passiflora suberosa	Widespread	Widespread vine in MU. It has a WRA of 12 (very high), roots from multiple nodes, smothers surrounding vegetation, and is labor-intensive to remove. Control around rare taxa as part of WCA efforts.
Pimenta dioca	Restricted	Found in gulch to the North of Ekahanui fence. Plants are localized and spread out of this gulch into the MU will be noted. Targeted for control. Effective IPA control method known.
Psidium cattleianum	Widespread	Targeted for control within WCAs, especially around rare plant taxa sites. *Psidium* is one of the most invasive tree species in Hawaii and has the ability to become the dominant species in the forest. However, *Psidium* will not be aggressively controlled in Subunit II, where Elepaio occur. Elepaio tend to use this tree species for nesting.
Ricinus communis	Scattered	Targeted for control whenever observed; map individuals/groups of plants within the MU. Bird dispersed, so could come up anywhere.
Schefflera actinophylla	Scattered	Targeted for control whenever observed; map individuals/groups of plants within the MU. High priority since it has the ability to become a canopy dominant species. Bird dispersed, so could come up anywhere. Effective IPA treatment known.
Schinus terebinthifolius	Widespread	Targeted for control within WCAs, especially around rare plant taxa sites and along the fenceline. Trees shade out rare plant taxa and rip apart slopes when they fall over. Trials conducted from 1996-98 suggest that girdling and applying herbicide is one of the best control methods. Since it may be a dominant canopy species around rare plant taxa, controlling *Schinus* will be gradually removed and replaced by common native outplantings.
Setaria palmifolia	Scattered	Large patches occur on the access trails below the MU, as well as several occurrences within the MU. This grass is controlled along well-used access trails and around rare taxa sites. *Setaria* can thrive in shaded areas, which makes it a major threat.
Spathodea campanulata	Scattered	Kill when seen. Effective IPA treatment known. Occurs in low densities in this MU.
Urochloa maxima	Scattered	*U. maxima* is widespread in the disturbed habitats that surround the MUs. *U. maxima* patches are found scattered throughout the Ekahanui MU and are targeted when feasible along with other grasses to reduce potential fire fuel loads. This grass is targeted for eradication in the Huliwai MU, and is controlled along well-used access trails and within frequently managed sites.

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 Ekahanui.

Taxa Considerations for Restoration Actions:

Native Taxon	Outplant?	Seedsow/ Division/ Transplant?	Notes
Acacia Koa	Yes	Yes	Tree. Grow from seed.
Antidesma platyphyllum	Yes	No	Tree. Grow from cuttings or seed.
Antidesma pulvinatum	Yes	No	Tree. Grow from cuttings or 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.
Carex wahuensis	Yes	Seedsow/Division	Sedge. Grow from seed. Seed sows slow to germinate but effective.
Coprosma foliosa	Yes	No	Shrub. Grow from cuttings or seed.
Claoxylon sandwicensis	Yes	No	Small tree. Grow from seed.
Dodonea visoca	Yes	No	Small tree. Grow from seed.
Dianella sandwicensis	Yes	Division	Herb. Conduct divisions in the field.
Eragrostis grandis	Yes	Seedsow/Transplant	Grass. Grow from seed, sow as stock available
Hibiscus arnottianus	Yes	No	Tree. Fast-growing. Grow from cuttings.
Kadua affinis	Yes	No	Small tree. Grow from seed.
Metrosideros polymorpha	Yes	No	Tree. Slow-growing. Grow from cuttings or seed.
Microlepia strigosa	Yes	Division	Fern. Survives transplanting in mesic-wet environments in moist conditions. Can also bring divisions back from field for more successful propagation and consequently outplant
Myrsine lessertiana	Yes	No	Tree. Grow from seed.
Pipturus albidus	Yes	Seedsow/Transplant	Small tree. Fast growing. Known to grow from seed sows, particularly in gulches and areas with light gaps.
Pisonia brunoniana	Yes	Seedsow/Transplant	Tree. Fast growing. Easy to propagate via cuttings. Known to grow from seed sows.
Pisonia sandwicensis	Yes	Seedsow/Transplant	Tree. Fast growing. Easy to propagate via cuttings. Known to grow from seed sows.
Pisonia umbelifera	Yes	Seedsow/Transplant	Tree. Fast growing. Easy to propagate via cuttings. Known to grow from seed sows.
Planchonella sandwicensis	Yes	No	Tree. Grow seed. Slow growing.
Plumbago zeylanica	Yes	Division	Herb/ground cover. Grow from cuttings or seed. Unknown if transplanting effective.
Psydrax odorata	Yes	No	Tree. Grow from seed.
Sapindus oahuensis	Yes	No	Tree. Grow from seed.
Urera glabra	Yes	No	Small tree. Grow from cuttings or seed.

WCA: Ekahanui-01 (Airplane Ridge)

<u>Veg Type</u>: Mesic Mixed Forest

<u>MIP Goal</u>: Less than 25% non-native cover

Targets: *Psidium cattleianum* and *Schinus terebinthifoius* are targeted for gradual removal from the overstory. *P. suberosa* densities are surprisingly low in this WCA given high densities elsewhere in the MU. Therefore, it is targeted on all weed sweeps.

Notes: This WCA occurs around a wild population of *C. agrimonioides* var. *agrimonioides.* Weed control is currently conducted across the north-facing slope on a large ridge around the many small patches of this rare grass. Overstory canopy consists mostly of *P. cattleianum* and *S. terebinthifolius,* which are gradually removed to reduce large light gaps. *G. robusta* is prevalent throughout the ridge and is controlled during weed sweeps.

Alien grass species are hand cleared around the wild *C. agrimonioides* var. *agrimonioides.* Grass specific herbicides may be used to treat alien grass across the ridge in the future, but only after thorough surveys have been conducted to identify all individuals. After all these small patches are thoroughly weeded, larger sweeps between all these patches will begin thus creating continuous habitat across the slope.

WCA: Ekahanui -03 (Small *S. kaalae* fences)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Understory weeds such as *Cyclosorus parsitica* and *Rubus rosifolius*

Notes: Originally this WCA was a very small area in Subunit II around a population of *S. kaalae* individuals, but was expanded in size to include an area for reintroduction of *Phyllostegia mollis* in 2012. As of 2016, none of the *P. mollis* outplants remain due to a powdery mildew that causes 100% mortality. Management of this reintroduction area through weed and slug control has improved the understory and canopy greatly. Although, the *P. Mollis* reintroduction have failed, the area will continued to be weeded because the native patch is so diverse and has few weedy species. In addition, this site may be a potential reintroduction site again for *P. mollis* or other managed plant taxa. For the two *S. kaalae* fences, targeting weeds in the understory for control is conducted directly around the rare plants. The canopy in both fences is predominately *P. cattleianum* canopy and has not been heavily weeded to maintain light levels.

WCA: Ekahanui -04 (Upper Cliffs to Crestline)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Understory and canopy weeds, targeting *P. cattleianum* and *S. terebinthifolius* for gradual removal.

Notes: Weed control is focused in this area around *Plantago princeps* var. *princeps*, *Tetramolopium lepidotum var. lepidotum*¸ *Achatinella mustelina,* and *Kadua parvula*. The area is steep, and weed control is therefore conducted in smaller patches between cliff areas. Removal of alien vegetation is targeted for slow removal as there is a mix of native and non-native plants throughout the WCA. Because there are snails in the area, alien trees and shrubs will be girdled, and not cut down. Grass control is important in maintaining native habitat for the cliff-dwelling rare plants. However, grass sprays are difficult given the steep terrain. Grass control will be conducted only after thorough surveys of grass locations are completed, thereby facilitating safer sprays. *Kadua parvula* was reintroduced on to the cliffs in this WCA in 2016. Weed control around this population will have to be conducted while on rappel. A protocol for weed control while on rappel should be developed in order to conduct this action.

WCA: Ekahanui -05 (Reintroduction Zone)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Understory weeds are currently the largest target in this WCA, however overstory *P. cattelianum* and *S. terebinthifolius* is targeted for gradual removal where it is found in mostly native areas.

Notes: Due to the existence of a small patch of native forest that has a long history of weeding by TNC and later by OANRP in this area, there is a high density of native cover in this WCA. This small native forest patch is appropriate habitat for several rare species and many reintroductions are established here. These species include: *C. agrimonioides* var. *agrimonioides, Cyanea grimesiana* subsp. *obatae*, *C. pinnatifida* (TNC reintroduction), *D. waianaeensis*, *P. mollis*, *Schiedea kaalae*, *S. hookeri* (TNC reintroduction), *Solanum sandwicense* (TNC reintroduction) and *Urera kaalae* (TNC reintroduction). There are also wild *S. kaalae* and formerly there was a wild *Alectryon macrococcus* var. *macrococcus* individual within the WCA. Regular weed sweeps will continue through the area to maintain this diverse native habitat.

While the areas around the rare plants are the most native, there are still a few larger stands of *P. cattleianum* throughout the WCA. These weeds are targeted for gradual removal during weed sweeps, with particular consideration of Elepaio, as there are several breeding pairs in this area. No canopy *P. cattleianum* will be treated during breeding season.

Large scale grass control has not yet been necessary in this WCA as most of it is gulch terrain. However, there is a fair amount of *Melinis minutiflora* growing on the *C. agrimonioides* var. *agrimonioides* reintroduction ridge. Grass is hand pulled directly around the rare grass to reduce the non-target impact from herbicide. After all the *C. agrimonioides* var. *agrimonioides* individuals have been identified and cleared around, the herbicide is sprayed far enough away to prevent the effects of drift. This area of the WCA needs common native reintroductions to reduce light levels in the understory and reduce competition from alien grasses with *C. agrimonioides* var. *agrimonioides*. Plantings of *Acacia koa* and *Dodonea viscosa* at a relatively high density may help.

WCA: Ekahanui -06 (Palai Gulch)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Understory weeds include: *R. rosifolius* and *C. parsitica. Passiflora suberosa* is also controlled.

Notes: Nicknamed Palai Gulch for its many native ferns, this WCA occurs around reintroduced *A. sandwicense*, *C. grimesiana* subsp. *obatae*, *U. kaalae* (TNC planting) and *S. kaalae*. Understory weeds such as *R. rosifolius* and *C. parsitica* compete with native ferns, and along with *P. suberosa* are the most common weeds controlled during weed sweeps. There is a significant amount of *P. cattleianum* that circles about half way around the WCA, however, control to push these dense stands back is limited by the fact that the WCA is within an Elepaio territory. Canopy weed control will not be conducted during

Elepaio breeding season to avoid disrupting foraging and nesting behavior. Canopy weed control, if any, will only be conducted outside of Elepaio breeding season, and in consultation with the Elepaio specialist.

Weed control has expanded in this WCA further up the gulch over the years. Recent efforts have focused on clearing understory weeds and *P. suberosa* in an area where *A. sandwicense* has been reintroduced. Once a relatively open area this section of the gulch has been filled in by *Pipturus albidus*, and weeding efforts focus on controlling *R. rosifolius*.

Due to the shady canopy, the weedy grass *Oplismenus hirtellus*, thrives in the gulch. Near the mauka edge of the WCA the canopy is more open and there is also *U. maxima* present. Annual grass sprays will be conducted to control these grasses.

WCA: Ekahanui -07 (Unit I)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 50% non-native cover

Targets: *G. robusta, P. cattelianum, Urochloa maxima*.

Notes: For this iteration of the MU plan the WCA has been expanded to include the rest of the undesignated areas in the unit I fence. Like its predecessor, this expanded WCA is comprised of alien dominated forest, with no actively managed rare plant populations. Elepaio pairs inhabit the majority of this WCA, therefore no control of any canopy weeds will be conducted during Elepaio breeding season, if at all. In years prior, on silky oak ridge TNC staff planted hundreds of small *A. koa*, with poor results. Most of the saplings did not do well under the dense *G. robusta* canopy. Since Elepaio seldom nest in *G. robusta* this would be a good potential test site to restore native habitat for nesting Elepaio. Weed control in this WCA will be focused on maintaining the trails that service the rat trapping grid.

WCA: Ekahanui -10 (Fenceline)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Fallen trees that may affect the integrity of fence, and thick understory along fence line that may obscure view of bottom of fence. *U. maxima* is abundant on the southeast corner of the fence and is a fire threat.

Notes: This WCA accounts for all weed control that takes place in order to maintain the fence line and facilitate fence checks. WCA Ekahanui-08 has been incorporated into this WCA as it fell along the fence line and had overlapping targets and goals. *U. maxima* is an extremely flammable fuel, and elimination from the fence as well as creating a buffer on the outside of the fence is desired. Other actions for this WCA may include: removing downed trees, treating thick understory, and spraying other grass as needed along the perimeter fences of subunit I and II. Weed control needs for this WCA will be assessed and conducted quarterly as needed in conjunction with quarterly fence checks.

WCA: Ekahanui -11 (Cenagragr EKA-C Site)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Understory weeds directly around remaining reintroduced *C. agrimonioides* var. *agrimonioides.*

Notes: Weed control was initiated in this area because of a reintroduction of *C. agrimonioides* var. *agrimonioides*. However, the population has had a sharp decline (6 of 39 plants remain) and the site has been determined to be unsuitable. No more plants will be planted here. Understory weed control will continue directly around the remaining plants but greater habitat restoration here will not be conducted.

WCA: Ekahanui -12 (*Amastra* fence slope)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Control all understory weeds and *P. suberosa*, and gradually treat *P. cattleianum* and *S. terebinthifolius.*

Notes: *A. mustelina* and several TNC rare plant reintroductions occur in this WCA. This WCA has similar species composition and range of topography as its neighbor adjacent on the same contour, WCA-05. However, WCA-12 has fewer native patches and more weedy zones. Weed efforts will be two fold; maintain the small native patches in the WCA, and weed between them in order to achieve the long term goal of having one continuous contour of suitable habitat for a number of rare taxa along the top of Subunit I. Weed sweeps and grass sprays will be conducted annually.

WCA: Ekahanui -13 (New Cenagragr EKA-D Site)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native

Targets: Understory weeds, gradual removal of *P. cattleianum* and *S. terebinthifolius* from canopy.

Notes: Weed control has been conducted in this area in support of a reintroduction of *C. agrimonioides* var. *agrimonioides* as well as a wild population that was discovered in 2011 on the day of the reintroduction. Canopy weeds of *P. cattleianum* and *S. terebinthifolius* have been removed gradually; however not much native canopy species recruitment has occurred.

Grasses and other understory weeds have become more plentiful in this WCA over the last five years. While many of the outplanted *C. agrimonioides* var. *agrimonioides* have died, many have reproduced and some of those F1's have matured. This site would benefit from an outplanting of *A. koa* and *D. viscosa* to decrease light levels in the understory and ease the control of understory broadleaf weeds and grasses.

WCA: Ekahanui -14 (Abutilon)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native

Targets: Understory weeds such as *Lantana camara, O. hirtellus*

Notes: This WCA is highly degraded, and minimal weed control is conducted around a wild/augmented population of *A. sandwicense.* The slope that the plants are on is somewhat steep and has soft soil. Heavy foot traffic around the plants is not desired. Weed control of nearby *L. camara* patches and thinning of *S. terebinthifolius* has been conducted annually along with rare plant monitoring to reduce negative impacts to the population. In 2013 incision point application (IPA) was used to treat *Grevillea robusta* in the overstory with mixed results. The focus on recent visits has been on controlling *O. hirtellus* and *Mesosphaerum pectinatum* in the understory. Once more of the *Grevilia* canopy has been successfully thinned, common reintroductions of *A. koa, S. oahuensis*, *D. viscosa,* and *M. strigosa, P. brunoniana* should be planted around the plants to aid in stabilization of soil, reduce weeding efforts, and to improve overall habitat.

WCA: Ekahanui -15 (Unit II)

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 50% non-native cover

Targets: *G. robusta, P. cattelianum,*

Notes: For this iteration of the MU plan the WCA has been expanded to include the rest of the undesignated areas in the unit II fence. This expanded WCA is comprised of alien dominated forest, with no actively managed rare plant populations. Elepaio pairs inhabit the majority of this WCA, therefore no control of any canopy weeds will be conducted during Elepaio breeding season, if at all. Weed control in this WCA will be focused on maintaining the fence line and trails that service the rat trapping grid.

WCA: Ekahanui NoMU-01 (DelWai EKA-A)

Veg Type: Mesic Mixed Forest

MIP Goal: Weed 2m around *D. waianaeensis* individuals

Targets: *S. terebinthifolius, Clidemia hirta*

Notes: This WCA occurs outside of the MU, however is still within Ekahanui drainage. Weed control is conducted primarily around a small wild, fenced population of *D. waianaeensis*. Weeding is done only directly around the plant as it is a genetic storage collection. Understory weeds and grasses are treated. No canopy is weeded; however *S. terebinthifolius* will be cleared if fallen on the fence.

WCA: Ekahanui NoMU-02 (Contour Trail)

Veg Type: Mesic Mixed forest

MIP Goal: N/A

Targets: *U. maximum* and *Setaria palmifolia*

Notes: This WCA was created to maintain access along the Honouliuli contour trail from Ekahanui to Huliwai MU. The trail is occasionally sprayed to prevent the spread of *U. maxima* and *S. palmifolia* further along the trail, ultimately preventing its spread into the MU. *S. terebinthifolius* and various shrubs will also be trimmed off the trail if necessary.

WCA: Ekahanui NoMU-03 (Ekahanui trail)

Veg Type: N/A

MIP Goal: N/A

Targets: *U. maxima* and *S. palmifolia*

Notes: This WCA was created to maintain the trail access into Ekahanui MU. The trail is occasionally sprayed to prevent the spread of *U. maxima* and *S. palmifolia* further along the trail, ultimately preventing its spread into the MU. *S. terebinthifolius* and various shrubs will also be trimmed off the trail if necessary.

WCA: Ekahanui NoMU-05 (Allspice gulch)

Veg Type: Mesic Mixed forest

MIP Goal: N/A

Targets: *Pimenta dioica*

Notes: WCA was created for control of *P. dioica* by the volunteer group "Friends of Honouliuli." OANRP staff performed one control effort in 2012, but it is unclear as to whether the volunteer group has continued work in this area.

WCA: Huliwai-02 (Abutilon)

Veg Type: Mesic Mixed forest

MIP Goal: Less than 25% non-native

Targets: Understory weeds such as *O. hirtellus*, *Rivina humilis*

Notes: This WCA is highly degraded, and minimal weed control is conducted around a wild population of *A. sandwicense*. *S. terebinthifolius* and *S. cumini* have been thinned out to increase light levels for *A. sandwicense* however the native *S. oahuensis* canopy cover has increased as a response. Due to the shady canopy, the weedy grass *O. hirtellus*, thrives throughout the WCA. *A. sandwicense* has recruited within a thick *O. hirtellus* understory and NRM staff noticed an increase in seedling mortality once *O. hirtellus* was removed. Due to the climate here, this may be because the seedlings became exposed and dried out. Further removal of the grass around seedlings will be compared to leaving it to see whether it is beneficial for the recruitment of the *A. sandwicense* or not. Replacing the non-native grass with natives that would allow for recruitment, such as *C. meyenii* and *C. wahuensis* will also be a goal.

WCA: HuilwaiNoMU-01 (Cenchrus)

Veg Type: Mesic Mixed forest

MIP Goal: Less than 25% non-native

Targets: Understory weeds such as *M. minutiflora*, *Paspalum conjugatum*, *P. cattelianum*, *C. hirta*

Notes: This WCA is highly degraded, and minimal weed control is conducted around a wild population of *C. agrimonioides* var. *agrimonioides*, which is only managed for genetic storage. Keeping non-native grasses and fast growing understory weeds out of area is a priority.

WCA: HuilwaiNoMU-03 (Satin leaf)

Veg Type: Mesic Mixed forest

MIP Goal: N/A

Targets: *Chrysophyllum oliviforme*

Notes: This WCA was created to control *C. oliviforme* along the Honouliuli contour trail. NRM staff now controls grass, target canopy and understory weeds from ridgeline as this is the access trail for the of *C. agrimonioides* var. *agrimonioides*. WCA is lower priority for OANRP staff since there are minimal rare taxa. WCA has been weeded by the volunteer group "Friends of Honouliuli" targeting the pockets of natives and *C. oliviforme* infestation.

Small Vertebrate Control

Species: *Rattus rattus* (black rat, roof rat), *Rattus exulans* (Polynesian rat, kiore)

Threat level: High

Seasonality/Relevant Species Biology: OANRP manages some species only seasonally for *Chasiempis ibidis* or 'Oahu Elepaio' during the nesting season that runs from December to June. Other species i.e. *A. mustelina* and *P. princeps* var. *princeps* are protected year-round. Spikes in rodent population is often observed following the fruiting season (about twice a year) of *Psidium cattelianum* then returns back to a regular level.

Management Objective:

- Maintain low levels of rat activity across entire MU. Ideally less than 10% activity measured in tracking tunnels.
- Facilitate stabilization or increasing of managed taxa populations across the MU.
- Keep sensitive *A. mustelina* populations safe from rat predation via construction of a predator proof fence (*A. mustelina* enclosure to be built offsite at the Palikea MU).

Strategy and Control Methods

- Control rodents annually around *A. mustelina* and *P. princeps* var. *princeps*.
- Monitor ground shell plots for predation of *A. mustelina* by rats
- Monitor rare plant resources to help guide localized rodent control
- Quarterly tracking tunnels for indicators.
- Convert Victor snap trap grid to Goodnature A24 grid.

Rat control strategies to be utilized by OANRP in 2015-2016.

MU/Area	Primary Spp. Protected	Control Method	Description	Trap Type	# Traps	Deployment	Check Interval
Ekahanui† *i*	*A. mustelina*	Trapping Grid	Many small grids	Victor® w/out boxes	47	Year-round	4-6 weeks
				A24 Automatic traps	30		
	C. ibidis	Trapping Grid	Large-scale grid	Victor® w/ & w/out boxes[i]	620	Annual: Dec-June	2 weeks

† *Contracted Pono Pacific to maintain rat grids during Elepaio nesting season.*
i The majority of traps have been removed from the wooden boxes and placed in trees.

Discussion: OANRP manages rats threatening some rare species only seasonally for *Chasiempis ibidis* during the nesting season, while *A. mustelina* and *P. princeps* var. *princeps* are protected year-round. Above is a table from the 2016 OANRP annual report and will be updated by the 2018 OANRP annual report after transforming the trapping grid to all A24s. There are small localized trapping grids consisting of 34 A24s and 47 Victor snap traps around the *A. mustelina* and *P. princeps* var. *princeps* areas. The large trapping grid for the entire MU currently has 620 Victor snap traps for *C. ibidis*. Although rodent control in the MU is mainly for *A. mustelina*, *P. princeps* var. *princeps* and *C. ibidis*, traps are placed throughout the MU, thereby protecting other MIP/OIP taxa that are also located in the MU. At other sites, rodent damage has been observed on *C. grimesiana* and *D. waianaensis*. If other MIP/OIP taxa are determined to be affected adversely by rodents, OANRP will evaluate the use of smaller localized grids for the protection of these species. By the end of 2017, the Ekahanui MU Victor snap trapping grid will be replaced by 350 Goodnature A24s. This will allow rodent control to become year-round for all managed taxa in this MU. OANRP staff will check A24s every 4 months and continue monitoring rodent activity using tracking tunnels quarterly.

Small Vertebrate Management Map

Map removed to protect rare resources

Slug Control

Species: *Deroceras laeve*, *Limax maximus* and *Meghimatium striatum*

Threat Level: High

Seasonality/Relevant Species Biology: Slugs are seasonally abundant during the wet season. However, slugs are not detectable during the dry season from May-September, therefore summer application is less critical.

Management Objectives:

- Control slugs locally to ensure germination and survivorship of *Cyanea grimesiana* subsp. *obatae*, *Delissea waianaeensis* and *Schiedea kaalae*.
- Conduct annual census monitoring of rare plant taxa to look for seedling recruitment and slug herbivory.
- Avoid potential impacts to rare snails.

Strategy and Control Methods: Slug Control Areas (SLCAs) around rare plant locations have been surveyed and receive treatment every 6 weeks with FerroxxAQ®. No rare snails are present within 20m of any SLCA.

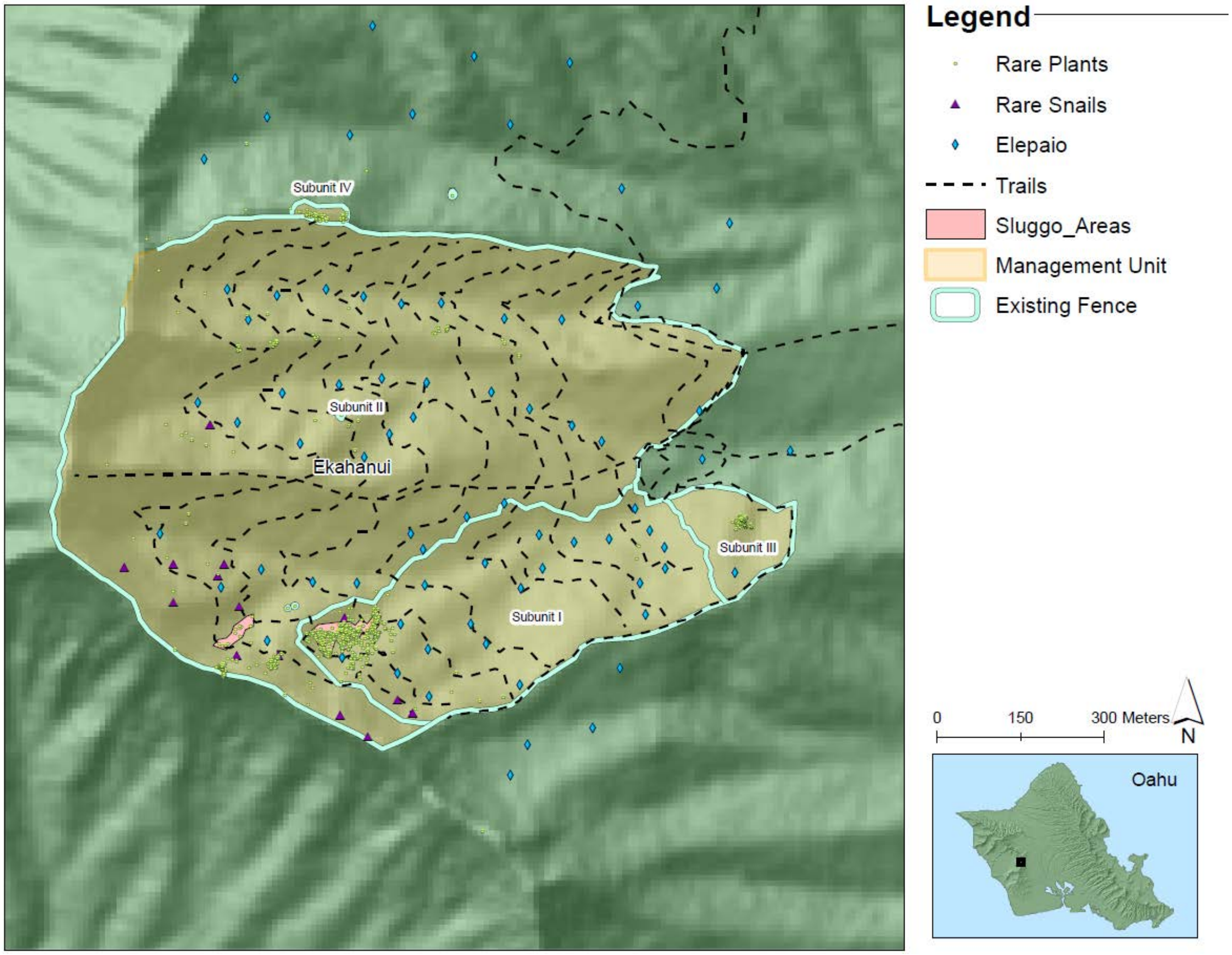
- If new sites for rare plant reintroductions are chosen outside of the existing SLCAs, and slug damage is observed, we will begin slug control if 1. Slug abundance monitoring indicates slugs are active in the area and 2. If surveys indicate there are no native snails nearby.

Slug Control Area Locations Table

SLCA Code	Plant population reference codes	Date slug control begun
EKA-A-1	*C. grimesiana* subsp. *obatae* (EKA-C) , *D. waianaeensis* (EKA-D), *S. kaalae* (EKA-D)	2011

Discussion: Slug control in Ekahanui began in early 2011 following the registration of Sluggo for use in natural areas. Since then, it has been applied regularly around rare plant taxa observed to be vulnerable to slug attack. Seedlings of *S. kaalae*, *C. grimesiana* and *D. waianaeensis* have emerged in areas receiving regular slug control. The use of FerroxxAQ® began in 2017 after determining that this slug control product was more effective managing slugs as compared to Sluggo.

Slug Management Map



Ant Control

Species: *Solenopsis papuana*, *Technomyrmex albipes* and *Plagiolepis alludi*

Threat Level: Medium to high (for *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 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.
- If incipient, high-risk ant species are found. Implement control methods that will not impact *Drosophila.*

Strategy and Control Methods:

- Sample ants at human entry points using the standard survey protocol (see survey protocol below) 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 areas with high traffic (i.e. flying new materials in for snail enclosures or plant reintroduction sites)
- 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**
2D outplanting site	This is a rare plant reintroduction site with a drop zone. Formerly a lot of material was flown into the area making it a high risk area for accidental introductions.

Discussion: Ants have been documented to pose threats to a variety of resources, including native *Drosophila*, plants (via farming of Hemipterian pests), and birds. It is therefore important to prevent new species to become established in areas of conservation value. Since 2008, we sampled ants at rare plant reintroduction sites, water tanks, and trailhead using the following survey protocol:

Survey protocol: 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 to invertebrate specialist for later identification.

Annual surveys at the current (2D) site may be discontinued in the near future since no new plants or materials have been flown into that area for three years. Ant species present are widespread and not a target for eradication. New sites may be surveyed for ants if plant reintroductions are planned for that area in the MU.

Predatory Snail Control

Species: *Euglandina rosea* (rosy wolf snail)

Threat level: High (for *Achatinella*)

Seasonality/Relevant Species Biology: Peak numbers recorded March through June.

Management Objectives:

- Keep sensitive snail populations safe from predatory snails via construction of a predator-proof fence (*A. mustelina* enclosure), which will be located at the Palikea MU. While the enclosure is being prepared, snails will be collected and maintained in a laboratory by the Snail Extinction Prevention Program
- Since our management objective is to maintain *A. mustelina* offsite, control of *E. rosea* is not necessary. Rather our focus will be to collect all *A. mustelina* and protect them from threats offsite

Strategy and Control Methods

- There are no effective techniques for controlling *E. rosea* in the field except for manual removal when found by known *A. mustelina* sites.
- *A. mustelina* at this MU have declined in numbers dramatically and the temporary enclosures failed, so translocating all A. mustelina to the SEPP rearing laboratory has been an ongoing action.
- *A. mustelina* removed from Ekahanui will be permanently translocated to the Palikea North snail enclosure once the enclosure is complete.

Discussion: Surveys confirm *E. rosea* and are present in this MU, though their numbers appear to have declined over the past year. Control options for *E. rosea* are limited to hand removal of snails when found near native snails. Such efforts are no longer a priority however as *A. mustelina* are actively being removed from Ekahanui for eventual translocation to the permanent predator proof fence, Palikea North enclosure, at Palikea by 2018. In 2016 two small temporary enclosures for *A. mustelina* were built near populations that were rapidly declining in order to protect the remaining *A. mustelina.* Snails from these areas were placed inside to see if this was a viable option. Unfortunately the *A. mustelina* did not fare well and the project was concluded. Management of the *A. mustelina* population (ESU-E) in this MU is discussed further in chapter 5 of the 2017 annual report.

Jackson's Chameleon Control

Species: *Chamaeleo jacksonii* ssp. *xantholophus* (Jackson's chameleon)

Threat Level: High (for *Achatinella*)

Seasonality/Relevant Species Biology: Unknown

Management Objectives:

- Survey MU for Jackson's chameleons
- Keep sensitive snail populations safe from chameleons via removing both Chameleons and native snails from the MU. The *Achatinella* will be maintained in a laboratory offsite, the chameleons will be euthanized

Strategy and Control Methods:

- Construct a predator proof fence at Palikea North for Achatinella
- Collect remaining *Achatinella* for ex-situ conservation until they are reintroduced to the predator proof enclosure in Palikea
- While surveying for native snails or conducting any other field work in the MU, note, GPS and remove any chameleons

Discussion: Chameleons are known to consume *Achatinella* where their ranges overlap. Therefore, if *Achatinella* are present within the MU, staff needs to note the presence of any chameleons while conducting periodic snail surveys and may be able to use dogs to detect chameleons. If chameleons are found, then staff should follow up immediately by searching for at least two full days and two full nights for more in the vicinity. All *A. mustelina* from Ekahanui will be translocated to the permanent predator proof fence, Palikea North enclosure, at Palikea by 2018. Although, chameleons have been found to the north at Hapapa and to the south at Palikea, chameleons have not yet been observed in Ekahanui. Staff will continue to look for them when surveying, for it is possible that they have not yet been detected due to their cryptic habits.

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 in areas below the Honouliuli Forest Reserve. Potential for fire ignition comes from the Kunia Loa farms development which is adjacent to the forest reserve, hikers who may be camping and hunting, and arson on the Kamehameha Hwy.

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:

- Communication through fire meetings between land owners and local agencies, to access forest reserve areas and water sources.
- Develop a plan for coordination of chain of command between Hawaii Fire Department and Federal Fire Department, and other ground crews involved.
- Include Army biologist in planning to provide information on locations of rare and endangered taxa.
- Helicopter water drops from the air.
- Local fire agencies fighting on the ground.
- Fuel Breaks. Discuss with DOFAW to have Honouliuli contour trail maintained as an access trail and as a fuel break. Discuss with Monsanto how to manage fallow fields to reduce fuel between Kamehameha Hwy. and Honouliuli forest reserve.

Discussion: In 2016, a fire burned inside the Forest Reserve boundary through moist, heavy fuels mostly dominated by iron wood trees (*Casuarina* sp.), with some *Grevillea robusta, Formosa koa, Schinus terebinthifolius,* and *Fraxinus uhdei* (see map below). The fire posed a threat to native mesic forest including rare and federally listed endangered plant species located approximately 250 meters to the south and about 300 meters to the north all in the Honouliuli Forest Reserve. The endangered plant taxa most directly threatened by this fire include *Delissea waianaeensis* and *Abutilon sandwicense.* Additionally, known pairs and single males of the endangered forest bird, the Oahu Elepaio (*Chasiempis ibidis*) were found as recently as 2016 in the North Ekahanui Gulch area, and *Achatinella mustelina* and *A. concavospira* snails were known from the adjacent Huliwai gulch area. Had the fire escaped from the North Ekahanui Gulch area into Central and South Ekahanui, and Huliwai gulch, numerous other rare and endangered taxa would have been threatened.

It was believed that this fire was ignited from a camp fire near the contour trail which was not sufficiently extinguished.

Since this fire, a volunteer conservation group known as the “Friends of Honouliuli” has begun efforts manage the site. They are planting native species such as *Dodonaea viscosa* and managing grass to help prevent fire fuel loads from building again.

In 2005, there was a fire on two ridges on the South side of Ekahanui (see map below). 170-acres burned, 5 of which were in the Honouliuli Forest Reserve. This fire started in the pineapple fields and burned heavy fuels dominated by *Urochloa maximus* grass, with some *Grevillea robusta, Acacia confusa*, and *Schinus terebinthifolius.* The fire posed a threat to native mesic forest including rare and federally listed endangered plant species located approximately 500m to the West. These included *Abutilon sandwicense* and Oahu Elepaio (*Chasiempis ibidis*) nesting territories.

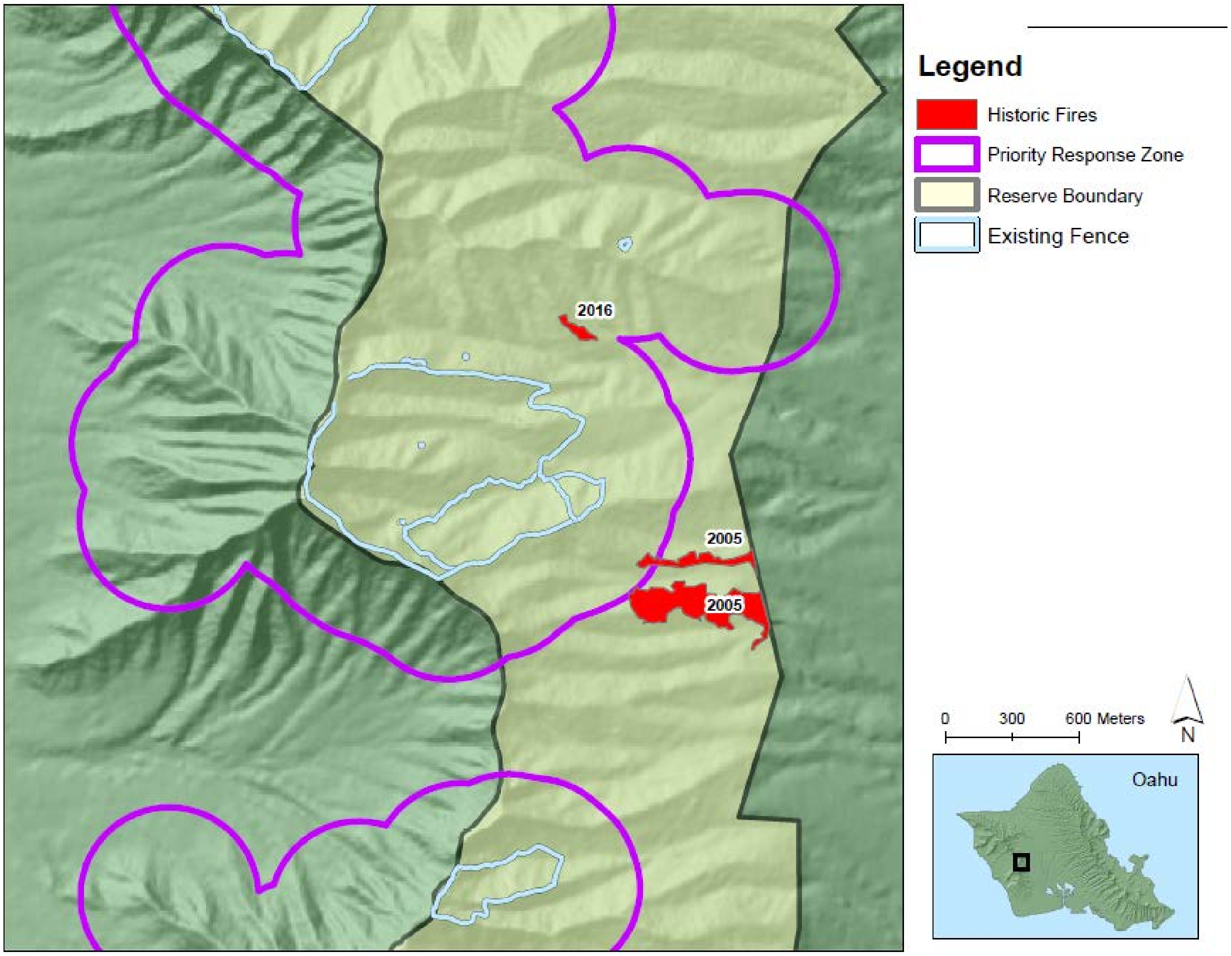
In conclusion of this fire, according to TNC personnel there were communication errors that could have prevented the fire from being contained more efficiently. There was chain of command issues between the Hawaii Fire Department and Federal Fire Department. There was also an issue of communication between HFD Air One, the contract helicopters, and the ground crews trying to direct them.

Historically, numerous fires have also have been ignited along Kamehameha Highway. Even though, Ekahanui MU is ~2.5 km from Kamehameha Highway, these fires pose a threat because they are separated by fallow fields and small farms in Kunia Loa dominated with *Urochloa maxima.* A grass known for high fuel load for fire. It would be beneficial to address this issue, by communicating with Monsanto to help manage fuel loads in their fallow fields, and with DOFAW to maintain fire breaks and access in Honouiliuli.

With development of the Kunia Loa farmland local firefighting agencies have conducted meetings with stakeholders to address the issues of communications for firefighting resources and access. This has become even more important due to the many new land holders, the development becoming gated and creation of several water reservoirs.

Most of the Ekahanui's rare and endangered taxa are in non-fire threatened areas. They persist in areas which are higher in elevation, where the moisture regime is more wet-mesic than dry-mesic. These areas are also buffered by vegetation which hold less fire fuel load potential like dense stands of *Psidium cattleianum* which dominate most of the mid elevation areas of the Ekahanui MU. The rare and endangered taxa most threatened by fire are in the lower elevations areas near Huliwai, Huliwai no-MU, and Ekahanui no-MU.

2016 Ekahanui Fire Management Map



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 hatch marks 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 Type	Actions	MIP Year 13 OIP Year 10 Oct 2016-Sept 2017				MIP Year 14 OIP Year 11 Oct 2017-Sept 2018				MIP Year 15 OIP Year 12 Oct 2018-Sept 2019				MIP Year 16 OIP Year 13 Oct 2019-Sept 2020				MIP Year 17 OIP Year 14 Oct 2020-Sept 2021			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
Vegetation Monitoring	MU vegetation monitoring by surveying every belt plot along transects.									X											
General Survey	LZ-HON-106: Survey Ekahanui Crestline LZ whenever used, not to exceed once per quarter. If not used, do not need to survey.																				
	LZ-HON-132: Survey Puu Kaua LZ whenever used, not to exceed once per quarter. If not used, do not need to survey.																				
	LZ-HON-136: Survey north Ekahanui LZ whenever used, not to exceed once per quarter. If not used, do not need to survey.																				
	WT-Ekahanui-01: Survey Ekahanui access trail, from parking area up gulch to exclosure, up to lower catchment on silky oak ridge; annually.		X				X				X				X				X		
ICA AcaMea	Ekahanui-AcaMea-01: Define infestation area. Survey greater area (aerial + ground) to delineate ICA. Adjust goals based on results. Survey areas around and between known AcaMea sites (top of side road, along access trail, just inside fence, up ridge between Airplane and Cyanea gulches) as well as 200m buffer around known plants.			X				X				X				X				X	
	Ekahanui-AcaMea-01: Monitor/control AcaMea along ridge between Airplane and *Cyanea* gulches in Unit 2 and along jeep trail access to MU, annually. Collect fruit and remove from field. Flag locations of any plants found to facilitate later follow-up. Track weeded area			X				X				X				X				X	

Action Type	Actions	MIP Year 13 OIP Year 10 Oct 2016-Sept 2017				MIP Year 14 OIP Year 11 Oct 2017-Sept 2018				MIP Year 15 OIP Year 12 Oct 2018-Sept 2019				MIP Year 16 OIP Year 13 Oct 2019-Sept 2020				MIP Year 17 OIP Year 14 Oct 2020-Sept 2021			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
	with GIS; large ICA.			▒				▒				▒				▒				▒	
ICA EhrSti	Ekahanui-EhrSti-01: Monitor/control EhrSti on Ekahanui south fenceline 2x/quarter. Spray. Flag location to facilitate revisitation. Pick and remove from field any potentially mature fruit. Use preemergent herbicide. This species is cryptic and can be difficult to id.	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
	Ekahanui-EhrSti-02: Monitor/control EhrSti on S line by ground AchMus shell plot 2x/quarter. Spray. Flag location to facilitate revisitation. Install webbing to improve access. Pick and remove from field any potentially mature fruit. Use preemergent herbicide. This species is cryptic and can be difficult to id.	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
	HuliwaiNoMU-EhrSti-01: Monitor/control EhrSti at junction of wiliwili trail and contour trail every 3-6 months. Spray. Flag location to facilitate revisitation. Pick and remove from field any potentially mature fruit. Use preemergent herbicide. This species is cryptic and can be difficult to id.	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Restoration	WCAs-05, 13, SE corner of 10, 1, 14. Consider koa/aalii combo for ridges. Sapoah for 14.																				
General WCA	Survey/evaluate/create WCAs MU, as resources allow. Use geographical and vegetation data; change and create new if necessary.		▒	▒																	
Ekahanui-01 (CenAgr EKA-A)	Conduct weed control around all CenAgr EKA-A groups annually. Control both understory and canopy weeds; remove canopy weeds gradually. Control alien grasses also.			▒				▒				▒				▒				▒	
Ekahanui-03 (PhyMol/SchKaa Bowl)	Control understory and canopy weeds across this area, focusing on native forest patches. Remove canopy gradually. Keep in mind Elepaio and *Amastra* considerations.				▒				▒				▒				▒				▒
	Control weeds around PhyMol reintro site every annually, targeting understory and gradual removal of			▒				▒				▒				▒				▒	

Action Type	Actions	MIP Year 13 OIP Year 10 Oct 2016-Sept 2017				MIP Year 14 OIP Year 11 Oct 2017-Sept 2018				MIP Year 15 OIP Year 12 Oct 2018-Sept 2019				MIP Year 16 OIP Year 13 Oct 2019-Sept 2020				MIP Year 17 OIP Year 14 Oct 2020-Sept 2021			
		4	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**
	canopy weeds. [REINTRO FAILED - MAY SEE RECRUITMENT, OR PLANT AGAIN]			■				■				■				■				■	
	Control weeds around SchKaa sites annually, targeting understory and gradual removal of canopy weeds. Do in conjunction with RP monitoring.		■				■				■				■				■		
Ekahanui-04 (Cliffs to Crestline)	Conduct weed sweeps through this steep area, focusing around wild rare plants (PlaPri A, B, and C; TetLep), snail trees, and native forest; annually. Control understory and canopy weeds, targeting PsiCat and SchTer for gradual removal.				■				■				■				■				■
	Control grasses throughout WCA as needed, annually. Includes MelMin, PasCon and SetGra. May need to access area via multiple points: ridgetop, base of Plapripri A cliff, ridge above CenAgr reintro.	■				■				■				■				■			
	Control weeds around PlaPri EKA-D reintro site every 3-6 months, targeting understory and gradual removal of canopy weeds.	■		■		■		■		■		■		■		■		■		■	
	Control weeds around KadPar EKA-A reintro site annually or as needed. Steep/cliff terrain.			■				■				■				■				■	
Ekahanui-05 (2D Reintro Zone)	Conduct weed control across WCA. Sweep whole area at least 1x/year. Target reintros across all the subgulches (2D, 2C) and on fenceline (CenAgr). Focus on understory weeds, PasSub, and gradual canopy removal.		■		■		■		■		■		■		■		■		■		■
	Control grasses across WCA annually or as needed. Focus on area around CenAgr reintro in particular.			■				■				■				■				■	
Ekahanui-06 (Palai Gulch)	Conduct weed control across WCA, at least twice a year. Focus efforts around rare taxa, native forest patches, pushing into weedier zones. Target understory, gradual removal of canopy. Elepaio in area, exercise caution when weeding any canopy, avoid dramatic change, and time work outside of breeding season.		■		■		■		■		■		■		■		■		■		■
	Control grasses, particularly Oplhir, through WCA annually. Focus around rare taxa, native forest patches.				■				■				■				■				■

Action Type	Actions	MIP Year 13 OIP Year 10 Oct 2016-Sept 2017				MIP Year 14 OIP Year 11 Oct 2017-Sept 2018				MIP Year 15 OIP Year 12 Oct 2018-Sept 2019				MIP Year 16 OIP Year 13 Oct 2019-Sept 2020				MIP Year 17 OIP Year 14 Oct 2020-Sept 2021			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
Ekahanui-07 (Unit 1)	Clear/maintain rat grid trails and access trails, as needed.																				
	Conduct gradual control of canopy, targeting Psicat and Grerob. Low priority project. Interactions with Elepaio breeding habitat. Use volunteer assistance. Do in conjunction with common reintros. [NO ACTION PLANNED IN NEXT 5 YEARS]																				
Ekahanui-10 (Ekahanui Fenceline)	Clear/maintain fence. Remove downed trees, spray grass, treat thick understory, as needed.																				
	Control weedy grasses at SE corner of fence, top of Palai Gulch, both inside and outside exclosure, every 6mo/year. Goal is to remove UroMax and reduce fuel loads.																				
	Maintain/clear contour trail in Ekahanui, as needed. Goal is to facilitate access, for general field work and fire response. Use volunteers if possible.																				
Ekahanui-11 (Cenchrus EKA-C Reintro)	Conduct weed control around CenAgr EKA-C reintro as long as plants are still alive (reintroduction has been discontinued). Control understory and canopy at both reintro groups. Target Psicat.																				
Ekahanui-12 (Amastra Fence Slope)	Control weeds across WCA, at least 1-2x/year. Focus effort around rare taxa, native forest patches, pushing into weedier zones. NW side of WCA more native (includes *Amastra* site), with habitat quality decreasing as move SE. Target understory, gradual removal of canopy.																				
Ekahanui-13 (North Fence Cenchrus D)	Conduct weed control around CenAgr EKA-D reintro site, native forest patches. Focus on understory weeds and opening up canopy gradually.																				
	Control grass across WCA, particularly UroMax. Treat as needed.																				
Ekahanui-14 (Abutilon Unit 3)	Conduct understory/canopy weed control around wild and outplanted AbuSan, at least 2x/year. Area fairly degraded. Target understory and select canopy removal.																				

Action Type	Actions	MIP Year 13 OIP Year 10 Oct 2016-Sept 2017				MIP Year 14 OIP Year 11 Oct 2017-Sept 2018				MIP Year 15 OIP Year 12 Oct 2018-Sept 2019				MIP Year 16 OIP Year 13 Oct 2019-Sept 2020				MIP Year 17 OIP Year 14 Oct 2020-Sept 2021			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
	Control grasses across WCA annually or as needed. Focus on area around AbuSan in particular.																				
	Conduct weed control across WCA, annually. Focus on native forest patches, and gradual removal of target species such as GreRob.																				
Ekahanui-15 (Unit 2)	Clear/maintain rat grid trails, as needed.																				
EkahanuiNoMU-01 (DelWai EKA-A)	Conduct weed control at DelWai EKA-A exclosure. Focus only around DelWai; this not an MFS location. Control understory weeds, grasses, some canopy (don't change light levels), keep fence clear of SchTer.																				
EkahanuiNoMU-02 (Contour Trail)	Maintain/clear contour trail north of Ekahanui fence, as resources permit. Goal is to facilitate access to trail, particularly for potential fire response. Use volunteers as much as possible. Target UroMax and SetPal.																				
EkahanuiNoMU-03 (Ekahanui Trail)	Control weedy grasses, remove tree falls along Ekahanui access trail, as needed. Target UroMax and SetPal.																				
EkahanuiNoMU-05 (Allspice Gulch)	Control PimDio and other weeds (HelPop, Ficus spp) in gulch with volunteer groups or State if asked; this is a Senior Day Care group work site. Not a priority OANRP action.																				
Huliwai-02 (Huliwai Abutilon)	Control weeds around AbuSan, in fenced area, twice a year. Focus on understory weeds and gradual removal of alien canopy weeds. Additional light may favor AbuSan.																				
HuliwaiNoMU-01 (Huliwai Cenchrus)	Conduct weed control around CenAgr HUL-A annually. This population is GSC only. Focus on understory weeds, gradual removal of some canopy species, directly around CenAgr sites.																				
HuliwaiNoMU-03 (Huliwai	Control ChrOli, GreRob, and other weeds in area. Not a priority OANRP action. Senior Day Care works in this area on ChrOli control; coordinate ChrOli efforts with																				

Action Type	Actions	MIP Year 13 OIP Year 10 Oct 2016-Sept 2017				MIP Year 14 OIP Year 11 Oct 2017-Sept 2018				MIP Year 15 OIP Year 12 Oct 2018-Sept 2019				MIP Year 16 OIP Year 13 Oct 2019-Sept 2020				MIP Year 17 OIP Year 14 Oct 2020-Sept 2021			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
Satinleaf)	them.																				
Ungulate Control	Maintain fence integrity.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Elimination of any pig ingress into the fence with use of snares and traps.																				
Rodent Control	Rat control for Elepaio, rare plants and Achatinella. A24s, blue team snaps, and large-scale grid.				■		■		■		■		■		■		■		■		■
	Tracking Tunnel Set up & Running					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Ant Control	Sample ants at 2D outplanting site				■				■				■				■				■
Predatory Snail	Euglandina seek and destroy in snail bait zone. For Achmus: EKA-A, EKA-B, EKA-C				■	■															
	Systematically search enclosure for *E. rosea* as designated by following chart. At least 2 hours a quarter at lowest level of effort. Be sure to rotate through entire enclosure over the year. [Not scheduled unless needed to assist with searches.]																				
Slug Control	FerroxxAQ® needed for entire site applied once every 6 weeks. Ekahanui 2D site	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Ecosystem Restoration Management Plan

MIP Year 14-18, Oct. 2017– Sept. 2022

MUs: Kaena and Kaena East of Alau

Overall MIP Management Goals:

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

Background Information

Location: Westernmost tip of O‘ahu, at Northern base of Waianae Mountains

Land Owner: State of Hawaii

Land Managers: Department of Land and Natural Resources (DLNR) - Natural Area Reserve System (NARS), DLNR – Land Division.

Acreage: 29.9 acres

Elevation Range: Sea level to 894 ft.

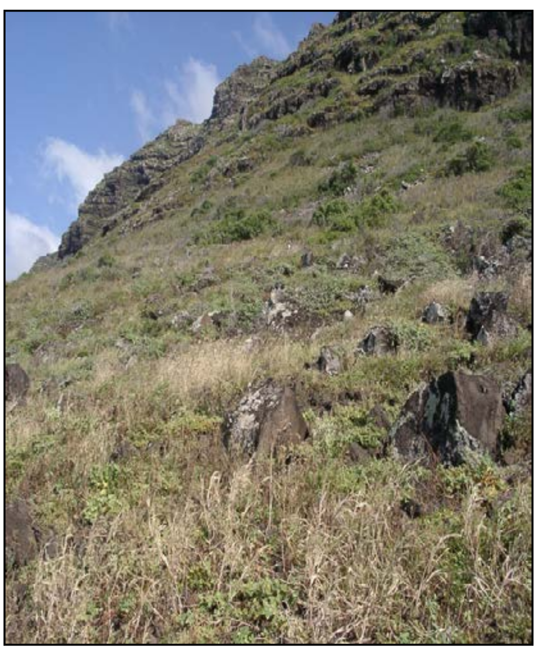
Description: Kaena Point includes two IP MUs: Kaena and Kaena East of Alau. Access is via a 4-wheel drive road along the Mokuleia coastline. The Kaena MU is within the Natural Area Reserve (NAR) boundary and is protected from off road vehicles by a large rock barrier. It is actively managed by DLNR, NARS, and OANRP, and contains areas of native dominant dry coastal strand and shrubland. The Kaena East of Alau MU is located on a parcel managed by DLNR Land Division and receives a minimal amount of management by OANRP staff. Vegetation within and surrounding the MU is alien dominant dry coastal shrubland. Fire serves as the greatest threat to these MUs due to heavy public use and high fuel loads in the surrounding area.

Native Vegetation Types

Wai‘anae Vegetation Types	
Dry Costal	Canopy includes: *Myoporum sandwicense, Psydrax odoratum, Gossypium tomentosum* Understory includes: *Eragrostis variabilis, Chenopodium oahuense, Sida fallax, Euphorbia degeneri, Jacquemontia ovalifolia, Melanthera integrifolia, Lipochaeta lobata* subsp.*lobata, Plumbago zeylanica, Plectranthus parviflorus*
NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted.	

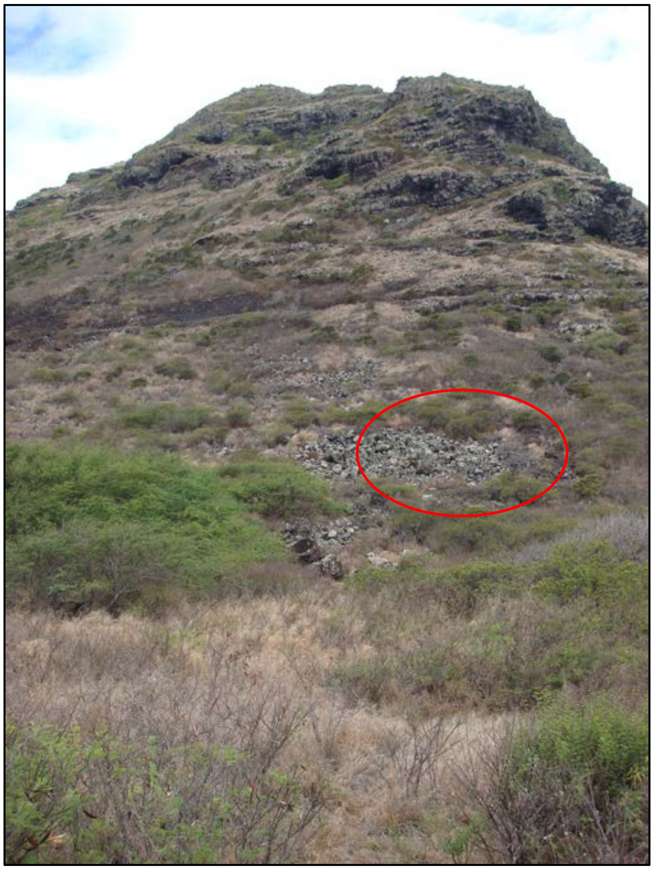
Dry Coastal Vegetation Type at Kaena and Kaena East of Alau

Aerial view of Kaena Point



Kaena MU looking Mauka

Kaena MU looking East



Kaena East of Alau MU, 2009 (prior to clearing *Prosopis pallida*)
Euphorbia celastroides var. *kaenana* population circled in red.

MIP/OIP Rare Resources at Kaena

Organism Type	Species	Pop. Ref. Code	Population Units	Management Designation	Wild/ Reintroduction
Plant	*Euphorbia celastroides* var. *kaenana*	KAE-A	Kaena East of Alau	MFS	Wild
Plant	*Euphorbia celastroides* var. *kaenana*	KAE-B	Kaena	MFS	Wild

MFS= Manage for Stability

Other Rare Taxa at Kaena

Organism Type	**Species**	**Status**
Plant	*Achyranthes splendens* var. *rotundata*	Endangered
Plant	*Scaevola coriacea*	Endangered
Plant	*Sesbania tomentosa*	Endangered

Rare Resources at Kaena and Kaena East of Alau

E. celastroides var. *kaenana*

E. celastroides var. *kaenana* flower and fruit

S. tomentosa flower

A. splendens var. *rotundata*

S. coriacea

Locations of Rare Resources at Kaena and Kaena East of Alau

Map removed to protect rare resources

MU Threats to MIP/OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2017
Weeds	*E. celastroides* var. *kaenana*	Rare taxa sites primarily, across MU secondarily	Regular maintenance performed twice per year.
Fire	*E. celastroides* var. *kaenana*	Across MU	Removal of grass and fire prone weeds every 6 months; 50 m fuel break maintained around Kaena East of Alau site
Ungulates	None	No Control	Ungulate sign has never been observed by OANRP staff since management began. There are no fencing plans for either MU.

Rodents	None	No Control	No rodent damage has been observed on *E. celastroides* var. *kaenana* at either MU; no plans for control.
Ants	*E. celastroides* var. *kaenana*	No Control	Ants have been surveyed and determined not to pose a significant threat. Risk of incipient ant species being introduced in this hot, dry climate and low elevation is very low.

Management History

- 2001: OANRP staff begins weed control efforts within NAR targeting *Leucana leucocephala*, *Atriplex semibaccata*, and grass species around known *E. celastroides* var. *kaenana*.
- 2004: OANRP staff begins weed control efforts at Kaena East of Alau MU targeting *Leucana leucocephala*, *Atriplex semibaccata*, and grass species around *E. celastroides* var. *kaenana*.
- 2007: Photopoints installed at Kaena MU.
- 2007 August: A wildland fire consumed approximately 74 acres near the Kaena East of Alau MU (approximately 35 m from the Kaena-02 WCA).
- 2007 November: Additional 140 plants found by OANRP about 100 m west of the known NAR population, wrapping around the slope towards Waianae; WCA area expanded.
- 2008: Ongoing restoration work including weed removal and re-vegetation with common native plants is performed by OANRP.
- 2009 July: A wildland fire burned within 95 m of the Kaena East of Alau population. OANRP active in fire response.
- 2009: The genetic storage goals were met for Kaena PU (50 plants represented in seed storage).
- 2009 November: Another group of approximately 30 *E. celastroides* var. *kaenana* found west of the known NAR population.
- 2010 June: Management begins on a new poplation of *E. celastroides* var. *kaenana* found within the proposed predator proof fence; a second WCA is added.
- 2010 November: Another group of approximately 25 *E. celastroides* var. *kaenana* found west of the known NAR population.
- 2011: State of Hawaii completes predator proof fence around a portion of the NAR (which includes a subset of the *E. celastroides* var. *kaenana* population).
- 2015 September: OANRP conducts a complete census of *E. celastroides* var. *kaenana* and maps the extent of all known populations.
- 2016: OANRP Orange team takes over management from the Blue team.

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 requirements.

Vegetation Monitoring

After a complete census of the *E. celastroides* var. *kaenana* population within the Kaena MU was conducted, it was determined a vegetation monitoring program at Kaena was not necessary in the management of *E. celastroides* var. *kaenana* populations. Vegetation communities will be monitored on a presence/absence basis using annual photopoints and field observations.

Surveys

Potential Vectors: OANRP and NARS staff, public hikers, 4-wheel drive vehicles, and birds.

Management Objective:

- Prevent the establishment of any new invasive alien plant or animal species through regular surveys along roads, trails and other high traffic areas (as applicable).

Strategy and Control Methods:

- Note unusual, significant, or incipient alien taxa during the course of regular field work and complete Target Species form to document sighting.
- Survey main access road every two years.
- Novel alien taxa found will be researched and evaluated for distribution and life history. If taxa found to pose a major threat, control will begin and will be tracked via ICAs.

Discussion:

Surveys are designed to be the first line of defense in locating and identifying potential new weed species. At Kaena, a road survey is conducted on the dirt road starting at the terminus of Farrington Highway and ending at the rock wall barricade. OANRP will consider installing additional surveys in other high traffic areas, however, due to Kaena's small size, incidental observations during regular field management should suffice.

Incipient Taxa Control (ICAs)

No incipient species have been identified by OANRP in the MU, and therefore there are currently no ICAs. OANRP will continue to monitor and consider control on possible incipients when appropriate. Priority will be given to surveying for *Chromolaena odorata* and *Cenchrus setaceus*, as invasion from these high-risk incipients is higher due to high public use and 4-wheel drive vehicles along the access road.

While there are no 'incipient' targets within this MU, *Atriplex semibaccata, Achyranthes aspera* var. *aspera, Cenchrus echinatus,* and *Verbesina encelioides* are targeted within the WCAs. OANRP will continue to control *Acacia farnesiana* and *Leucaena leucocephala* in order to remove all matures within WCAs. Return visits will be scheduled in order to prevent immature individuals from reaching maturity.

Incipient and Weed Control Areas

Map removed to protect rare resources

Ecosystem Management Weed Control (WCAs)

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 Objective:

- Reduce alien cover and increase native cover in both understory and canopy across the MU, working towards a goal of 50% or more native vegetation cover.

Discussion: OANRP weed control at Kaena is focused on reducing alien vegetation encroachment on populations of *E. celastroides* var. *kaenana* and providing expanded habitat for population recruitment. Ongoing efforts have been effective at removing woody weeds. Grass species require more difficult and consistent management, and should be targeted across the MU to reduce the threat of fire. Weeding efforts will be modified if *E. celastroides* var. *kaenana* population monitoring indicates weed control efforts are not contributing to stable population growth.

The table below summarizes invasive weeds found at Kaena and Kaena East of Alau, 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 farnesiana	Widespread	The majority of weed efforts have focused on this taxa within the WCAs. Always targeted for removal during weed sweeps.
Agave sisalana	Restricted	A population is located along the mauka side of the access road prior to Kaena East of Alau, previously known from Kaena MU. Zero tolerance within WCAs.
Achyranthes aspera var. *aspera*	Widespread	Common throughout MUs. NARS targets around Laysan albatross areas. OANRP controls within WCAs. Can form dense mats. Seeds spiky, easily dispersed via birds (attach to feathers) and staff (attach to clothes)
Cenchrus echinatus	Widespread	Common along access road. OANRP will always target for control within WCAs. Easily dispersed seeds (hitchhike via spikes), so priority to keep out of bird zones).
Chloris barbata	Widespread	Grass is widespread throughout Kaena WCAs. Control has been performed in past via grass specific herbicide and outplanting of the native grass Kawelu. NARS will continue to monitor the extent and perform control as necessary. It is seasonal, flushes during wet weather, then quickly dries out and dies, making it difficult to remove from *E. celastroides* var. *kaenana* areas. Not a major fire risk, but should be controlled directly around rare taxa to promote recruitment.
Digitaria insularis	Widespread	Most common grass in MU, especially around Kaena East of Alau, therefore posing greatest localized fire threat. Control performed by OANRP within WCAs.
Leucaena leucocephala	Widespread	The majority of OANRP weed efforts were used to control within WCAs. Always targeted for removal during weed sweeps. Mostly only immatures and seedlings left; these can be controlled by handpull or by clip and drip with G4 40%. Note that G4 20% not very effective on LeuLeu.
Passiflora edulis	Scattered	Common along access road. Will monitor within WCAs and perform control as necessary.
Urochloa maxima	Scattered	Mostly found around the perimeter of MUs. OANRP will target for removal within WCAs. Priority for removal due to fire threat.
Verbesina encelioides	Restricted	Targeted for removal within WCAs during weed sweeps. Usually easy to handpull. Short life cycle, and new plants grow and mature quickly. Colonizes disturbed areas. Focus should be on keeping out of WCAs.

WCAs: Kaena-01

Veg Type: Dry Coastal

MIP Goal: 25% or less alien cover (rare taxa in WCA).

Targets: All woody species, particularly *A. farnesiana* and *L. leucocephala*, as well as herbaceous weeds *A. aspera* var *aspera*, *V. encelioides*, and *A. semibacatta.* Grasses such as *C. barbata*, *D. insularis* and *U. maxima* are also targeted as needed.

Notes: Weed control began at the Kaena MU in coordination with NARS in 2001. The focus of control efforts has been around the Kaena Point *E. celastroides* var. *kaenana* population in the eastern portion of the NAR. WCA control efforts were expanded in 2007, and again in 2009, 2010 and 2016 upon discovery of new groups of plants. The WCA boundary was expanded to encompass these additional areas. Control of *A. farnesiana* and *L. leucocephela* within this WCA has succeeded in drastically diminishing their overall extent. Visitation frequency has been dramatically reduced. Few woody weeds are now found throughout the WCA, most of which are small immatures. We will continue to control these woody species directly around *E. celastroides* var. *kaenana* individuals, and to connect the populations.

Although common along the access road, there is zero tolerance for *C. echinatus* and *A. aspera* var. *aspera* within the WCAs. *Digitaria insularis* and *U. maxima* are targeted along the upper portion of WCA to aid fire suppression. OANRP is currently evaluating control of *C. barbata* found throughout WCA. Previous control efforts have proven to be relatively effective; it does not appear to be spreading beyond its initially observed extent. OANRP will continue to monitor and control *C. barbata* as necessary.

OANRP also target *A. semibacatta*, a creeping shrub that densely occupies *E. celastroides* var. *kaenana* habitat. *A. semibacatta* is easily removed by handpulling during weed sweeps. OANRP will continue to monitor *A. semibacatta* and investigate further control methods if necessary.

Common native plant reintroductions of *Myoporum sandwicense* and *Eragrostis variabilis* were conducted in 2008 to aid in weedy grass control, habitat restoration, and fire prevention. OANRP staff hopes to continue working with DOFAW staff to grow more common native plants and reintroduce them in order to aid in restoration and fire suppression efforts, but there are no current plans.

WCA: Kaena-02

Veg Type: Dry Coastal

MIP Goal: 25% or less alien cover (rare taxa in WCA).

Targets: All woody species, particularly *A. farnesiana* and *L. leucocephala*, as well as herbaceous weeds *A. aspera* var *aspera*, *V. encelioides*, and *A. semibacatta.* Grasses such as *D. insularis* and *U. maxima* are also targeted as needed.

Notes: OANRP control efforts in Kaena-02 began in 2010. This WCA is enclosed by the predator proof fence at Kaena point. Weed control is conducted around a patch of *E. celastroides* var. *kaenana* that is fragmented from the larger patch below a road. The substrate here is rockier; hence, there is less grass and vegetation, both native and non-native, and less control is necessary. The weed control goals and targets in this WCA are largely the same as those in Kaena-01. Annual sweeps for target weeds across the entire WCA will be conducted.

WCA: KaenaEastOfAlau-01

Veg Type: Rock/talus slope

MIP Goal: 25% or less alien cover (rare taxa in WCA).

Targets: All weeds, focusing on *A. farnesiana* and *L. leucocephala* and grasses.

Notes: OANRP control efforts began in 2004 at the Kaena East of Alau MU. Minimal weed control effort is needed because *E. celastroides* var. *kaenana* plants are found on rock talus with few weeds directly surrounding them. A small weed-free buffer is maintained around this talus slope to reduce any impacts to the *E. celastroides* var. *kaenana*, and to encourage recruitment. OANRP has reduced fire fuel loads east of the patch by clearing a large stand of Kiawe (*Prosopis pallida).* Removal of *A. farnesiana* and *L. leucocephala*, and regular controls of non-native grasses around the WCA to create a wide fire buffer zone (approximately 50 m) will also aid in fire suppression.

Fire Control

Historic Fires near Kaena East of Alau MU

Map removed to protect rare resources

Threat Level: High

Seasonality/Potential Ignition Sources: Due to high fuel loads, low precipitation levels, and high arson activity, fire poses a constant threat to both MUs. Dry summers can further exacerbate the situation. Rarely does a year go by without a wildfire starting somewhere within Kaena State Park or the surrounding DLNR Land Division lands.

Management Objective:

- To prevent fire from burning any portion of the MU at any time.

Strategy and Control Methods:

- Maintain a 50 m fuel break in order to reduce fuel loads surrounding the *E. celastroides* var. *kaenana* at the Kaena East of Alau MU.
- Reduce fuel loads within both MUs

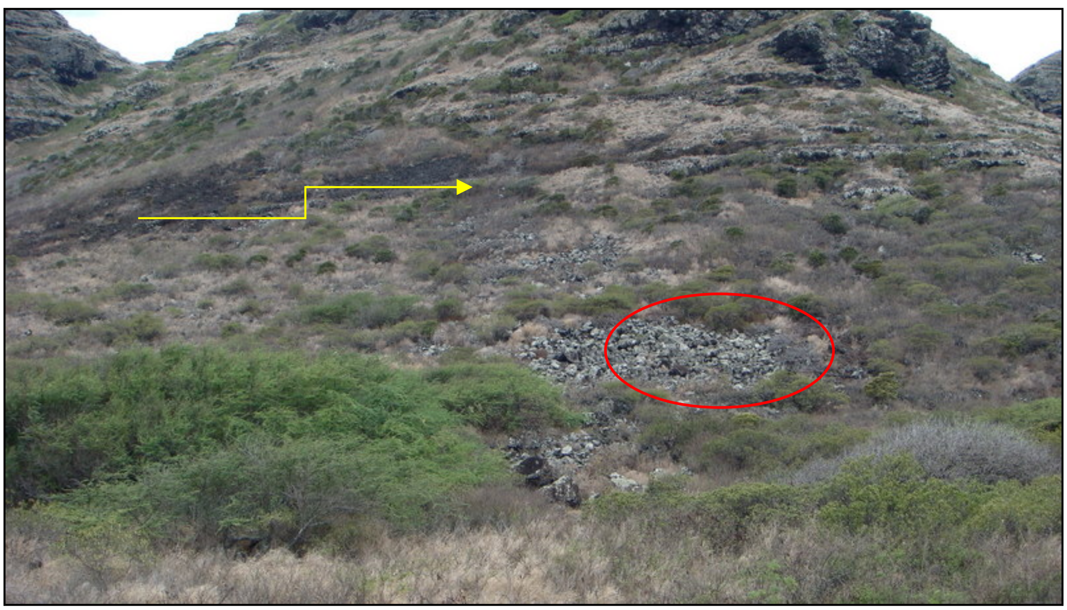
- If a fire occurs, conduct a post-fire survey, including mapping the perimeter of the fire and document damage via photos. If possible, rehabilitate burned areas within the fuel break with native species in collaboration with State Parks and/or NARS staff.

Discussion: OANRP efforts have focused on preventative fire measures, notably weed control within the MUs. Removal of the most fire prone weeds (*A. farnesiana*, *L. leucocephela* and *U. maxima*) remains a high priority within the MUs. The Kaena East of Alau MU has a higher fire threat then the Kaena MU, due to higher fuel loads. OANRP will continue to maintain a 50 m fuel break in order to reduce fuel loads surrounding the *E. celastroides* var. *kaenana* PU. See the Weed Control section for further details. While there are no definite plans, OANRP staff will discuss possible common reintroductions in the future to serve as a green fuel break around the Kaena East of Alau site.

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 fire.

August 2007 fire; Kaena east of Alau population to the west (left) of the photo

August 2007 fire, Red circle indicates Kaena East of Alau *E. celastroides* var. *kaenana* PU



July 2009 fire, Kaena East of Alau *E. celastroides* var. *kaenana* PU circled in red,
yellow arrow indicates furthest extent of burned area.

Action Table

The table below is a comprehensive list of threat control actions planned for the MU for the next five years. Weed control actions are grouped into the following categories: General Survey, ICA code, or WCA code. Cells filled with hatch marks 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 Type	Actions	MIP Year 14 Oct 2017-Sept 2018				MIP Year 15 Oct 2018-Sept 2019				MIP Year 16 Oct 2019-Sept 2020				MIP Year 17 Oct 2020-Sept 2021				MIP Year 18 Oct 2021-Sept 2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
General Survey	Survey along Kaena dirt road from gate at the end of the paved road to the NAR barrier. Every other year.						X								X						
Kaena-01	Control weeds across entire WCA every 6 months/year. Focus on *L. leucocephala*, *A.farnesiana*, *A. semibacatta*, *A. aspera* var. *aspera*, *C. echinatus*, and *V. encelioides*. Work to remove all mature *L. leucocephala* from area, expand to boundaries of WCA, and connect various *E. celastroides* var. *kaenana* patches.			X				X				X				X				X	
	Control grass across WCA as needed, every 6 months/year. Focus on upper portion of patch (*D. insularis* and *U. maxima*). On lower portion of patch, consider strategies for *Chloris sp*. Zero tolerance for *C. echinatus* within WCA.			X				X				X				X				X	
	Take Photopoints annually at Kaena-01.			X				X				X				X				X	
Kaena-02	Control weeds across entire WCA annually. Focus on *L. leucocephala*, *A.farnesiana*, *A. semibacatta*, *A. aspera* var. *aspera*, VerEnc. Work to remove all mature *L. leucocephala* from area, expand boundaries of WCA.			X				X				X				X				X	
KaenaEastofAlau-01	Control weeds across WCA annually (minimum). Target *A.farnesiana* and *L. leucocephala* but include other weeds as well. Expand boundaries of weeded area to improve habitat. Area severely fire threatened.			X				X				X				X				X	
	Control weedy grasses in area. Fire threat is high.	X		X		X		X		X		X		X		X		X		X	

Action Type	Actions	MIP Year 14 Oct 2017-Sept 2018				MIP Year 15 Oct 2018-Sept 2019				MIP Year 16 Oct 2019-Sept 2020				MIP Year 17 Oct 2020-Sept 2021				MIP Year 18 Oct 2021-Sept 2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
	Use chainsaws and possibly chipper to remove a large *P. pallida* on the East side of the WCA, and a 50m swath of *A.farnesiana* and *L. leucocephala* surrounding the WCA in order to create a fire buffer zone.																				

Ecosystem Restoration Management Plan

MIP Year 12-16, Oct. 2015 – Sept. 2020

OIP Year 9-13, Oct. 2015 – Sept. 2020

MU: Kaluakauila Gulch

Overall MIP Management Goals:

- Form a stable, native-dominated matrix of plant communities which support stable populations of IP taxa.
- Control ungulate and weed threats in the next five years to allow for stabilization of IP taxa.

Background Information

Location: Waianae Mountains, northern rim of Makua Military Reservation

Land Owner: U.S. Army

Land Managers: Oahu Army Natural Resources Program, Division of Forestry and Wildlife

Acreage: 110 acres

Elevation Range: 800-1750 feet

Description: The Northwest facing slope of Kaluakauila Gulch extending from the rim of Makua Valley to the gulch bottom of Kaluakauila stream. The MU consists mostly of steep rocky slopes with several large cliff faces. Soil thinly covers rocky areas and soils are considerably hydrophobic. The MU is bisected into two primary work sites by a large waterfall which divides the upper and lower management areas. Kaluakauila Stream is an intermittent stream with some perennial seeps. Several smaller intermittent streambeds also dissect the northwest face of the MU. The Northern rim of Makua Valley consists of exposed, weathered basalt. Talus slopes dominate the lower slope and gulch bottom areas. Winter rains produce small but significant flash flooding events which are responsible most of the erosion along the streambeds.

Two vegetation types intergrade at Kaluakauila. Along the ridges and crestline area, a mix of native and non-native elements comprise a lowland dry shrubland/grassland community. Large patches of *Heteropogon contortus* grass and *Dodonaea viscosa* still persist along the ridgeline dividing Kaluakauila Gulch from Makua Valley, especially in the rockier areas where *Heteropogon contortus* can effectively compete against other alien grasses which need more soil. This vegetation type can also be seen on the makai line of the unit, which is largely dominated by non-native grass, mainly *Urochloa maxima*. Not much management is being done in this area, although a historical *Hibiscus brackenridgei* subs. *mokuleianus* genetic storage population exists.

In the gulches and slopes a diversity of native and non-native trees and shrubs comprise the mixed dry forest community. Significant stands of *Diospyros* spp. trees form the core of the two upper and lower Kaluakauila dry forest patches. Non-native grasses (mostly *Urochloa maxima*) and shrubs (*Leuceana leucocephala*) dominate the landscape between forest patches. *Aleurites moluccana* dominates the gulch bottom area of this community.

The native dry forest community is extremely rare on Oahu (less than 2% remains) and disappearing across the state. Stabilizing the dry forest habitat from further degradation in order to allow rare plant species to thrive is the most feasible goal in the long-term given the amount of weeds already present and the small size of the native forest patches.

Native Vegetation Types

Wai'anae Vegetation Types	
Lowland Dry Shrubland/ Grassland	Canopy includes: *Erythrina sandwicensis, Myoporum sandwicense, Dodonaea viscosa, Santalum ellipticum, Hibiscus brackenridgei* subsp. *mokuleianus.* Understory includes: *Heteropogon contortus, Sida fallax, Eragrostis variabilis, Abutilon incanum, Leptecophylla tameiameiae. Bidens sp.*
Dry forest	Canopy includes: *Diospyros* sp., *Myoporum sandwicense, Erythrina sandwicensis, Reynoldsia sandwicensis, Rauvolfia sandwicensis, Santalum ellipticum, Psydrax odoratum, Nestegis sandwicensis* and *Myrsine lanaiensis*. Understory includes: *Dodonaea viscosa, Sida fallax, Bidens sp.*
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 Kaluakauila

Ridgeline separating Kaluakauila Gulch and Makua Valley (background)

Looking makai into Kaluakauila Gulch

Dry forest community at Kaluakauila

MIP/OIP Rare Resources at Kaluakauila

Organism Type	Species	Pop. Ref. Code	Management Designation	Wild/ Reintroduction/ Future Planting
Plant (MIP)	*Neraudia angulata*	MMR- F, G, H*	MFS	Reintroduction
Plant (MIP)	*Melanthera tenuifolia*	MMR-F	MFS	Wild
Plant (MIP)	*Nototrichium humile*	MMR- A, J, L*, M*, N*	MFS	Wild
Plant (MIP)	*Euphorbia celastroides var. kaenana*	MMR-B	GSC	Wild
Plant (OIP)	*Abutilon sandwicense*	MMR-B MMR-C	GSC	Reintroduction
Plant (MIP)	*Hibiscus brackenridgei* subsp. *mokuleianus*	MMR- C, D, E*	GSC	Reintroduction
Plant (MIP)	*Delissea waianaensis*	MMR-D	GSC	Reintroduction

MFS= Manage for Stability *= Population Dead
GSC= Genetic Storage Collection

Other Rare Taxa at Kaluakauila

Organism Type	Species	Status
Plant	*Euphorbia haeleeleana*	Endangered
Plant	*Schiedea hookeri*	Endangered
Plant	*Schiedea kealiae*	Endangered
Plant	*Bonamia menziesii*	Endangered
Plant	*Chrysodracon forbesii*	Endangered
Plant	*Bobea sandwicensis*	SOC
Bird	*Asio flammeus sandwichensis*	State Endangered
Bird	*Chasiempsis ibidis**	Endangered
Mammal	*Lasiurus cinereus semotus*	Endangered

***population extirpated**

Rare Resources at Kaluakauila

Euphorbia haeleeleana

Hibiscus brackenridgei subsp. *mokuleianus*

Melanthera tenuifolia

Neraudia angulata

Locations of Rare Resources at Kaluakauila

Map removed to protect rare resources

Threats to MIP/OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2017
Pigs	All	Across MU	No animals within fence
Weeds	All	Rare taxa sites primarily, across MU secondarily	Regular maintenance required several times per year
Black Rat	Unknown	No control	Unknown
Slugs	*Delissea waianaensis*	Affected rare taxa sites only	Surveys done as needed
Ant	*Neraudia angulata*	No control	Surveys conducted before sling load operations or as needed
Black Twig Borer	*A. sandwicense, N. angulata*	No control	Annual surveys during rare plant monitoring
Fire	All	Along fencelines and rare taxa sites	Regular maintenance required several times per year

Management History

- 1970: Large military fire burns Makua Valley
- 1984: Large military fire burns Makua Valley
- 1995: Rare plant surveys are conducted, though no management is being done
- 1995: Escaped prescribed fire in Makua burns to forest edge of Kaluakauila.

- 1997-2009: Rat control initiated and expanded to protect *E. haeleeleana* fruits and forest.
- 2001: Fence completed, ungulates removed. Heavy rains blow out fence, pigs re-enter MU and removed via snaring.
- 2001-2017: Grass and weed control in forest patches. Catchments installed.
- 2003: Escaped prescribed fire burns into Kaluakauila MU as well as burning most of Makua Valley. Damage to Kaluakauila includes: 2 *B. sandwicensis* with burn damage, fire w/in 28m of *N. humile*, 100 acres elepaio critical habitat burned, 6 acres of Oahu Plant Critical Habitat burned, fire w/in 20m of *B. menzesii*, fire w/in 30m of *E. haeleeleana*, perimeter of native forest patches burned, about a km of the fence burned.
- 2005: White phosphorus fire burns Makua after escaping from fire break road
- 2006: Arson fire burns to forest edges, destroying a *H. brackenridgei* reintroduction along the western edge of the fence and a portion of a *E. celastroides* var. *kaenana* wild population.
- 2006: *Cirsium vulgare* (thistle), a highly invasive herb, is found in the lower forest patch. Also, *Syzigium jambos* (rose apple), is found on the northeastern edge of the fence, in the gulch. Both are removed and ICAs are created.
- 2007-2014: Slug, ant and arthropod surveys conducted. Low slug numbers detected.
- 2009: Rat tracking tunnels deployed (no activity detected).
- 2010: Fire started inside the range fence between the range control building and Ukanipo Heiau burns into Kaluakauila MU. Damage includes: about 90 *M. tenuifolia* burned, 3 *B. sandwicensis* singed, fire burned within 10m of *E. haeleeleana* and forest perimeter was burned.
- 2011: Assisted with Range Division Intetrated Vegetation Management Plan by working with contractor to spray fuel breaks at Kaluakauila in January and May.
- 2013: Rat control efforts halted due to change in priorities.
- 2015-2016: OANRP staff are prohibited from entering Makua Military Reservation.
- 2016: Rat control resumes by the State (DOFAW) around wild *Euphorbia haeleeleana* populations in the Upper and Lower patches.

Ungulate Control

Species: *Sus scrofa* (pigs)

Threat Level: Low

Management Objectives:

- Maintain entire unit as ungulate free.
- Remove all ungulates from unit if sign is present.

Strategy and Control Methods:

- Exclusion of all ungulates from MU via large-scale fencing. The fence was completed in 2001.
- Conduct quarterly fence checks, and monitor after major weather events.
- Note any pig sign while conducting day to day actions within fenced MU.
- If any pig activity is detected, work with Ungulate Manger to implement hunting or snaring.

Discussion: Due to the very large waterfalls along the gulch bottom, a complete fence check requires considerable time and effort. Controlling the guinea grass along the westernmost makai line using aerial spraying of glyphosate and a pre-emergent herbicide would make checking that line considerably easier. An initial cut would likely be required to facilitate spraying (as well as remove fuel loads). Checking the makai line could then be done far more quickly. Alternatively, cursory aerial inspections could also be done for the crest line and the makai line as needed.

The bottom fenceline was strategically placed on the south side of Kaluakauila gulch, rather than gulch bottom, to avoid damage from flooding. However, fence blowouts do occur at the base of the intermittent side streams on an irregular basis. These hog-wire sections need to be reinforced with hog panels and checked after extreme rainfall events. Additional panels may need to be placed upslope of the main fenceline to prevent rockfall from damaging the main fenceline itself.

Debris also frequently piles up along gulch bottom sections as these sections are built parallel to the slope. Removal of these debris piles is periodically necessary to prevent small pigs from passing through the larger holes in the panels and fence mesh.

The crestline fenceline is subjected to a considerable amount of pitting from winds and corrosion due to the salt air. Portions of this line should be carefully inspected and replaced before failure. Replacement or repairs will be done as needed.

Weed Control

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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

Currently there is no plan for MU-scale vegetation monitoring in Kaluakauila. Since the majority of the MU is covered in weeds (*U. maxima*, *L. leucocephala*, etc.) and only few forest patches are being actively managed, large-scale belt plot monitoring would not represent the vegetation composition in the areas where most of the work is being done. Instead, considerations are underway for gigapan monitoring of target taxa and/or point-intercept vegetation monitoring in select high priority areas (Upper Patch and Lower Patch).

Surveys

Potential Vectors: OANRP activity, hikers/hunters, pigs/goats, 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:

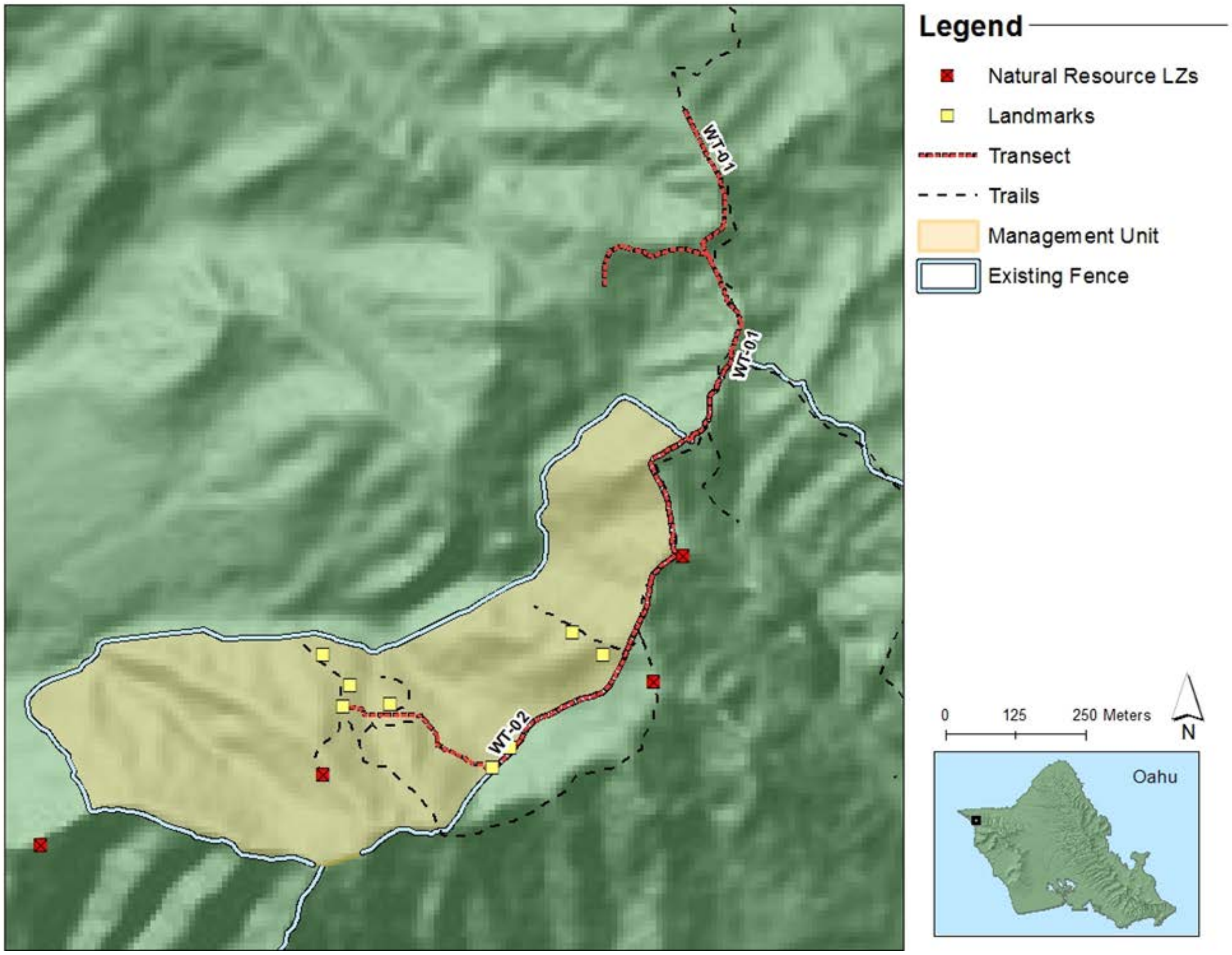
- Note unusual, significant, or incipient alien taxa during the course of regular field work. Map and complete Target Species form to document sighting.
- Survey of all of Kuaokala Road from Peacock Flats to the Kaena Point Satellite Tracking Station once every other year. GPS roads driven to document extent of survey in a given year.
- Survey LZs and campsites used in the course of field work, not to exceed once per quarter.
- Survey weed transects annually. These include WT-Kaluakauila-01, which begins at the trailhead and ends at the crossover to the Upper Patch and WT-Kaluakauila-02, which follows the trail from the Upper Patch to the Lower Patch catchment.

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 Kaluakauila LZs are not used often, since the MU can be reached easily via Kuaokala Road. However, in times of outplanting LZs may be used to shuttle staff close to the worksite. Camping also occurs during a large outplanting. The campsites used are close to the road and infrequent, therefore, scheduled campsite surveys do not occur.

Fence and 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, aerial spraying, and frequent visits.

Summary of ICAs

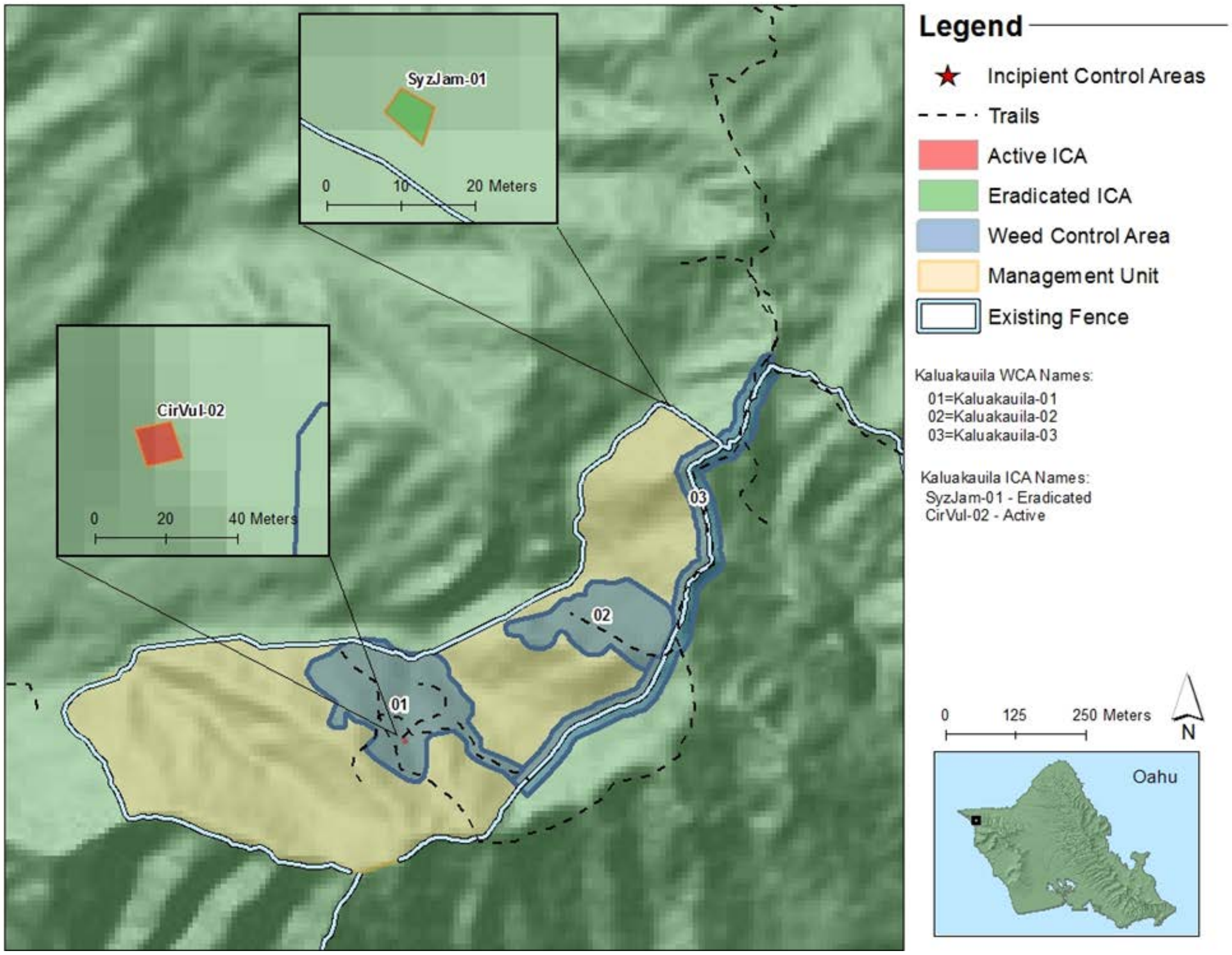
Taxon	ICA Code	Control Discussion
Cirsium vulgare	MMR-Cirvul-02	This ICA is located in a drainage within Kaluakauila Gulch on the Northwest side of Makua Valley. A population of Cirvul had previously been recored from Ohikilolo, on the Southeast side of the valley. However, it is not clear where the Kaluakauila individual dispersed from. NRS found two immature individuals in 2006. The plants were pulled out and the area around was searched. None were found. NRS plans to re-survey the area thoroughly two more times in two years. It is highly probable that NRS will be able to eradicate *C. vulgare* from this ICA.

ICAs Eradicated at Kaluakauila: Syzigium jambos (MMR-Syzjam-01)

Incipient Weed Photos

Cirsium vulgare left: flowers; right: habitat. Photo: Forest & Kim Starr

Incipient and Weed 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/OIP 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:

- Achieve less than 25% perennial weed cover within 2m of IP taxa. Weed cover around rare taxa visually assessed qualitatively on a quarterly basis.
- Implement quarterly weed control to ideally achieve 50% or less of canopy and perennial understory weed cover in WCA-01 and WCA-02. Weed cover visually assessed qualitatively on a quarterly basis.

- As feasible, conduct fire pre-suppression efforts in the spring and fall each year to reduce fuel loads and fire threats (see Fire Control section).
- Keep grass (*U. maxima*) levels low (visually estimated below 10%) in WCA-01 and WCA-02.

Discussion: Weed control efforts in Kaluakauila have been focused in forest patches around outplatings. These patches consist of native and non-native overstory and understory. Outside the forest patches the unit consists entirely of weedy grass (Uromax) and shrubs (Leuleu), which readily move in to the patches if not kept in control. Strategies for removal include targeting canopy species (Grerob, Alemol, Schter, etc.), especially where native canopy exists and can fill light gaps. Grass is controlled around the perimeter of and within the patches to prevent spreading. Herbaceous understory weeds (Rivhum, Bleapp, Agerip, Passub, etc.) are removed, especially around rare taxa. Qualitative assessments on weed abundance have been ongoing by NRS staff and weeding occurs as needed.

Common reintroductions will be used to complement weeding efforts. Common reintroductions can include seed sowing, divisions, transplanting of seedlings already found in the field, and outplanting of greenhouse grown plants. The first common reintroduction is slated to begin in November 2017, which will include greenhouse-grown cuttings and plants from seed. NRS is currently experimenting with which species and methods are best for Kaluakauila.

Fire is a constant threat to rare taxa in Kaluakauila and fuel load suppression is ongoing to lessen the threat. Fuel load suppression is further discussed in WCA-03, as this WCA was created as a fire break to prevent flames burning over the ridge from Makua into Kaluakauila.

The table below summarizes invasive weeds found at Kaluakauila, 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
Ageratina riparia	Scattered	Scattered in light gaps on newly disturbed forested areas. It is a priority to clear, especially around rare plant populations.
Anredera cordifolia	Restricted	Found in a single location in Kaluakauila-02. Has the ability to climb and could potentially cover large areas. Surveys will be done to determine distribution and evaluate potential threat posed to habitat.
Grevillea robusta	Scattered	Large individuals scattered throughout the forest patches. Can be controlled using Incision Point Application (IPA) with Milestone®.
Cenchrus setaceus	Potentially widespread	Absent within the unit, but found on neighboring ridges in Makua. A priority to control if ever found within the unit. Any plants found would be targeted as an ICA.
Leuceana leucocephala	Widespread	A major component across the entire MU. Often forms dense monotypic stands and can grow to canopy height. Can be controlled with IPA using Milestone® or a 40% mixture of Garlon4® and biodiesel.
Melia azedarach	Scattered	Large trees scattered throughout the forest patches.
Melinus minutiflora and *repens*	Scattered	On the edge of the forest patches. *M. repens* doesn't form the dense, biomass-rich piles created by *M. minutiflora*. Both taxa are targeted within the forest patches and in fuelbreaks.
Mesosphaerum pectinatum	Widespread	Found at high densities, especially during the rainy season. Removal is necessary near outplantings.
Passiflora suberosa	Widespread	Widespread throughout the MU, especially in forest patches (Kaluakauila-01 and Kaluakauila-02).

Rivinia humilis	Widespread	Widespread throughout the MU as an understory groundcover. Removal is necessary near outplantings.
Schinus terebinthifolius	Scattered	Large trees and younger shrubs scattered in forest patches.
Syzigium cuminii	Widespread	Large trees, especially in forest patches and ridges. Control near outplantings.
Urochloa maxima	Widespread	A major component across the entire MU. It is a priority to control to reduce fuel load in the event of a fire.

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 Kaluakauila.

Taxa Considerations for Restoration Actions

Native Taxon	Outplant?	Seedsow/ Division/ Transplant?	Notes
Carex wahuensis	Yes	Seedsow/Division	Sedge. Grow from seed. Seed sows slow to germinate but effective.
*Dodonea visoca**	Yes	No	Small tree. Grow from seed.
*Erythrina sandwicensis**	Yes	No	Tree. Fast-growing. Grow from seed.
Microlepia strigosa	Yes	Division	Fern. Survives transplanting in mesic environments.
*Myoporum sandwicense**	Yes	No	Tree. Grow from cuttings or seed.
Polyscias sandwicensis	Yes	No	Tree. Grow from cuttings or seed.

* Outplanting slated for November 2017

WCA: Kaluakauila-01 (Lower patch)

Veg Type: Dry forest

IP Goal: Within 50m of rare taxa: 25% or less alien vegetation cover

Targets: All perennial weeds including *Schinus terebinthifolius*, *Leucaena leucocephala*, *Grevillea robusta*, *Urochloa maxima*, *Melinus minutiflora*, and *Rivinia humilis*.

Notes:

Several rare taxa are present including, *Hibiscus brackenridgei* subs. *mokuleianus*, *Melanthera tenuifolia* and *Nototrichium humile*. A few failed reintroductions are in the Lower Patch and are not a priority to weed around.

The lower patch is dominated at its center by a dense stand of *Diospyros ssp.* Large *Erythrina sandwicensis*, *Sapindus oahuensis*, and *Euphorbia haeleeleana* are also significant native components. *L. leucocephala* has been significantly reduced although it still recruits readily and control is ongoing.

Most of the weeding effort has been directed toward the control of *U. maxima* and other grasses in order to reduce fuel loads and increase shrub and canopy tree recruitment. *U. maxima* control should also focus on the cliff area below the WCA and to the western makai end to reduce the ability of any fire to move into the core dry forest area.

Annual weeds such as *Hyptis* ssp. are largely uncontrollable given their high density during the rainy season. *Hyptis* should be pulled or treated only around rare outplantings unless a better control method is found.

In addition to weeding outplantings, *S. terebinthifolius* needs to be controlled around *N.humile* plants and general weed control is also needed around the declining *Melanthera tenuifolia* population.

WCA: Kaluakauila-02 (Upper Patch)

Veg Type: Dry forest

MIP Goal: Within 50m of rare taxa: 25% or less alien vegetation cover

Targets: All perennial weeds including *Schinus terebinthifolius*, *Leucaena leucocephala*, *Grevillea robusta*, *Urochloa maxima*, *Melinus minutiflora*, and *Rivinia humilis*

Notes:

Several rare taxa present including a large number of *N. humilis*. The upper patch is dominated at its center by a dense stand of *Diospyros ssp.* Large *Erythrina sandwicensis, Sapindus oahuensis, Polyscias sanwicensis* and *Euphorbia haeleeleana* are also significant native components. *L. leucocephala* has been significantly reduced although it still recruits readily and control needs to be ongoing. *A. moluccana* dominates most of the shallow gulches within the upper patch and maintains a good canopy for *N. angulata* outplantings and other native understory plants.

Most of the weeding effort has been directed toward the control of grasses in order to increase shrub and canopy tree recruitment. Grass control should also focus on the area to the east of the WCA near the stream bed to reduce the ability of any fire to move into the core dry forest area.

In addition to weeding outplantings, *S. terebinthifolius* needs to be controlled around the wild *N. humile* and *N. angulata* outplants. Grass and fern control is also needed for the *D. waianaensis* population close to the gulch bottom.

WCA: Kaluakauila-03 (Grandma's Hill)

See fire control section

Veg Type: Dry forest

MIP Goal: Act as a buffer within 50m of rare plant taxa to reduce fuel loads and prevent the spread of fire.

Targets: Non-native grasses and other fire prone weeds, including *Urochloa maxima* and *Acacia farnesiana*.

Notes:

The WCA extends from Grandma's Hill to the first drainage (cross-over to Lower Patch) and is composed of ridgetop weedy species, mainly *U. maxima*. The main goal of this WCA is to have a proactive effort in reducing fuel loads around populations of rare plants in the event that a fire may occur in the area. A 50 m buffer allows significant area for rare plants and surrounding habitat to survive and regenerate. In addition to keeping fuel loads low, a clear fenceline facilitates fence checks and hiking along the fenceline.

Small Vertebrate Control

Species: *Rattus rattus* (Black rat), *Rattus exulans* (Polynesian rat), *Mus musculus* (House mouse)

Threat Level: High for *Rattus spp* for *Neraudia angulata* and *Abutilon sandwicense*. Unknown for *Mus*.

Seasonality/Relevant Species Biology: Rats may cue in to different foods at different times of the year, and sometimes exclusively target certain food sources. During very dry periods, rat damage has been seen on the stems of *N. angulata*.

Management Objectives:

- Maintain low levels of rat/mouse populations to a level that facilitates stabilized or increasing plant populations across the MU by the most effective means possible.
- Monitor rare taxa populations for rat damage; promptly initiate control if damage is noted.

Strategy and Control Methods:

- Monitor rare plant (*N. angulata* and *A. sandwicensis*) populations, as well as other native species to determine impacts by rodents.
- If rats are detected, deploy localized A-24 grid. Check bait and carbon dioxide cannisters every four months.

Discussion: Currently no rodent control is conducted by OANRP at Kaluakauila, since rodents are not deemed a threat to MFS populations at this time. The State (DOFAW) is currently managing an A24 grid in the Upper and Lower Patches around *E. haleleeleana* to promote seedling recruitment and protect trees from damage. If MFS populations of *N. angulata* and *A. sandwicense* are determined to be adversely impacted by rodents, OANRP will evaluate the use of localized rodent control for the protection of these species. Given the small size and dry habitat, a grid of A-24 traps might effectively reduce rate numbers to allow for even greater regeneration of fruiting canopy species like *Diospyros* spp.

Slug Control

Species: *Veronicella cubensis*, *Deroceras laeve*

Threat Level: Unknown

Seasonality/Relevant Species Biology: Wet season (September-May)

Management Objectives:

- During annual rare plant monitoring, look for seedling recruitment and slug herbivory
- If damage seen, eradicate slugs locally to ensure germination and survivorship of *Delissea waianaensis*.

Strategy and Control Methods:

- Define Slug Control Areas (SLCAs) around rare plant populations if determined present with beer traps.
- Control slugs if determined to be a priority by the rare plant manager.

Discussion: During annual rare plant monitoring, plants will be inspected 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, leaf margins are consumed before the interior of the leaf (unless the midrib is resting on the ground while the margins are curled).

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 Sluggo monthly until slug numbers are reduced.

Ant Control

Species: *Anoplolepis gracilipes*, *Cardiocondyla emeryi*, *Cardiocondyla wroughtoni*, *Monomorium floricola, Ochetellus glaber, Paratrechina bourbonica, Pheidole megacephala, Plagiolepis alluaudi, Solenopsis papuana*, *Technomyrmex albipes*

Threat Level: High for *A. gracilipes, M. floricola* and *P. megacephala*. Much is unknown about the threats to rare taxa by *M. floricola* and *P. megacephala*. There is no known control method for *A. gracilipes*.

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.
- 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* host plant sites as needed (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.
- 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**
Ridge top	High risk of accidental ant introduction via NRS staff or hikers
Upper Patch Catchment	High risk of accidental ant introduction via NRS staff
Lower Patch Catchment	High risk of accidental ant introduction via NRS staff
Grandma’s Hill	High risk of accidental ant introduction via NRS staff
Kaku Pleomele	*Drosophila* are sensitive to high ant abundance
Parking spot	High risk of accidental ant introduction via NRS or public vehicles

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.

No further surveys are planned for Kaluakauila, since many unwanted species were discovered during previous surveys. Long-legged ant species that were categorized as high risk in other areas have already established populations in the MU, probably due to the low elevation. Because NRS staff and hikers travel the area repeatedly, transport of these ants could easily spread to other management units. The probablitiy of transporting long-legged ant species to new MUs is the highest during sling load operations. If sling load operations could pose a possibility for transporting unwanted species from Kaluakauila to a new area, NRS staff will survey ant species at Kaluakauila DZs and LZs in the methods mentioned above one month before the operation. If incipient species are discovered, treatment will begin (Amdro or Maxforce). Sampling will be done a second time, two weeks later, and a second treatment will be applied if needed.

Black Twig Borer (BTB) Control

Species: *Xylosandrus compactus*

Threat Level: Medium

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

Management Objectives:

- Monitor presence of BTB during annual plant monitoring of *Abutilon sandwicense* and *Neraudia angulata*.
- If damage observed, determine the extent (ie; damaged plants on outskirts of population, largest plants damaged, etc.)
- Notify the Alien Invertebrate Control Specialist and Rare Plant Program Manager if any damage observed.

Strategy and Control Methods:

- There are no control methods available. If new techniques become available they will be implemented.

Discussion: The management of BTB has been challenging. Testing of traps equipped with high-release ethanol bait have shown to be ineffective at controlling the pest in other MUs. In Kaluakauila little damage has been observed to rare taxa but serious damage could pose a problem to these plants in the future. Any new techniques will be implemented if feasible for forestry use.

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, both from fires set by the military and 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 rare taxa locations.

Strategy and Control Methods:

- Reduce fuel loads within WCA-03, which acts as a fuel break along the fenceline.
- Control large weedy tree species (Grerob, Leuleu, Schter, etc.) to reduce fuel loads.
- 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 with native species.

Escaped prescribed burn at Makua 2003. The fire burned between the grass bowl between the Upper and Lower Patches. Kaluakauila fenceline at left of photo.

Discussion: Kaluakauila MU is one of the most highly fire-threatened units in all of Makua. The area is vulnerable to fires from nearly all directions, with steep fuel-laden slopes which make fire suppression a difficult task. With each burn, the fires burn the edges of the native forest patches lessening their area. An aerial photo taken in 1977 shows that the forest was significantly larger, particularly toward the Makua rim area. The burned areas have been colonized with invasive species, which serve as fuel for future fires. The last two recent fires (2003 and 2010) that affected the area burned an outplanted *Hibiscus brackenridgei* subsp. *mokuleianus* population, and a group of *Chamaecyse celastroides var. kaenana* plants.

In their 2007 report, the Army Wildland Fire Crew outlined a plan for fire prevention and management to protect Kaluakauila MU from future burns. The plan consists mainly of three components, including the creation and maintenance of new fuelbreaks in strategic locations around the MU, the reduction of arson along Farrington Highway, and fuel reduction directly around protected species within the MU. Also, the 2007 Makua Biological Opinion (Reinitiation of the 1999 U.S. Fish and Wildlife Service for U.S. Army Military Training at Makua Valley) recommended a number of required measures and alternatives to protect the Kaluakauila MU. The Army announced that it would not be using certain classes of weapons at Makua that were the trigger for many of the fire mitigation measures at Kaluakauila and the surrounding Punapohaku area. Also, Dawn Greenlee of the FWS went on a site visit to look at different pre-suppression options with agency partners. Recommendations from the Army Wildland Fire Crew plan, Dawn Greenlee's notes, and recommendations from the Summary of Wildland Fires Aspects of the 2007 Makua Biological Opinion are included below.

The military's Range Integration Vegetation Management Plan was written in 2011 regarding fire prevention and control in Kaluakauila. The following are excerpts from the plan:

"In August 2010, the CALIBRE team approached the Oahu Army Natural Resource Program (OANRP) to solicit input on their Integrated Vegetation Management Plan (IVMP). This project, run by Range Control, had a wide scope, which included developing an integrated vegetation management strategy for Army training ranges in Hawaii. The project also had options for multiple years of funding. The primary thrust of the project was fire mitigation via the creation/treatment of fire breaks. The IVMP included a research component including testing herbicide mixes for efficacy, developing control methodologies, and even experimenting with green firebreaks (although this last item was never implemented). Two of the control methodologies in the IVMP were aerial boom spraying and TimberMark™ aerial spot spraying, both via helicopter. At first, OANRP became involved with the project specifically to guide the IVMP in selection/placement of remote fuel breaks. Later, OANRP was able to propose other projects on the training ranges; these had a weed control focus."

The IVMP project ended up focusing on firebreak creation/maintenance via herbicide spraying and spot treatment of selected weeds. They received one year of funding and reported back on the spraying done at Kaluakauila:

"Kaluakauila: sprayed fuel break zones (2). Provided IVMP team with shapefiles detailing the approved remote fuel break zones. Conducted pre-flight brief on these zones with Kevin Eckert, who in turn rode with pilot during spray operation."

"Two locations were sprayed in the grassy bowls around the forest patches in January. These areas were monitored in April, and all had dead, brown grass. This treatment was effective. The fuel breaks were sprayed again in May. The pilot was asked to provide a large buffer around the forest patches, and no non-target effects were seen."

Although no action has been taken to reduce fuel loads to the extent mentioned below, all considerations are taken into account when dealing with fire as a threat. Whether natural or man-made, not much can be done to mitigate the effects of fire without costing money, time and resources. Fire is an inevitable part of management in Kaluakauila, however, there is no easy fix to the problem. NRS staff will continue to discuss the proposed actions to mitigate fire in Kaluakauila.

Discussion of Proposed Actions

1. **Create a 20 m wide fuelbreak atop the ridge between Makua and Kaluakauila MU and along the forest edge.** This fuel break would ideally be wide enough to have a good chance of slowing and stopping fires before entering the forested area. Permanent helispots and safety zones were also recommended for this area in the 2007 Makua BO to provide firefighters with safe access to the area in the event of another catastrophic fire. A maximum height of one foot tall grass is the recommended standard for the fuel break (Army Integrated Wildfire Plan). Large patches of native grass may need to be killed in order to ensure adequate fuel reductions. The treated area would also be prone to erosion and invasion by herbicide tolerant weeds. To treat this large of an area, aerial ball or aerial boom spraying with Roundup and Oust may be the most cost-effective method after the initial cut to eliminate the dead biomass. Oust is a pre-emergent herbicide that has been effective in the Lower Ohikilolo area at reducing germination rates of grasses and other weeds and the amount of followup herbicidal treatments.

   OANRP will pursue additional funding from the Army to subcontract out this action as well as requesting assistance from the Army Wildland Fire Crew. If no additional funds are secured, a narrower fuel break constructed by OANRP staff (e.g. 10m) may have to suffice. This 20m wide fuelbreak encompasses some of the area already in WCA-03.

   Greenfire breaks have also been considered at Kaluakauila. Essentially, drought tolerant trees and/or shrubs would be planted with an irrigation system to eventually shade out grasses and slow any fires that approached the core areas. Research is ongoing regarding this approach by the U.S. Forest Service on the island of Hawaii at Pohakuloa Training Area. Results from those studies will hopefully be applicable in the near future to Makua and Kaluakauila.

   Some combination of these above approaches might also work and NRS remain open to committing resources to the best approach. The remaining actions largely rely on cooperation from other agencies and additional funding. They are included here for discussion purposes.

2. **Install real or mock surveillance cameras on Farrington Highway to deter roadside arsonists.** Reducing civilian ignitions near Farrington Highway may be possible through use of real or imitation surveillance cameras and an associated sign notifying trespassers that they are on government land, under surveillance, and illegal acts will be recorded and prosecuted to the fullest extent of the law. In 2009 alone, at least 7 small fires were started along this stretch of road between the Makua cave and the mouth of Kaluakauila Gulch. Two of these fires were stolen cars that were torched. OANRP will rely on the expertise of the Army Wildland Crew and other partners to plan and implement these pre-suppression actions.

3. **Build a fuelbreak along Farrington Highway and across the mouth of Kaluakauila drainage.** By improving a pre-existing road that cuts across the mouth of Kaluakauila drainage, it may be possible to stop fires before they ever pose a real threat. A small 20 m wide fuel break was recently created near the mouth of Makua Valley near the Range Control gate. Ideally this fuel break would be expanded to the area north of the base of Puakanoa and south to the Makua cave. Small, controlled

burns on a one-time or regular basis may be the best method of clearing this area followed by herbicide treatments. OANRP will rely on the expertise of the Army Wildland Crew and other partners to plan and implement these pre-suppression actions.

4. **Manage fuels within and immediately surrounding the Kaluakauila MU.** A final defense against fires should be considered within the Kaluakauila MU itself. Cutting grass and shrubs and clearing downed vegetation around individuals and populations of protected species may allow the individuals to survive a fire. For example, clearing the guinea grass around the wild *C. celastroides* population would probably help it survive another fire. For a number of years now, NRS have been controlling the fuel loads in the core dry forest habitat (see also Weed control section). The fuel load has been substantially reduced within the upper and lower patches of remnant dry forest and this work will continue.

   Of particular concern at Kaluakauila are the guinea grass patches surrounding the core native areas. At the Upper Patch, a large patch of guinea lies to the west of WCA-02. At the Lower Patch around WCA-01, large patches of guinea grass lie to the south, east and west. Some type of systematic fuel control for these patches to essentially buffer the forest edge is needed. Again, aerial spraying using Roundup and Oust where feasible and allowable, might be the best short to medium term solution as expansion of the forest boundary is not likely given the scale of weed control, planting and supplemental irrigation that would be required. Backpack spraying of these additional areas is also possible near the cliffs where aerial spraying is difficult given the vertical areas. Herbicide ballistic technology (i.e. paintball guns) also has the potential make cliff control of grass patches and other fuels cost-effective.

   While less of a threat, the guinea grass at the base of the cliffs above the gulch bottom can also serve as fuel ladders to preheat vegetation above or carry fire into the core forested areas. These patches should also be carefully controlled given their proximity to rare resources especially the scattered *N. humile* individuals.

5. **Manage fuels in Makua and Keawaula through targeted grazing.**
   See the following Appendices. OANRP will rely on the expertise of the Army Wildland Crew and other partners to plan and implement these pre-suppression actions.

<u>Appendix A: Dawn Greenlee Notes</u>

Waianae Mountains Kaluakauila, Waianae Kai, Honouliuli, Site Visits to Brainstorm New Fuelbreaks – March 11 and 12, 2009

All plans presented in these notes are preliminary and have, for the most part, not been discussed with landowners, action agencies, or regulatory partners

Site Visit Participants: Dawn Greenlee (USFWS), Andy Beavers (CEMML), Scott Yamasaki (Army FMO), and, on March 12, Ryan Peralta (DOFAW Oahu Protection Forester)

Kaluakauila: It may be possible to graze the guinea grass below Kaluakauila Management Unit on both the Keawaula and Makua sides (Figures 1 and 2). Areas with slopes less than 40 percent are targeted for grazing. If cattle were used, steep slopes may be sufficient to prevent cattle from impacting listed species. Strategic fences which may be necessary in less steep areas are shown in Figures 1 and 2. NRCS may be available to assist with fence and water source infrastructure design.

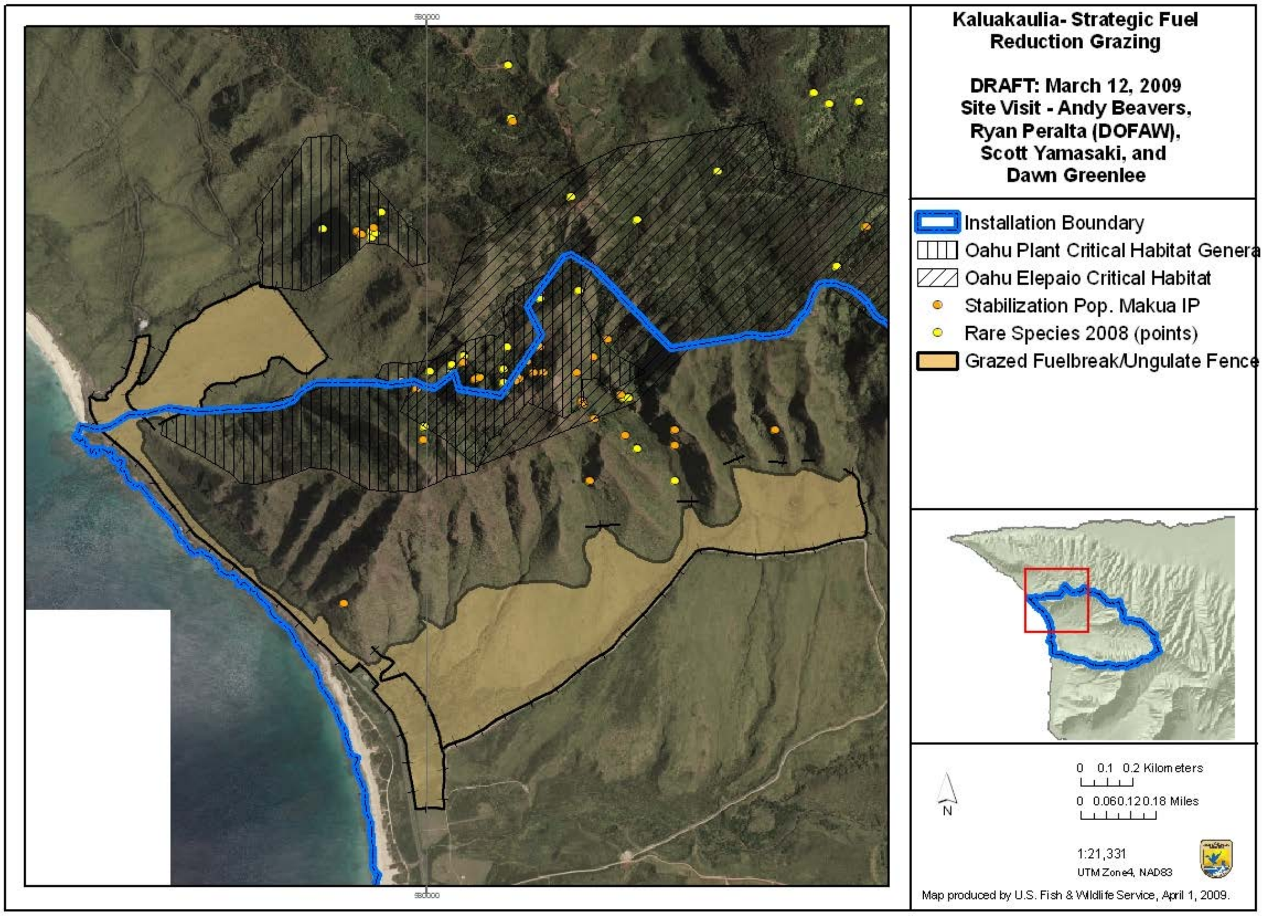


Figure 1. Targeted grazing areas to minimize fire threat to Kaluakauila MU

Figure 2. Kaluakauila – Keawaula Side

Appendix B: Approximate costs of Fuel Pre-suppression Actions (D. Greenlee notes)

Management Action	Priority	Cost	Annual cost?	Project type	Notes
Install fuel break along ridge line. Fuel break 20-30 ft wide depending on terrain.	P1	10,000	No	Fuel break	**$110/month per acre based on Makua Grass cutting contract DOC.**
Maintain fuel break between one peak north of 1737 and the peak at 1673 along the main ridge dividing KMU from Makua and Punapohaku via spraying with backpack sprayers.	P1	$2,500	Yes	Fuel break	**$110/month per acre based on Makua Grass cutting contract DOC.**
Develop helicopter landing zones along main Kaluakauila ridgeline	P1		No	Infrastructure	
Maintain helicopter landing zones	P2		Yes	Infrastructure	
Mark fenceline with cyperstakes on the western boundary where fires burn from Keawaula. with reflective tape so it is visible by helicopter crews from the air. Along chimney and above grassy bowl.	P1	$2,000	No	Infrastructure	
Construct chainlink fence to deter arsonists	P2	200K	No	Infrastructure	Based on two quotes from chainlink contractors
Install artificial surveillance cameras along chainlink fence at the base of Kaluakauila Drainage.		$20,000			
Control fuel along newly installed chainlink fenceline	P2	$4,000	Yes	Fuel modification	30 ft wide x .8 miles long=3 acres x $110/month/acre
Revegetation of grassy bowl with Mango	P3		No	Fuel modification	For FWS, very long term and costly!
Spray grassy bowl between upper and lower forest patches with herbicide via a helicopter ball sprayer in preparation for planting mango.	P3	100K	No	Fuel modification	For FWS, very long term and costly!
Maintain grass control in grassy bowl around plantings.	P4			Fuel modification	For FWS, very long term and costly!
Orient fire response crews to KMU and priority response areas.	P1	5,000	No	Infrastructure/ Communication	Helicopter time

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 filled with hatch marks 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 Type	Actions	MIP Year 12 OIP Year 10 Oct 2017-Sept 2018				MIP Year 13 OIP Year 11 Oct 2018-Sept 2019				MIP Year 14 OIP Year 12 Oct 2019-Sept 2020				MIP Year 15 OIP Year 13 Oct 2020-Sept 2021				MIP Year 16 OIP Year 14 Oct 2021-Sept 2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
General Survey	LZ-MMR-078: Survey Kaluakauila upper campsite LZ survey (at Pinetree) whenever used, not to exceed once per quarter. If not used, do not need to survey.																				
	LZ-MMR-079: Survey LZ Above Lower Euphae Patch whenever used, not to exceed once per quarter. If not used, do not need to survey.																				
	LZ-MMR-006: Survey Punapohaku LZ whenever used, not to exceed once per quarter. If not used, do not need to survey.																				
	RS-KUAOKA-01: Survey Kuaokala road from start of Kuaokala Rd off the Pahole Rd to where dirt road meets paved road that heads to tracking station, every other year.																				
	WT-Kaluakauila-01: Survey access trail from parking area on Kuaokala Rd, as well as alternative route from Keawaula firebreak road, along trail and fence to top of Upper Patch, ending at fence tag A-153; annually.																				
	WT-Kaluakauila-02: Survey access trail from top of Hill at fence tag A-153, along fence to cut off to Lower Patch, along trail to Lower Patch, ending at water catchment; annually.																				
	Survey and map locations of Anredera cordifolia in Kaluakauila. Use information to determine if control warranted and feasible. One spot known																				

Action Type	Actions	MIP Year 12 OIP Year 10 Oct 2017- Sept 2018				MIP Year 13 OIP Year 11 Oct 2018- Sept 2019				MIP Year 14 OIP Year 12 Oct 2019- Sept 2020				MIP Year 15 OIP Year 13 Oct 2020- Sept 2021				MIP Year 16 OIP Year 14 Oct 2021- Sept 2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
	from Upper Patch	X																			
ICA CirVul	MMR-CirVul-02: Monitor/control CirVul at veg plots every 6 months/annually. Pick and remove from field any potentially mature fruit.	X			X																
General WCA	GPS boundaries of all current WCAs		X	X																	
	Define priority 1 and 2 areas in MU after baseline vegetation monitoring is conducted		X	X	X																
WCA: Kaluakauila-01 (Lower Patch)	Control weedy grasses across entire WCA quarterly or as needed. Focus on borders of WCA. Goal is to reduce fuel load throughout patch. Also spray trail up to fence. Target UroMax, MelMin.			X	X			X	X			X	X			X	X			X	X
	Control woody and canopy weeds across entire WCA annually. This may require several trips. Target GreRob and LeuLeu. Remove more common species like SchTer/PsiCat gradually. Focus on mature trees first. Prioritize areas around rare taxa sites and native forest patches.				X				X				X				X				X
	Sweep forested area above upper catchment, focusing on areas around rare taxa (Bonmen, Bobsan) and native forest patches, annually.	X				X				X				X				X			
	Control weeds around NotHum, 1-2x per year. Focus on understory weeds, Schter, and gradual canopy removal.				X				X				X				X				X
	Control understory weeds around Euphae, particularly female trees, as feasible. Not IP taxon.	X				X				X				X				X			
	Control understory weeds around Nerang/Hibbramok/Abusan reintros every 6 months/year. [NOT SCHEDULED, REINTROS FAILED]																				
WCA: Kaluakauila-02 (Upper Patch)	Control weedy grasses across entire WCA quarterly or as needed. Focus on borders of WCA. Goal is to reduce fuel load throughout patch. Target UroMax,			X	X			X	X			X	X			X	X			X	X

Action Type	Actions	MIP Year 12 OIP Year 10 Oct 2017-Sept 2018				MIP Year 13 OIP Year 11 Oct 2018-Sept 2019				MIP Year 14 OIP Year 12 Oct 2019-Sept 2020				MIP Year 15 OIP Year 13 Oct 2020-Sept 2021				MIP Year 16 OIP Year 14 Oct 2021-Sept 2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
	MelMin.																				
	Control woody and canopy weeds across entire WCA annually. This may require several trips. Target GreRob, AcaMea, LeuLeu. Remove more common species like Schter/Psicat gradually. Focus on mature trees first. Prioritize areas around rare taxa sites and native forest patches.																				
	Control understory weeds around Delsub reintro every 6 months/year.																				
	Control understory weeds around Nerang/Hibbramok/Abusan reintros every 6 months/year. Always target PasSub.																				
	Control weeds around NotHum, 1-2x per year. Focus on understory weeds, Schter, and gradual canopy removal.																				
	Control understory weeds around Euphae, particularly female trees, as feasible. Not IP taxon.																				
WCA: Kaluakauila-03 (Kaluakauila Fuelbreak/Trail)	Establish/maintain fuelbreak along ridge and fenceline on eastern side of exclosure, as needed/quarterly. Fuelbreak should be 5m wide (subject to change). Targets are weedy grasses (Uromax, Melmin) and shrubs (Leuleu) and Acamea. Ensure fuel breaks in good shape Q2 and Q3.																				
Restoration Actions	Outplant common natives in early outplanting season Q4.																				
	Collect cuttings, fruits, seeds and divisions.																				
Ungulate Control	All fence monitoring and maintenance actions. Maintenance is defined as any minor repair work or that is LESS THAN 100m.																				
Ant Control	Conduct surveys for ants at LZs and DZs one month before use for unwanted ant species.																				
	Implement control if deemed necessary																				

Action Type	Actions	MIP Year 12 OIP Year 10 Oct 2017- Sept 2018				MIP Year 13 OIP Year 11 Oct 2018- Sept 2019				MIP Year 14 OIP Year 12 Oct 2019- Sept 2020				MIP Year 15 OIP Year 13 Oct 2020- Sept 2021				MIP Year 16 OIP Year 14 Oct 2021- Sept 2022			
		4	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**
Black Twig Borer Control	Monitor BTB activity at rare plant populations of *N. angulata* during annual rare plant monitoring.																				
Slug Control	Monitor slug activity at rare plant population(s) *Delissea waianaeensis*																				
	If slugs found to exceed acceptable levels during monitoring, maintain slug bait at sensitive plant population(s)																				
General Maintenance	Water catchments: repair/maintain as needed. 3 catchements in MU. Assumed water to be used primarily for grass spraying so put into MU threat control CEA. If build for watering rare plants, a new action ID should be created and assigned to appropriate rare plant CEA.																				

Ecosystem Restoration Management Plan

OIP Year 10-14, Oct. 2017 – Sept. 2022

MU: Koloa

Overall OIP Management Unit 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: Summit of Northern Koolau Mountains

Land Owner: Hawaii Reserves Inc.

Land Managers: OANRP, Hawaii Reserves Inc.

Acreage: 176 acres

Elevation Range: 1950 ft - 2400 ft

Description: The Koloa MU is bordered by the Koolau Summit Trail to the south, Kaipapau to the east, and Wailele to the west. The land to the north (makai) lies within the same Koloa gulch, but is separated from the exclosure by a series of waterfalls. The Koloa MU is a wet forest dominated by native vegetation. Perhaps due to its relatively flat topography, lacking the extremely steep walls and deep valleys like that of Kaipapau, the Koloa MU has a large number of IP taxa, including in situ populations of *Euphorbia rockii*, *Phyllostegia hirsuta*, *Cyanea koolauensis,* and reintroductions of *Labordia cyrtandrae.* The Koloa MU can be accessed via the Kawailoa and Laie trails, however due the length of these unmaintained trails, OANRP uses helicopters to access the MU to do management. Due to lack of military training OANRP is no longer required to manage Tier1 and Tier 2 taxa. However, the majority of the Tier 1, 2, and 3 rare taxa in Koloa overlap thus, management actions will provide benefits for native and rare taxa across the MU.

Native Vegetation Types

Koolau Vegetation Types	
Wet forest	Canopy includes: *Metrosideros* spp., *Cheirodendron* spp., *Cibotium* spp., *Ilex anomala*, *Myrsine sandwicensis*, and *Perrottetia sandwicensis*. Understory includes: Typically covered by a variety of ferns and moss; may include *Dicranopteris linearis*, *Melicope* spp., *Cibotium chamissoi*, *Machaerina angustifolia*, *Nertera granadensis*, *Kadua centranthoides*, *Nothoperanema rubiginosa*, *Sadleria* spp., and *Broussaisia arguta*.
NOTE: For future MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted.	

Terrain and Vegetation Types at Koloa

From Northern LZ looking NW towards Laie.

From the northern fenceline looking east

From the NW corner looking SE.

OIP Rare Resources at Koloa

Organism Type	Species	Pop. Ref. Code	Population Units	Management Designation	Wild/ Reintroduction
Plant	*Euphorbia rockii*	KOL-A,B, D,E,G,H,J,L	Kawainui to Koloa and Kaipapau	T2	Wild
Plant	*Cyanea koolauensis*	KOL-A,B,C,D, E,F,H,J,K,L,N,O	Koloa	MFS/T1	Wild
Plant	*Cyrtandra viridiflora*	KOL-A,B,C,D, F,H,I,K	Kawainui to Koloa and Kaipapau	T2	Wild
Plant	*Hesperomannia sweyzei*	KOL-A,D	Koloa	MFS/T1	Wild
Plant	*Huperzia nutans*	KOL-B,O	Koloa	T2	Wild
Plant	*Labordia cyrtandrae*	KOL-A,B	Koloa	MFS/T1	Reintro
Plant	*Myrsine judii*	KOL-B	Kaukonahua to Kamananui-Koloa	T2	Wild
Plant	*Phyllostegia hirsuta*	KOL-A,B,C	Koloa	MFS/T1	Wild and Reintro
Plant	*Viola oahuensis*	KOL-A,B,C, D,	Koloa	T2	Wild

MFS = Manage for Stability *= Population Dead T1 = Tier 1
MRS = Manage Reintroduction for Genetic Storage GU = Geographic Unit T2 = Tier 2

Other Rare Taxa at Koloa

Organism Type	Species	Status
Plant	*Cyanea humboldtiana*	Endangered
Plant	*Cyanea calycina*	Endangered
Plant	*Cyanea lanceolata*	Endangered
Plant	*Joinvillea ascendens* ssp. *ascendens*	Endangered
Plant	*Lobelia gaudichaudii* ssp. *gaudichaudii*	Species of Concern
Plant	*Myrsine fosbergii*	Endangered
Plant	*Zanthoxylum oahuense*	Endangered
Snail	*Achatinella livida*	Endangered
Insect	*Drosophila* nr. *truncipenna*	Rare
Insect	*Drosophila nigribasis*	Rare
Insect	*Drosophila oahuensis*	Rare

Rare Resources at Koloa

Labordia cyrtandrae

Cyanea koolauensis

Euphorbia rockii

Viola oahuensis

Achatinella livida

Huperzia nutans

Zanthoxylum oahuense

Locations of Rare Resources at Koloa

Map removed to protect rare resources

Threats to OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2017
Pigs	All	Across MU	No animals within fence
Slugs	*Euphorbia rockii*, *Cyrtandra viridiflora*, *Cyanea acuminata*, *Hesperomannia swezeyi*, *Labordia cyrtandrae*, *Myrsine judii*, *Phyllostegia hirsuta*, *Viola oahuensis*, *Cyanea koolauensis*	No Control	No control necessary at this time. FerroxxAQ is available for local control if area has been surveyed by an experienced malacologist to determine whether native snails are present. However, damp conditions would render the FerroxxAQ moldy quickly and reduce its efficacy.

Ants	Unknown	No control	No control necessary at this time, no ants found during survey.
Weeds	All	Rare taxa sites primarily, across MU secondarily.	Regular maintenance required several times per year.
Fire	None	N/A	Fire is expected to be highly unlikely given the wet habitat at Koloa. 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. The most likely ignition source is a campfire set by recreational hikers.
Rats	All	No control	Rat control is available but management has not been implemented unless damage to rare taxa is observed.

Management History

- 1993: HIHNP conducts rare resource surveys along Koolau Summit Trail through Koloa
- 1997: First OANRP record of an endangered plant in Koloa.
- 1998: First OANRP record of *Achatinella livida.*
- 1998: Incipient weed taxa *Hedychium* spp. control begins. Species found is believed to be *Hedychium coronarium* but unconfirmed.
- 2002: Predator control around *Achatinella livida* begins.
- 2002: Staff control *Leptospermum scoparium* around the Puu Kainapuaa/Norton LZ, in areas which later become WCA KaiwikoeleEleNoMU-01.
- 2007: Staff control *Leptospermum scoparium* around the Puu Kainapuaa/Norton LZ, in areas which later become WCA KaiwikoeleEleNoMU-01.
- 2011: MU fence construction begins and WCA boundaries are drawn. Container cabin was flown to Puu Kainapuaa to serve as fence contractor campsite.
- 2011: Staff control *Leptospermum scoparium* around the Puu Kainapuaa/Norton LZ, in areas which later become WCAs KawainuiNoMU-01, KaiwikoeleEleNoMU-01, and WaileleOmaoNomU-01.
- 2012: Fence completed, ungulate control initiated. One volunteer hunt conducted catching several pigs. No pigs caught in several hundred snares.
- 2012: Container cabin used at Puu Kainapuaa was flown to site of the former Kahuku cabin to facilitate natural resource staff management in MU.
- 2012: OANRP ends rodent control grid and bait stations around *Achatinella livida* populations. Rodent control responsibility is appointed to the Snail Extinction Prevention Program (SEPP)
- 2012-2013: Weed control begins in MU. Staff target *Angiopteris evecta* and *Psidium cattleianum*.

- 2013: Cabin construction completed.
- 2013: First reintroduction of *Labordia cyrtandrae* (from Waianae stock) to Koolau Mountains
- 2013: Due to Army training level changes and a decrease in funding OANRP no longer work with Tier 2 or 3 Taxa. OIP taxa in Koloa only to include *Cyanea koolauensis*, *Hesperomannia swezeyi*, *Huperzia nutans*, *Labordia cyrtandrae* and *Phyllostegia hirsuta*. OANRP no longer manages for *Euphorbia rockii*, *Cyrtandra viridiflora*, *Myrsine juddii* and *Viola oahuensis*.
- 2014: First reintroduction of *Phyllostegia hirsuta*.
- 2015: Second reintroduction of *Phyllostegia hirsuta* happens at same site as the previous year.
- 2016: Koloa cabin locked due to increase in public use and rat infestation.
- 2016: Northern LZ discontinued for use due to poor infrastructure.
- 2016: Ecosystem Restoration team assists in *Psidium cattleianum* control.
- 2017: Koloa cabin vandalized. It is scheduled to be fixed later this year.
- 2017: As a result of a significant decline of *Labordia cyrtandrae* at the first reintroduction site, a second reintroduction of *Labordia cyrtandrae* was planted at a different site closer to the Koloa cabin.

Ungulate Control

Species: *Sus scrofa* (Pigs)

Threat Level: High

Management Objective:

- Maintain MU as ungulate-free.

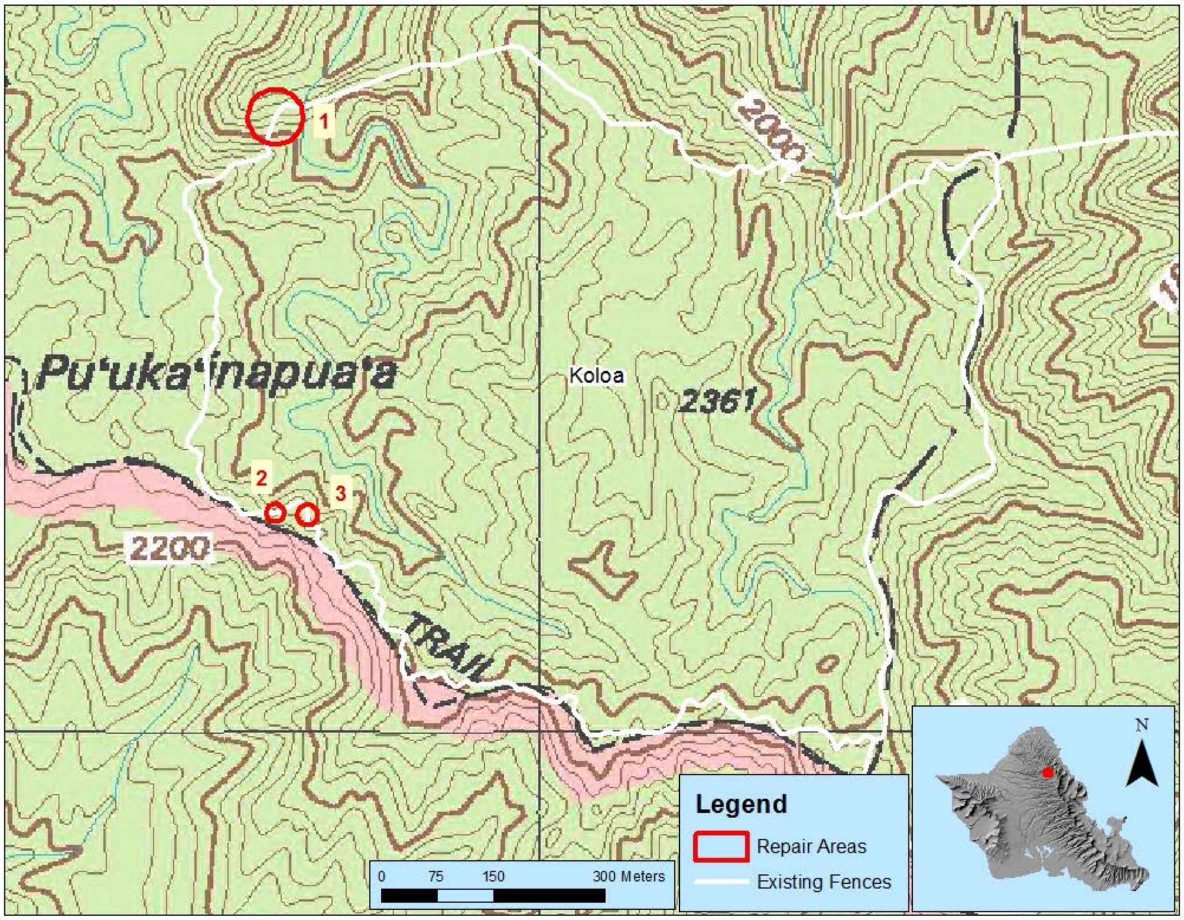
Strategy and Control Methods:

- Maintain the fenced area as ungulate-free by maintaining fence and monitor for sign while conducting other management actions. Conduct quarterly fence checks and monitor stream crossings after storms.
- Note any pig sign while conducting day to day actions within fenced MU. If any pig activity is detected in the fence area, implement snaring program. Fence construction started in September 2011 and was completed in the beginning of 2013.

Discussion: The MU fence is 4.5 kilometers long and encompasses 164 acres. The major threats to the perimeter fence include fallen trees, landslides, vandalism, stream crossings, and flooding. Waterfalls in Koloa provide excellent natural barriers against ungulates. The fence ties in to these strategic areas to avoid the need to cross streams. Special emphasis will be placed on checking the fence after extreme weather events. Monitoring for ungulate sign will occur during the course of other field activities. After the fence was completed, snares were set and monitored for two years. No ungulates were caught during this time and there was no activity within the fence. The fence is ungulate free. However, there are lots of pig sign along the outside of the fence line especially along the summit trail towards the northwest end. The fence will be kept clear of vegetation (especially grasses) to facilitate quarterly monitoring. This weed control is discussed in the Weed Control section.

The terrain in Koloa is steep and highly precipitous. Heavy rain storms have been an issue causing landslides and rock falls to occur causing damage to the fence. If a landslide or rock fall is not detected quickly, pigs can easily enter the Koloa MU. In 2017 three significant landslides occurred causing damage to the fence line (see map below). Repairs were completed and no ungulate sign has been observed.

Map of fence repairs at Koloa



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 protocols used in other MUs may not be feasible in the Koloa MU. Due to the relatively intact condition of the Northern Koolau summit region, current monitoring practices would increase traffic through the MU and may negatively impact the area by introducing weedy species normally found in the fence corridors and trails. Possible alternatives to transect monitoring may be aerial monitoring surveys (UAV), remote vegetation mapping, gigapan, or a combination. Utilizing new technologies and methodologies to develop vegetation monitoring protocols is a priority for this MU.

Objectives:

- Develop vegetation monitoring protocol for Koloa MU.
- Conduct vegetation monitoring for Koloa MU every three years.
- Produce vegetation map every three years for comparative analysis of weeding efforts.

Surveys

Potential Vectors. The Army conducts helicopter training in Kawailoa, immediately south and west of Koloa. The nearby Norton LZ is not currently used by the Army but if the Army gets permission to land there, we will resume surveys. Also, a high number of recreational hikers pass along the summit and Koloa trails, as well as OANRP staff, ungulates, rats and birds.

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 LZs (if used, LZ Norton once annually).
- Quarterly survey of Koloa Cabin campsite (if used).
- Annual survey of the Koolau Summit Trail/fenceline.
- 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 to pose a major threat, control will begin and will be tracked via ICAs.

Discussion: Surveys are designed to be the first line of defense in locating and identifying potential new weed species. Koloa currently remains unaffected by highly invasive weed species that infect surrounding areas, such as *Falcataria moluccana* and *Leptospermum scoparium* in Wailele, Kaiwikoele, and Kawainui. In the past, OANRP has controlled *F. moluccana* and *L. scoparium* in the surrounding areas to prevent their spread west into the Koloa MU. Time permitting, these species may be controlled in the future. A transect is in place (WT-Koloa-01) on the southern portion of the fence, that follows the Kooalu Summit Trail from the Koloa Cabin to the western corner of the fence, which is a high traffic area for recreational hikers, as well as NRS. NRS will monitor new incoming taxa and evaluating the threat of new taxa to 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.

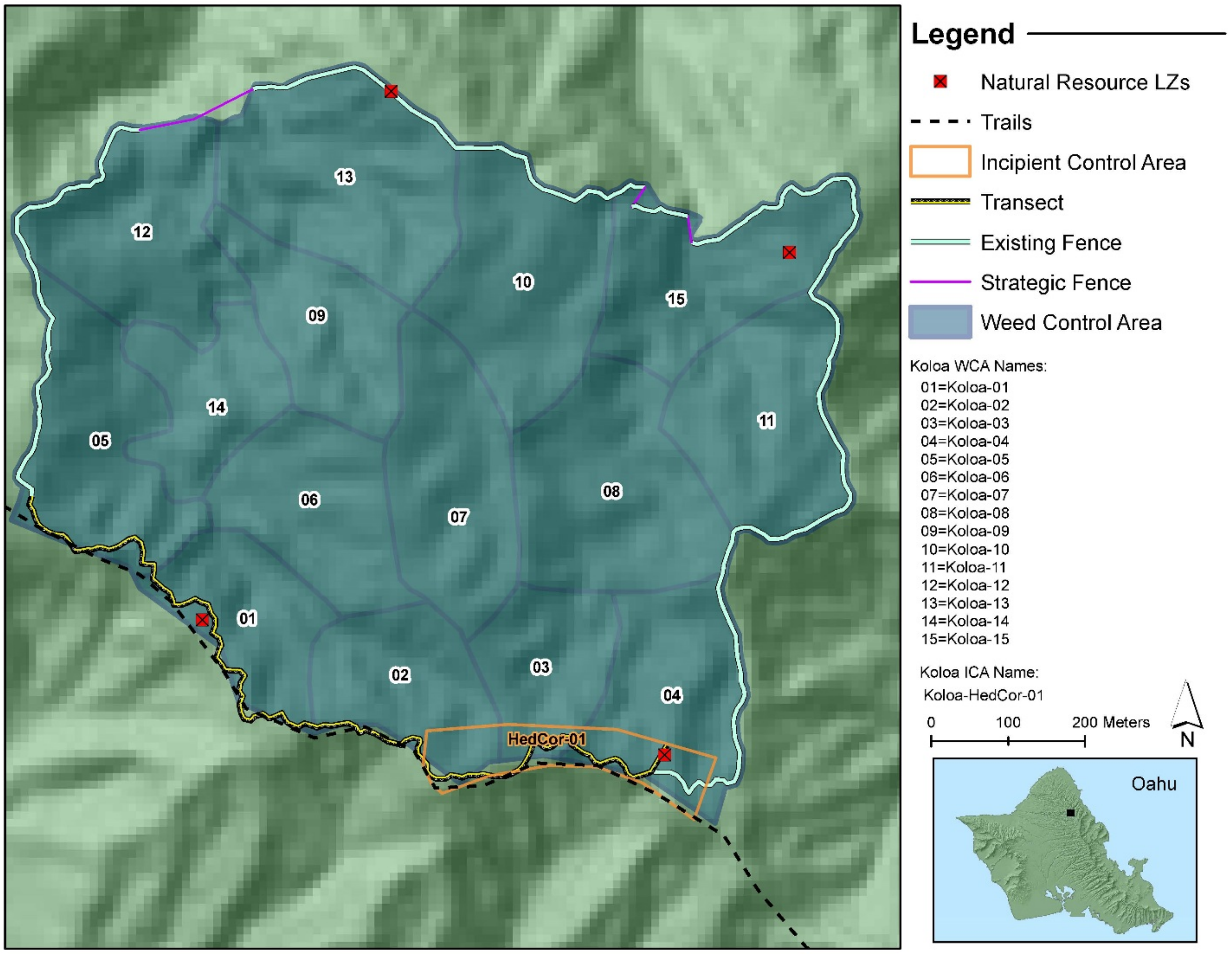
Management Objectives:

- 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 whenever possible.

Incipient, Transect and Weed Control Areas Map



Summary of Target Taxa and ICAs

Taxon	ICA Code	Control Discussion
Hedychium coronarium	Koloa-HedCor-01	There is one site of this taxa in Koloa along the Summit trail. Area needs to be surveyed again and the boundary of this ICA still needs to be defined as exact known locations of hotspots were lost due to staff changes. This is a high priority for control, as ginger thrives in wet environments. Aerial surveys in 2009 revealed large patches of all 3 species of ginger on many windward cliffs to the south.

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.

OIP Goals:

- Within 2m of rare taxa: 0% alien vegetation cover, except where removal 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:

- 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.
- Increase/expand weeding efforts if MU vegetation monitoring (conducted periodically, interval and technique to be determined) indicates that goals are not being met.

Discussion: Although no monitoring has been done, based on the quality of the habitat, we assume that native canopy cover is over 50% and alien canopy cover is under 50%. Goal is to further reduce alien canopy to 10% or less. The major weed threat in the MU is *P. cattleianum*, which has the potential to form dense monotypic stands, and is a dominant presence in other areas of the Koolau Mountains. Weed control in Koloa will focus on conducting ground sweeps across all walkable portions of the MU, targeting *P. cattleianum* and other weeds (listed in the Summary Target Taxa table below). 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. *P. cattlenianum* sweeps will conducted by two separate teams: the Ecosystem Restoration team and the Green team. Staff will use aerial and ground surveys to guide control efforts.

Areas that are most accessible, have the gentlest terrain, the large amounts of rare resources, and the fewest weeds will be prioritized first for control.

In general, weed sweeps involve all staff lining up and walking in a phalanx across a WCA, treating every target weed seen. In the dense and often steep terrain of the Koolaus, this method is modified, with some staff acting as ‘spotters’ from ridges and other vantage points, directing other staff to the target weeds. Binoculars are critical for this spot-and-treat method. The goal of a sweep is to survey and achieve complete coverage of a WCA.

The table below summarizes invasive weeds found at Koloa, 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
Andropogon virginicus	Scattered	Scattered along trails and cliffs. Goal is to keep off of cliffs, as it is difficult to control in such steep environments.
Angiopteris evecta	Scattered	Incidental observations of *A. evecta* around the MU have been made. Plants seen should be GPSed and removed manually or with 100% Polaris applied directly to the brain on discovery. The adjacent Kaipapau MU is infested with this taxa, which feeds spores into Koloa. Control is a high priority. Control any plants found during regular weed sweeps. Also control plants seen outside the MU, if near the fence. Conduct aerial surveys as needed to guide ground treatments.
Clidemia hirta	Widespread	Widespread throughout the Koloa MU. OANRP does not currently target it for control, except in the vicinity of rare taxa.
Erigeron karvinskianus	Scattered	Status of this species in the MU is unknown. Note locations of *E. karvinskianus* during regular control work. Evaluate whether species should be a target once have additional distribution information. This taxa is a threat to open cliff communities.
Falcataria moluccana	Scattered	Not known in Koloa at this time, but known from adjacent area in Kawainui. If seen, plants are GPSed and added to target species layer and will become a target for control during regular weed sweeps.
Leptospermum scoparium	Unknown	Not known in Koloa at this time, however a large population exists to the northwest and keeping it out of the MU is a priority. Historically, *L. scoparium* was controlled around Puu Kainapuaa.
Melaleuca quinquenervia	Scattered	A few trees were treated in adjacent Wailele gulch by KMWP in 2010. Species has been seen once in MU, taxa will be targeted during regular weed sweeps.
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 occurred in Opaeula fence.
Psidium cattleianum	Widespread	Patches scattered across Koloa. Primary target of WCA sweeps. In the Koolaus, *P.* cattleianum take on a multi-trunked clump form and have the proclivity for slash to resprout. The largest and thickest stands tend to be in gulches and draws. Currently, best practice is to treat with G4 20% with 1% Milestone. In areas with difficult terrain, staff will investigate alternative control techniques, such as Herbicide Ballistic Technology and aerial ball spraying.
Sphaeropteris cooperi	Scattered	No plants known in MU, but individuals known from scattered locations across the Koolaus. *S. cooperi* will be targeted during regular weed sweeps. No herbicide is necessary, plant can just be cut down.

WCA: Koloa-01

<u>Veg Type</u>: Wet Montane

<u>OIP Goal</u>: 25% or less alien cover (rare taxa in WCA)

<u>Target:</u> *P. cattleianum*, tree weeds

<u>Notes</u>: High priority for control due to amount of rare taxa and habitat is generally better. Weed sweeps can be performed in this WCA from the Summit Trail north and down to the river. However the north side of the stream is too steep to do sweeps. To minimize the impact to the area, and for safety concerns

of our staff, sweeps will be done via spot-and-treat method: spotting from open ridges with binoculars and directing other staff to the plants for treatment (as described above).

WCA: Koloa-02

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: High priority for control due to amount of rare taxa and habitat is generally better. This WCA is the most fragile in the MU, and contains large populations of *V. oahuensis, E. rockii, C. humboltiana, C. calycina,* and the *H. nutans,* among others. There has been a recent introduction of *L. cyrtandrae* into this WCA and weed control will be conducted around this planting site. To minimize the impact to the area, *P. cattleianum* sweeps will be done via the spot-and-treat method with extreme care taken to minimize disturbing native habitat.

WCA: Koloa-03

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: High priority for control due to amount of rare taxa and habitat is generally better. This WCA is home to a large population of *E. rockii,* and a reintroduction of *P. hirsuta*. The area in this WCA consists of many small ridges and gulches. Weeding efforts are concentrated around *P. hirsuta.* Weed sweeps can be performed across the entire WCA.

WCA: Koloa-04

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: High priority for control due to amount of rare taxa and habitat is generally better. This WCA surrounds the camp site, borders the Kaipapau MU, and consists of more endangered species than any other WCA. Plants found in this WCA include *Cya. calycina, Cya. koolauensis, Cyr. viridiflora, H. swezeyi, L. gaudichaudii* ssp. *gaudichaudii, V. oahuensis, Z. oahuense,* and a large population of *E. rockii.* Half of this WCA is relatively open and weed sweeps in this area can be completed quickly with no damage to the endangered taxa. In the other half, to minimize the impact to the area, weed sweeps will be done via the spot-and-treat method.

WCA: Koloa-05

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: High priority for control due to amount of rare taxa and habitat is generally better. This WCA is the most southwest in the MU and consists of many small gulches and ridges. Weed sweeps can be performed in this entire WCA from the Summit Trail to the north, and from the west fence line to the East boundary, which is the river. The Ecosystem Restoration Team primarily conducts sweeps in this WCA.

WCA: Koloa-06

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: High priority for control due to amount of rare taxa and habitat is generally better. Part of this WCA consists of extremely degraded pasture like habitat which makes weed sweeps quick. The area likely will benefit from being pig-free, and native vegetation may recover on its own. Sweeps for *P. cattleianum* and other tree weeds will be conducted. Photopoints should be installed to document any potential vegetation recovery.

WCA: Koloa-07

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: High priority for control due to amount of rare taxa and habitat is generally better. Part of this WCA consists of extremely degraded pasture like habitat which makes weed sweeps quick. This WCA would benefit greatly from common plant reintroductions. The area likely will benefit from being pig-free, and native vegetation may recover on its own, otherwise sweeps for *P. cattleianum* and tree weeds will be conducted. Photopoints should be installed to document any potential recovery.

WCA: Koloa-08

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: High priority for control due to amount of rare taxa and close proximity to summit and cabin. To minimize impact to the area, and for safety concerns of our staff, sweeps will be done via spot-and-treat method. The Ecosystem Restoration Team primarily conducts sweeps in this WCA.

WCA: Koloa-09

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: Low priority for control due to large area, difficult terrain, and more weeds. This WCA is steep. To minimize the impact to the area, and for safety concerns of our staff, sweeps will be done via the spot-and-treat method. This area may be a candidate for remote/aerial control techniques.

WCA: Koloa-10

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: Low priority for control due to large area, difficult terrain, and more weeds. This WCA for the most part is relatively flat; full weed sweeps can be conducted.

WCA: Koloa-11

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: Low priority for control due to large area, difficult terrain, and more weeds. To minimize the impact to the rare plants in this area, and for safety concerns of our staff, sweeps will be done via the spot-and-treat method. This WCA borders Kaipapau gulch.

WCA: Koloa-12

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: Low priority for control due to large area, difficult terrain, and more weeds. This WCA is in the northwest corner of the fence and is very steep. To minimize the impact to the area, and for safety concerns of our staff, sweeps will be done via the spot-and-treat method. The area has not been well surveyed yet. There is a reintroduction of *L. cytandrae* near the stream bottom that will be maintained via focused weed control.

WCA: Koloa-13

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: Low priority for control due to large area, difficult terrain, and more weeds. This WCA is very steep. To minimize the impact to the area, and for safety concerns of our staff, sweeps will be done via the spot-and-treat method. The area has not been well surveyed yet. There is a reintroduction of *L. cytandrae* near the stream bottom that will be maintained via focused weed control.

WCA: Koloa-14

Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA)

Target: *P. cattleianum*, tree weeds

Notes: Low priority for control due to large area, difficult terrain, and more weeds. The West boundary of this MU is the river at the bottom of the west gulch. To minimize the impact to the area, and for safety concerns of our staff, sweeps will be done via the spot-and-treat method. The area has not been well surveyed yet.

WCA: Koloa-15

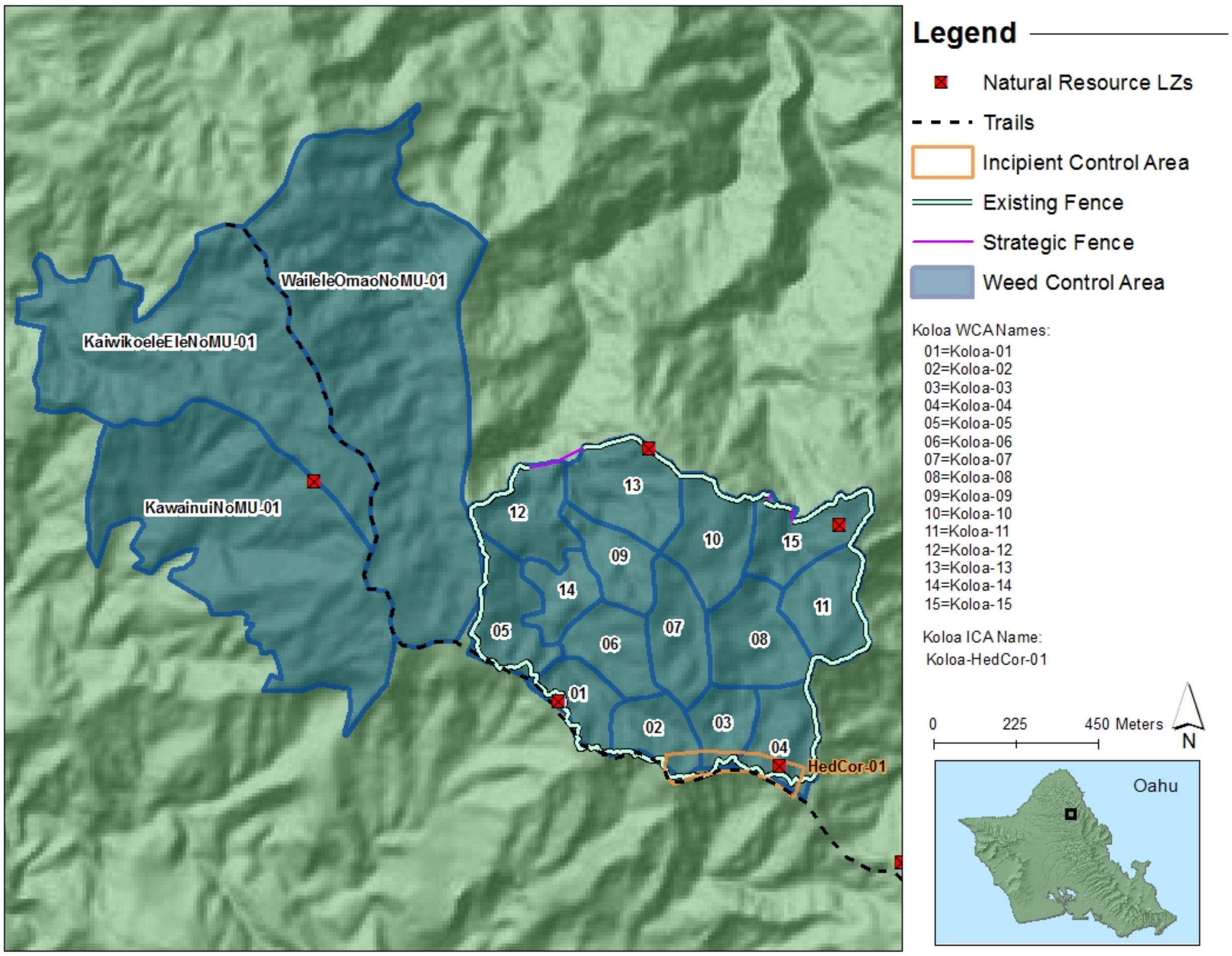
Veg Type: Wet Montane

OIP Goal: 25% or less alien cover (rare taxa in WCA).

Target: *P. cattleianum*, tree weeds

Notes: Low priority for control due to large area, difficult terrain, and more weeds. This WCA is in the northeast corner of the exclosure and is very steep. To minimize the impact to the area, and for safety concerns of our staff, sweeps will be done via the spot-and-treat method. The area has not been well surveyed yet.

KoloaNO MU Weed Control Areas



Discussion: In previous years, NRS conducted sweeps targeting *L. scoparium* to the northwest of Koloa . This is not a current priority as it is outside the MU, possible collaborative project with KMWP will be discussed. Utilizing new technologies and methodologies, such as Herbicide Ballistic Technology (HBT), to develop control methods for *L. scoparium* will be examined in the future.

WCA: KawainuiNoMU-01

Veg Type: Wet Montane

OIP Goal: None (not in MU)

Target: *L. scoparium*, *A. evecta*

Notes: This WCA is steep and comprised of many small ridges and gulches. To minimize the impact to the area, and for safety concerns of our staff, sweeps will be done via spot-and-treat method.

WCA: KaiwikoeleEleNoMU-01

Veg Type: Wet Montane

OIP Goal: None (not in MU)

Target: *L. scoparium*, *A. evecta*

Notes: This WCA once held a large population of *L. scoparium.* Remnant seedlings and immature plants continue to sprout and will require additional visits to maintain the low numbers left in this area. This WCA is relatively easy to work in as it is generally flat and not as heavily vegetated as the surrounding area.

WCA: WaileleOmaoNoMU-01

Veg Type: Wet Montane

OIP Goal: None (not in MU)

Target: *L. scoparium*, *A. evecta*

Notes: This WCA has been swept in the past, but continues to produce *L. scoparium* plants. This WCA has extremely steep walls as well as a relatively flat gulch bottom with a stream running through the center. To minimize the impact to the area, and for safety concerns of our staff, sweeps will be done via Spot-and-treat method: spotting from open ridges with binoculars and directing other staff to the plants for treatment

Small Vertebrate Control

Species: *Rattus rattus* (Black rat), *Rattus exulans* (Polynesian rat), *Mus musculus* (House mouse)

Threat level: Low

Management Objectives:

- To maintain rodent populations to a level that facilitates stabilized or increasing plant populations across the MU by the most effective means possible.
- Implement rodent control if determined necessary for protection of plant populations. Monitor susceptible species for evidence of rodent impacts.

Strategy and Control Methods:

- OANRP currently does not control rodents at Koloa.

Discussion: Currently, no rodent control is conducted by OANRP at Koloa, since *Achatinella livida* is listed as a Tier 2 taxa. Rodent control round these *A. livida* populations has been appointed to SEPP. However, rodent control may be implemented if there is observed damage to any managed plant species. *Labordia cyrtandrae* is susceptible to rodents as damage has been reported in the *L. cyrtandrae* populations located in the Kaala MU.

Slug Control

Species: *Deroceras laeve*, *Limax maximus*

Threat level: High

Seasonality/Relevant Species Biology: Likely abundant year round since area is wet.

Management Objectives:

- Reduce slug population to levels where germination and survivorship of rare plant taxa are unimpeded.
- Determine slug species present and estimate baseline densities using traps baited with beer.
- Determine slug damage monitoring methods for *Cyanea koolauensis*, *Labordia cyrtandrae* and *Phyllostegia hirsuta*.
- If Sluggo or FerroxxAQ is deployed, monitor efficacy via beer traps.
- Annual census monitoring of slug densities during wet season.
- If slug numbers are high enough to damage native plants, survey areas for the presence of rare snails. If no rare snails are present begin slug control using Sluggo or FerroxxAQ at the label rate.
- Additional threats will be assessed and control options weighed.

Strategy and Control Methods:

- Define Slug Control Areas (SLCAs) around rare taxa locations.
- 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. Apply Sluggo monthly at each site or apply FerroxxAQ every 6 weeks. A buffer of at least 5 meters from vulnerable plants is recommended. 10 meters is optimal.

Discussion: During annual rare plant monitoring, we will inspect plants for herbivory. If present, this will be noted and may trigger a management response. Indication that slugs are responsible includes the following: lower leaves closer to the ground are more damaged, slime is present, 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 Sluggo monthly or apply FerroxxAQ every 6 weeks until slug numbers are reduced.

Although slug control may be necessary around the managed plant taxa, using Sluggo or FerroxxAQ may not be feasible due to the access constraints (only via helicopter) and the usually wet habitat.

Ant Control

Species: None detected in 2016

Threat level: Unknown

Seasonality/Relevant Species Biology: Area may prove to be too wet for ant establishment

Management Objectives:

- Determine what ant species are preset and monitor these sites over time.

Strategy and Control Methods:

- Continue to sample ants Koloa cabin annually in the summer. 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 with AMDRO.

Discussion: Ants were sampled around the cabin in March 2016 using bait cards with vials baited with SPAM, peanut butter and honey. While baits were out, staff looked for ants visually for one hour. No ants were found.

The cabin site is the most likely place for accidental human introduction to take place, since both gear and people are flown to that site. We sample ants according to the following protocol: 10 vials baited with SPAM, peanut butter and honey are left out for ants for at least 1 hour. We remove open the vials and space them 5 meters from each other around the cabin. 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. Any ants visiting baits are collected and returned to the office for later identification.

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 filled with hatch marks 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 Type	Actions	OIP Year 10 Oct 2017-Sept 2018				OIP Year 11 Oct 2018-Sept 2019				OIP Year 12 Oct 2019-Sept 2020				OIP Year 13 Oct 2020-Sept 2021				OIP Year 14 Oct 2021-Sept 2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
General Survey	LZ-KLOA-025: Survey Koloa Cabin LZ whenever used, no more than once per quarter. If not used, do not need to survey.																				
	LZ-Koloa-163: Survey Koloa/Kaiapapau LZ whenever used, no more than once per quarter. If not used, do not need to survey.																				
	LZ-Koloa-169: Survey Koloa Midridge LZ whenever used, no more than once per quarter. If not used, do not need to survey.																				
	LZ-KLOA-034: Survey LZ Norton/Kainapuaa annually. [NOT CURRENTLY LEASED BY ARMY, WILL SCHEDULE IF TRAINING RESUMES]																				
	OS-KLOA-01: Survey Koloa Cabin campsite whenever used, not to exceed once per quarter. If not used, do not need to survey.																				

Action Type	Actions	OIP Year 10 Oct 2017-Sept 2018				OIP Year 11 Oct 2018-Sept 2019				OIP Year 12 Oct 2019-Sept 2020				OIP Year 13 Oct 2020-Sept 2021				OIP Year 14 Oct 2021-Sept 2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
	WT-Koloa-01: Survey from LZ to Cabin, then along Koolau Summit trail/Koloa fenceline to W side of fence, where fence turns off KST and cuts N; annually. Note, this is expansion over earlier years (<2017), which ran only from Cabin to LZ Northern.		X				X				X				X				X		
	Survey aerially for AngEve and PsiCat, to assist in guiding control efforts.				X				X				X				X				X
ICA HedCor	KLOA-HedCor-01: Monitor/control Hedcor in Koloa cabin vicinity annually.	X			X	X			X	X			X	X			X	X			X
ICA HedCor	KLOA-HedCor-01: Survey area around known locations; check out mini gulches. Easiest to do with 4 people. Define ICA. GPS.	X			X																
WCA: Koloa-01 (Northern LZ)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.			X	X	X															
WCA: Koloa-02 (Hupnut site and LabCyr reintro)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.	X																			
WCA: Koloa-02 (Hupnut site and LabCyr reintro)	Control weeds around rare taxa reintro (LabCyr) 2x/year, or as needed. Minimize disturbance to protect rare plants and reduce invasion by PteGlo, CliHir, etc.	X		X		X		X		X		X		X		X		X		X	
WCA: Koloa-03	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.	X																			

Action Type	Actions	OIP Year 10 Oct 2017- Sept 2018				OIP Year 11 Oct 2018- Sept 2019				OIP Year 12 Oct 2019- Sept 2020				OIP Year 13 Oct 2020- Sept 2021				OIP Year 14 Oct 2021- Sept 2022			
		4	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**
(Between Hupnut WCA and Camp WCA)	Control weeds around rare taxa reintro (PhyHir) 2x/year, or as needed. Exercise care when working around sprawling PhyHir. Minimize disturbance to protect rare plants and reduce invasion by PteGlo, CliHir, etc.																				
WCA: Koloa-04 (Cabin WCA)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.																				
WCA: Koloa-05 (South West WCA, West of Northern LZ WCA)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.																				
WCA: Koloa-06 (Mid ridge to bottom of West gulch)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.																				
WCA: Koloa-07 (Mid ridge to Puu 2361)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.																				
WCA: Koloa-08 (Puu 2361 across East gulch)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.																				
WCA: Koloa-09 (Mid ridge to bottom of West gulch, North of 6)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.																				
WCA: Koloa-10 (Midridge to 2361 ridge)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.																				

Action Type	Actions	OIP Year 10 Oct 2017-Sept 2018				OIP Year 11 Oct 2018-Sept 2019				OIP Year 12 Oct 2019-Sept 2020				OIP Year 13 Oct 2020-Sept 2021				OIP Year 14 Oct 2021-Sept 2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
WCA: Koloa-11 (Kaipapau side)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.							■	■	■											
WCA: Koloa-12 (North West corner with huge waterfall)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.															■	■	■			
	Control weeds around rare taxa reintro (LabCyr) 1x/year, or as needed. Minimize disturbance to protect rare plants and reduce invasion by PteGlo, CliHir, etc.				■				■				■				■				■
WCA: Koloa-13 (Mid ridge to WCA 12)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.															■	■	■			
	Control weeds around rare taxa reintro (LabCyr) 1x/year, or as needed. Minimize disturbance to protect rare plants and reduce invasion by PteGlo, CliHir, etc.				■				■				■				■				■
WCA: Koloa-14 (West river towards Mid ridge)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years.															■	■	■			
WCA: Koloa-15 (North East Corner)	Conduct canopy weed control across WCA. Focus effort around rare plant sites. Re-sweep every 3-5 years. [NO ACTIONS SCHEDULED FOR NEXT 5 YEARS]																			■	■
Ungulate Control	All fence monitoring and maintenance actions. Maintenance is defined as any minor repair work or that is LESS THAN 100m.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Ant Control	Conduct surveys for ants at annually at Koloa cabin			■					■				■				■				■

Action Type	Actions	OIP Year 10 Oct 2017-Sept 2018				OIP Year 11 Oct 2018-Sept 2019				OIP Year 12 Oct 2019-Sept 2020				OIP Year 13 Oct 2020-Sept 2021				OIP Year 14 Oct 2021-Sept 2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
	Implement control if deemed necessary.																				
Slug Control	Determine slug species are a threat to any managed species.																				
General Maintenance	All camp maintenance including cabin construction, repairs etc.																				

Ecosystem Restoration Management Plan
MIP Year 13-16, Oct. 2016- Sept. 2021
MU: Pualii, PualiiNoMU

Overall MIP Management Goals:

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

Background Information

Location: Southern Waianae Mountains

Land Owner: State of Hawaii, DOFAW (Honouliuli Forest Reserve)

Land Managers: DOFAW, OANRP, OPEPP, OSEPP

Acreage: 25 acres

Elevation Range: 1800-2775 ft.

Description: Pualii MU is located in the Southern Windward Waianae Mountains and consists of two major drainages, North Pualii and South Pualii. Overall the area is characterized by steep vegetated slopes and cliff especially at higher elevations. Much of the MU is dominated by alien vegetation. There are only small pockets of native vegetation worthy of intensive management. The alien dominated areas were included in the MU boundary to capture the rare elements and unique native habitat at the heads of North and South Pualii as well as a native dry-mesic forest stand on the north face of North Pualii gulch.

The fenced portion of North Pualii consists of a non-native dominated southern facing (*Eucalyptus* sp. and *Schinus terebinthifolius* mostly) and a mixed native and non-native north face. The lower slope and gulch bottom of the north face contains a fairly intact, diverse dry-mesic forest canopy (dominated by *Sapindus oahuensis* and *Antidesma pulvinatum*) and open talus/soil understory. The left fork of North Pualii contains an intact *Planchonella sandwichensis* stand and an adjacent draw used for various reintroductions.

The fenced portion of South Pualii is the head of the gulch above a large dry waterfall. It contains a small patch of diverse mesic forest transitioning to an ohia shrubland cliff habitat. A small *Pisonia* stand located just outside the fence in South Pualii contains a remnant population of *Achatinella concavospira* snails.

Other rare resources outside the South Pualii fence include a few large wild *Urera kaalae* trees near the large waterfall and a ridgeline with scattered *Schiedea ligustrina*.

Infrastructural resources include two 250 gallon water catchments and tanks on adjacent ridges atop North and South Pualii, a landing zone at the crestline above South Pualii, and a small PU fence in the adjacent Napepeiaoolelo Gulch to the south. The small PU fence once contained a wild *Hesperomannia oahuensis* population. Currently, a small patch of *Dissochondrus biflorus* grass (a Species of Concern) is the only rare taxon still in the Napepeiaoolelo fence.

The MU is accessed via Kunia Road through the Kunia Loa development and the northern start of the Honouliuli Contour Road. The 25 acre fence was installed by The Nature Conservancy in 2006. Majority of rare plant reintroductions were done by TNC in the 2004-2006 period. OSEPP translocated most of the

A. concavospira snails to the Palikea enclosure in 2014-2015. OPEPP continues to use the North Pualii fence gulch bottom for reintroductions of *Urera kaalae* and *Solanum sandwicense.*

Native Vegetation Types

Waianae Vegetation Types	
Mesic mixed forest	Canopy includes: *Acacia koa*, *Metrosideros polymorpha*, *Nestegis sandwicensis*, *Diospyros* spp., *Pouteria sandwicensis*, *Charpentiera* spp., *Pisonia* spp., *Psychotria* spp., *Sapindus oahuensis*, *Antidesma platyphyllum*, *A. pulvinatum*, *Bobea* spp. and *Santalum freycinetianum*. Understory includes: *Alyxia stellata*, *Bidens torta*, *Coprosma* spp., *Microlepia strigosa* and *M. speluncae*
NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted.	

Mixed Mesic and Dry-Mesic Vegetation Types at Pualii

North Pualii at center top of photo, South Pualii at left of photo above large cliff face

Intact *Planchonella sandwichensis* stand with photopoint marker

South Pualii Diverse Mesic Forest Patch

MIP/OIP Rare Resources at Pualii

Organism Type	Species	Pop. Ref. Code	Population Units	Management Designation	Wild/ Reintroduction
Plant	*Cenchrus agrimonioides var. agrimonioides*	PUA-A	Pualii North	GS	Both
Plant	*Hesperomannia oahuensis*	PUA-A	Pualii North	MFS	Reintroduction
Plant	*Phyllostegia mollis*	PUA-A	Pualii North	MFS	Reintroduction (failed)
Plant	*Flueggea neowawraea*	PUA-A	Pualii North	GS	Reintroduction (failed)
Arthropod	*Drosophila montgomeryi*	PUA-A	Pualii North	MFS	Wild, possibly extirpated
Snail	*Achatinella mustelina*	N/A	Pualii North	GS	Wild

MFS= Manage for Stability GS= Genetic Storage

Other Rare Taxa at Pualii

Organism Type	**Species**	**Status**
Plant	*Abutilon sandwicense*	Endangered (reintroduction)
Plant	*Asplenium unisorum*	Endangered
Plant	*Asplenium dielfalcatum*	Endangered
Plant	*Bobea sandwicensis*	Endangered
Plant	*Chrysodracon forbesii*	Endangered (wild)
Plant	*Delissea waianaeensis*	Endangered (reintroduced)
Plant	*Dissochondrus biflorus*	Rare on island
Plant	*Gardenia brighamii*	Endangered (reintroduced)
Plant	*Neraudia melastomifolia*	Endangered (wild)
Plant	*Sideroxylon polynesicum*	Vulnerable (from Napepeiaoolelo)
Plant	*Solanum sandwicense*	Endangered (reintroduced)
Plant	*Schiedea ligustrina*	Species of Concern
Plant	*Sicyos lanceoloideus*	Endangered (wild and reintroduced)
Plant	*Stenogyne kanehoana*	Endangered (reintroduced)
Plant	*Tetramolopium lepidotum* var. *lepidotum*	Endangered (reintroduced)
Plant	*Urera glabra*	Vulnerable (reintroduced)
Plant	*Urera kaalae*	Endangered (wild and reintroduced) (OPEPP managed)
Snail	*Achatinella concavospira*	Endangered (wild)
Snail	*Auriculella ambusta*	Species of Concern
Arthropod	*Drosophila flexipes*	Vulnerable

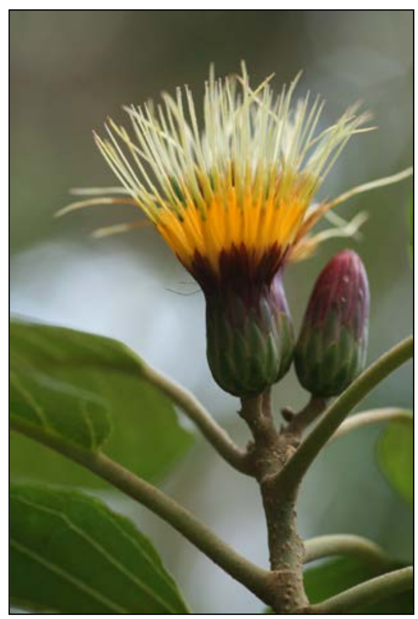
Rare Resources at Pualii

Reintroduced stand of *Abutilon sandwichensis*

TNC reintroductions*: Tetramolopium lepidotum* subsp*. lepidotum.* outplants at left in South Pualii. *Delissea waianaeensis* outplants at right, North Pualii.

Drosophila montgomeryi laying eggs in a rotting trunk of *Urera kaalae,* Pualii.

Phyllostegia mollis with inflorescence



Hesperomannia oahuensis

Locations of Rare Resources at Pualii

Map removed to protect rare resources

MU Threats to MIP/OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2017
Ungulates	All	Fenced MU	No animals within fence
Rats	All	Localized control around *Hesperomannia oahuensis*	Trap grid maintained regularly
Ants	*Drosophila* sp.	Control Big-headed ants found in North Pualii within fence. Big-headed ants negatively impact *Drosophila* sp.	Infestation delineated, control imminent
Weeds	All	Rare taxa sites primarily, across MU secondarily	Regular maintenance required several times per year
Fire	All	No control	No control necessary at this time
Black Twig Borer	*Flueggea neowawraea*, *Abutilon sandwicense*	No control	No control necessary at this time. All *F. neowawraea* outplants have died. OANRP currently does not manage *A. sandwicense* in this MU.

Slugs	*Hesperomannia oahuensis*	Affected rare taxa sites only	Monitor rare plants; no control needed currently
Jackson's Chameleons	*Drosophila* spp., *Achatinella* spp.	No control	No control necessary at this time for *Drosophila* spp. All *Achatinella* spp. have been moved.

Management History

- 2006: The 25 acre fence was installed by The Nature Conservancy after previous survey work detected numerous rare species and a remnant, but intact dry-mesic forest community.
- 2004-2006: Numerous rare plant reintroductions done by TNC.
- 2006: TNC ends management of Honouliuli Preserve. Area transferred to DOFAW as a forest reserve.
- 2006: OANRP collaborates with TNC to manage MU.
- 2010-2014: OANRP reintroduces *Hesperomannia oahuensis* and *Phyllostegia mollis* to Pualii. *P. mollis* reintroductions all fail to recruit and die. *H. oahuensis* reintroduction thrives.
- 2013: First mature *H. oahuensis* observed.
- 2013-2014: OANRP surveys Pualii for *Drosophila* spp., small population of *D. montgomeryi* detected in North Pualii *Urera kaalae* outplanting/wild site. *Drosophila flexipes* detected in gulch bottom of fence area near crossing style.
- 2014-2016: Goats detected along crestline and in South Pualii. Control efforts initiated.
- 2014-2015: OSEPP translocated most of the *A. concavospira* snails to the Palikea snail enclosure.
- 2015: *Urera glabra* outplanted in gulch. First *H. oahuensis* fruit/seed collected from hand pollinated plants at site
- 2015-2016: OPEPP continues to use the North Pualii fence gulch bottom for reintroductions of *U. kaalae* and *Solanum sandwicense.*
- 2016: First *H. oahuensis* recruit discovered in area of dehisced achene.

Ungulate Control

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

Threat Level: High (pigs and goats)

Management Objectives:

- Maintain ungulate free exclosure.

Strategy and Control Methods:

- Snaring along crestline and portions of South Pualii outside of the fence to prevent goats from jumping in the fence.
- Maintain fence line.
- Conduct ground and aerial hunts for goats opportunistically.
- Conduct quarterly fence checks or as needed after extreme weather events.
- Note any pig sign while conducting day to day actions within fenced MU.
- If any pig or goat activity detected within the fence implement hunting and/or additional snaring program.

Discussion: Pigs are somewhat frequent visitors outside the fence area due to low and ineffective hunting pressure. Goats are also now an ongoing threat given their presence along the crestline and into South Pualii. Small goats have been trapped inside the South Pualii fence area. The Pualii fence was not built to keep out goats since goats were not a threat at the time of construction. However, parts of the fence where goats may be able to jump the fence, have been modified to stand taller by adding another panel in order to prevent goats from breaching the fenceline.

Special emphasis will be placed on checking the fence after extreme weather events and any vandalism on adjacent fences or resources. The area where the fence crosses the gulch bottom of South Pualii is prone to heavy stream/debris flows and fence blowouts. Fence may be altered in the future to have a hypalon to prevent heavy stream flows impacting the fence.

Pigs have infrequently made their way into the fence, particularly from the north fence line where debris piles up along the contouring fence line. The last pig observed inside the fence was in 2014 flowing a fence blowout in the stream. No pigs have been observed inside since. Debris should be periodically cleared during fence checks to keep small squares effective at eliminating ingress. At some point, fickle fencing may be warranted along this section if pig populations rise significantly.

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

No vegetation monitoring planned at this time given few MIP/OIP targets and the degraded status of MU.

Surveys

Potential Vectors: OANRP staff, pigs/goats, birds, hikers/hunters, 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 survey of one LZ (if used).
- Note unusual, significant or incipient alien taxa during the course of regular field work.
- 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. There are no surveys planned for roads or trail transects since NRS does not frequently work in the Pualii MU. However, action surveys for the road (past the main Kunia Loa Ridge road) and the main trails may be implemented in the future if NRS increases use.

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 Objective:

- As feasible, eradicate high priority species identified as incipient invasive aliens in the MU.

Strategy and Control Methods:

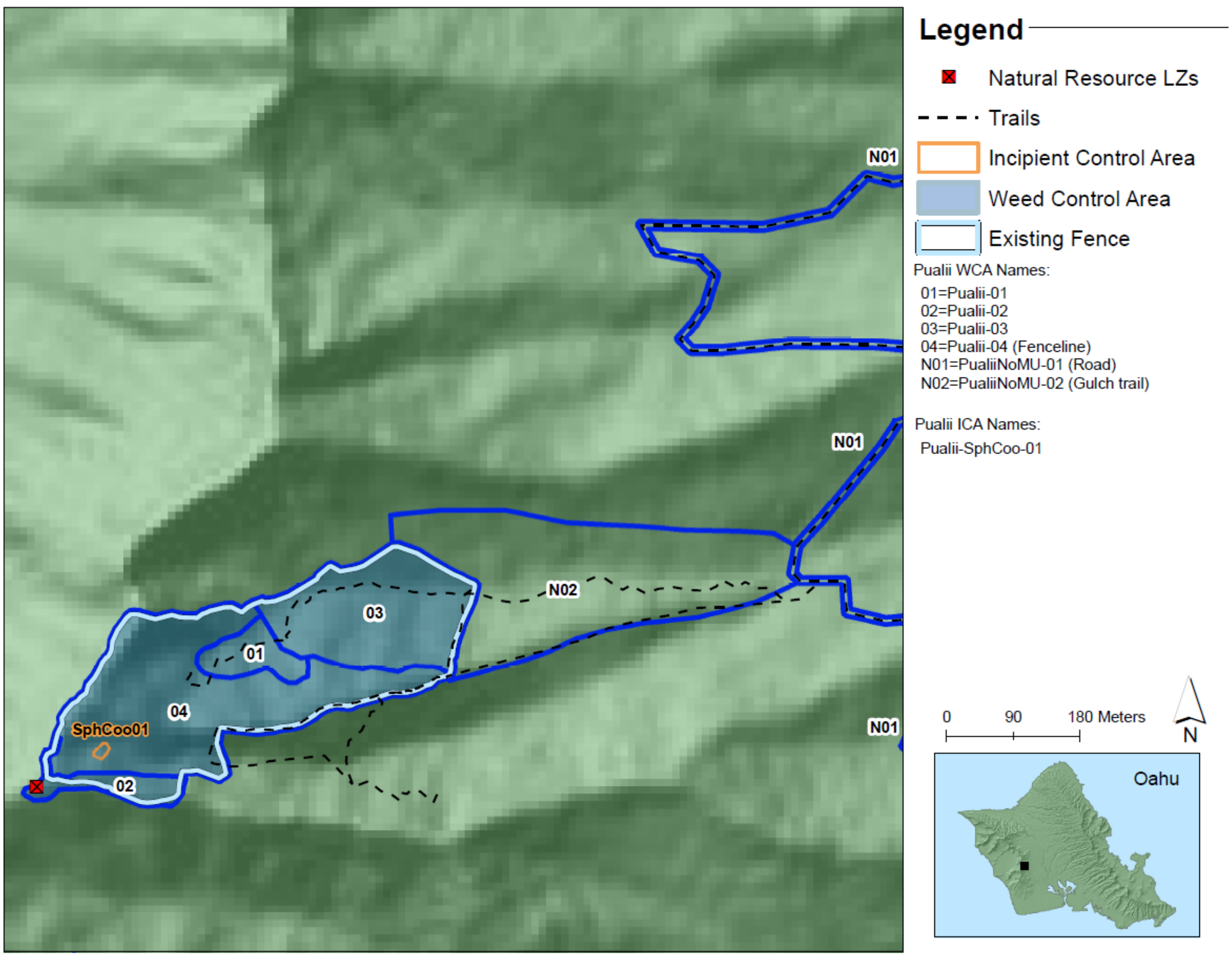
- Visit ICAs at stated re-visitation intervals. Control all mature plants at ICAs and prevent any immature or seedling plants from reaching maturity.
- If unsuccessful in preventing immature plants from maturing, increase ICA re-visitation interval.

Discussion: Only one incipient, *Sphaeropteris cooperi*, has been identified by OANRP in the MU. OANRP will continue to monitor and consider control on other possible incipient taxa when appropriate. Return visits will be scheduled in order to prevent immature individuals from reaching maturity.

Summary of Target Taxa and ICAs

Taxon	ICA Code	Control Discussion
Sphaeropteris cooperi	Pualii-SphCoo-01	Scattered individuals in the drainage of South Pualii. Few large, mature individuals have been found. Due to its documented invasive capability, it is a priority for control.

Incipient and Weed 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.

OIP/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:

- Reduce alien cover in both understory and canopy across the MU, working towards goal of 50% or less alien vegetation cover.
- Increase native cover in both understory and canopy across the MU, working towards a goal of 50% or more native vegetation cover.
- All portions of the MU are within 50m of rare taxa. However, weeding efforts will focus mainly on the rare taxa that are MFS.

Discussion: Weed control began in Pualii with the efforts of TNC. *Passiflora suberosa,* which is pervasive throughout the MU, was cleared out of the many *Pisonia* dominated gulches, and *Psidium cattleianum* was thinned from areas with native canopy. Hundreds of endangered plants were planted in this MU by TNC, and more followed by OANRP. Other natives such as *Urera kaalae* were reintroduced into the area by OPEPP to increase *Drosophila* habitat that had some existing wild *Urera*. OANRP continues to focus around rare plant taxa and around native forest patches.

Summary of Target taxa

Taxa	Management Designation	Notes
Angiopteris evecta	Control Locally	Scattered immature individuals along streambed in South Pualii below *Hesperomannia oahuensis* reintroduction. Control when found. Take GPS points when observed in MU to inform management strategy.
Blechnum appendiculatum	Control Locally	Widespread in MU. Control in native dominated areas and areas with endangered plant species. This habitat-altering, invasive fern forms dense mats if left unchecked.
Clidemia hirta	Control Locally	Not widespread, occasionally found in patches throughout the MU.
Cyclosorus dentatus and *C. parasitica*	Control Locally	Concentrated around the gulch bottom/trails in disturbed areas. Control as needed along trails and in reintroduction areas.
Ehrharta stipoides	Control Locally	Widespread along crestline and South Pualii ridgeline. Control along fence line near reintroduction area and LZ. Take GPS points when observed outside of known core areas in MU.
Erigeron karvinskianus	Control Locally	Widespread across MU. Control near reintroduction areas and wild endangered plant locations.
Eucalyptus spp.	Control Locally	Widespread across MU. Control near native dominated areas by drilling holes and inserting 100% RangerPro into the tree.
Grevillea robusta	Control Locally	Widespread in MU. Target for IPA treatment in native dominated area (north face, North Pualii and near Plasan stand). Selectively control trees as part of WCA efforts. IPA method using Aminopyralid (Milestone) is effective in controlling *Grevillea robusta*.
Heliocarpus popayanensis	Control Locally	Not common in MU as area is a bit dry for this large tree species. Zero tolerance within WCAs. Effective IPA method known.
Melinis minutiflora	Widespread	This grass invades open areas, especially fence lines, and forms fuels which are a fire risk. Control when grass prohibits staff from thoroughly inspecting the fence.
Oplismenus hirtellus	Widespread	Dominant grass in the understory. It thrives in shade and can form dense mats. Control around rare taxa to encourage recruitment. Treat regularly to maintain at low levels.
Montanoa hibiscifolia	Control Locally	Known to create monotypic stands in mesic forests. Occasionally found in fence. Zero tolerance within WCAs.
Passiflora edulis	Control Locally	Occasionally found in fence. Zero tolerance within WCAs.
Passiflora suberosa	Widespread	Widespread vine in MU. It has a WRA of 12 (very high), roots from multiple

		nodes, smothers surrounding vegetation, and is labor-intensive to remove. Control around rare taxa as part of WCA efforts.
Paspalum conjugatum	Control Locally	Concentrated around the gulch bottom/trails in disturbed areas. Control as needed along trails and in reintroduction areas.
Psidium cattleianum	Widespread	Widespread and often forming dense patches in select areas of the MU. Control in native dominated areas.
Psidium guajava	Widespread	Widespread throughout the MU but only in localized patches. Control in native dominated areas.
Rivinia humilis	Widespread	Becoming widespread outside the fence in North Pualii. This weed quickly recolonizes areas from which it has been weeded, reducing the benefit of control efforts. Zero tolerance in fence area.
Rubus rosifolius	Widespread	Control in native dominated areas and near rare resources.
Schefflera actinophylla	Control Locally	Scattered throughout the MU as saplings and recruiting across widespread area. It is a priority for control whenever found. Effective IPA control method known.
Spathodea campanulata	Control Locally	Scattered individuals across MU. Few large mature individuals found. Priority for control in native dominated areas given active recruitment across MU. Effective IPA control method known.
Syzygium cumini	Control locally	This tree has a wide distribution. It thrives on slopes and in gulches, and forms dense shade. Large trees are difficult to kill, and often require multiple treatments. It should be gradually removed from native dominated areas.
Trema orientalis	Control Locally	Scattered mature individuals, but recruiting across widespread area. Priority for control.
Triumfetta semitriloba	Control Locally	Not common in MU. It thrives in disturbed areas. Pull during weed control efforts and along trails, LZ, and fence lines.
Urochloa maxima	Widespread	Zero tolerance within WCAs and along fence lines, trails, and DZs and LZs. Poses a fire risk from producing high fuel loads.

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 Pualii.

Taxa Considerations for Restoration Actions:

Native Taxon	Outplant?	Seedsow/ Division/ Transplant?	Notes
Acacia koa	Yes	Seedsow	Tree. Fast growing. Known to grow from seed sows.
Bidens torta	Yes	Seedsow	Fast growing. Known to grow from seed sows.
Metrosideros polymorpha	Yes	No	Tree. Slow-growing. Grow from cuttings or seed.
Pipturus albidus	Yes	Seedsow/Transplant	Small tree. Fast growing. Known to grow from seed sows.
Pisonia brunoniana	Yes	No	Small tree. Fast growing. Grow from cuttings.
Sapindus oahuensis	Yes	No	Tree. Grow from cuttings or seed.
Urera glabra	Yes	No	Tree. Grow from cuttings.
Urera kaalae	No	No	Tree. Grow from cuttings or seed. Only grown and planted by OPEPP.

WCAs: Pualii-01 (North Pualii, *Planchonella* stand and adjacent reintroduction gulch)

Veg Type: Dry-Mesic Forest

OIP/MIP Goal**:** 25% or less alien cover (rare taxa in WCA).

Targets: Alien canopy trees at edges of WCA and alien understory weeds in gulch and *Planchonella* stand.

Notes: Alien canopy was largely removed from this WCA. Large beautiful *Planchonella* stand remains. Continued effort needed at boundaries of WCA for *Casuarina* sp. at top, western edge of gulch near *Asplenium unisorum* and northwestern edge along *Pisonia brunoniana* patch near fence line to crestline. IPA treatment also needed for *G. robusta* stand also in this fence line area bordering the *Planchonella* stand. Handpulling needed for recruits of various canopy species in this WCA, including *T. orientalis, S. actinophylla* and *S. terebinthifolius*. Understory treatment mainly needed in gulch area for periodic control of *R. rosifolius, U. maxima, P. suberosa, B. asiatica,* and other weeds. Growing *E. karvinskianus* patch at top edge of WCA adjacent to *A. unisorum* patch. Water on site in 55 gallon barrel and two six gallon jugs at old dropzone along western edge of WCA. Weeding around introduced and wild *Urera* plants are needed to maintain healthy *Drosophila* habitat. Although *Phyllostegia mollis* outplantings failed at this site, continue to control weeds around WCA (understory and canopy) for possible reintroductions of *P. mollis* again in the future.

WCA: Pualii-02 (South Pualii, *Hesperomannia* reintroduction area)

Veg Type: Dry-Mesic Forest

OIP/MIP Goal: 25% or less alien cover (rare taxa in WCA).

Targets: Alien canopy trees at edges of WCA and alien understory weeds in reintroduction area. Occasional ICA work in gulch bottom below reintroduction.

Notes: Hiking to this WCA takes about 45 mins to 1 hour, so the main priority for this WCA is to control weeds around the *H. oahuensis* outplants. *Psidium cattleianum* and *S. terebinthifolius* were largely removed from this WCA. Continue *S. terebinthifolius* control along bottom edge of WCA to avoid trees getting too large and ripping out slope. Continue grass control (*U. maxima*, *M. minutiflora*, *P. conjugatum* and *E. stipoides*) in reintroduction area, along fence line and area to the south. Continue *C. hirta* control and other understory weeding to increase open ground opportunities for rare plant recruitment. TNC rare plant reintroductions still in the area as well as *Hesperomannia oahuensis* and recruits require careful understory weed control during sweeps. *Sphaeropteris cooperi* and *A. evecta* have been found in the gulch bottom below the reintroduction area around the year 2010. Annual visits are needed to ensure that these incipient species do not reappear. Water catchment available for grass control. In addition, Landing Zone (LZ) located in this WCA must be maintained as needed to continue helicopter landing/use. LZ should be clear from tall grass and trees/branches that encroach the LZ.

WCA: Pualii-03 (North Pualii, North facing slope, gulch bottom area below Pualii-01 to lower fence bottom.)

Veg. Type: Dry-Mesic Forest

OIP/MIP Goal: 25% or less alien cover (rare taxa in WCA).

Targets: Minimal understory alien control (mainly *B. appendiculatum*). Alien canopy control includes *S. terebinthifolius*, *Eucalyptus spp.*, *G. robusta*, *T. orientalis*, *S. campanulata* and *P. cattleianum*.

Notes: This native dominated and open understory stand of mesic-dry forest is bordered by the gulch bottom and a planting of Eucalyptus along the upper elevation WCA boundary approximately 100-150 m off the gulch bottom. *Sapindus oahuensis* and *Antidesma pulvinatum* are the dominant native canopy trees with occasional large *Nestegis sandwicensis* and *Rauvolfia sandwicensis*. Canopy weeding should target the remaining *S. terebinthifolius* and other canopy weed trees as well as some IPA work along the upper elevational border to buffer the native dominated stand below. A few large *T. orientalis* can also be found in that upper elevational boundary area and should be targeted as well to prevent ongoing recruitment in native dominated areas. Canopy weeding can be accomplished in about 6 trips with a few staff over the next three years. After that, only maintenance weeding is needed to prevent recruits of *S. actinophylla*, *S. terebinthifolius*, and other canopy weeds from re-establishing.

Understory weeding can be limited to hand pulling or treating alien canopy recruits, treating patches of *C. parasitica*, as well as an approximately 10 x 15m patch of *B. appendiculatum. R. rosifolius* and *P. suberosa* should also be treated in the two sunnier gap draws along the north face of this WCA (which are closer to the lower fence line) to preserve the potential for additional rare outplantings in those draws.

The gulch bottom area has a few disturbed zones which are dominated by alien weeds. Semi-annual grass sprays are needed to control guinea grass and other understory weeds. Seed sowing or transplanting *Pisonia* recruits is needed on an ongoing basis each winter season to re-colonize the weedier gulch bottom areas to prevent a cycle of weed treatment with little to no native recruitment.

Since there are no IP taxa located in this WCA, weeding efforts in the understory have been assisted by volunteers in this area for the past few years. Volunteers focus weeding around common native plants and weed from the fenceline up to the *A. sandwicense* outplantings.

WCA: Pualii-04 (Fence line, between Pualii-02 and Pualii-03)

Veg. Type: Dry-Mesic Forest

OIP/MIP Goal: 50% or less alien cover (no rare taxa in WCA).

Targets: Alien canopy control along the fence line includes *S. terebinthifolius*, *Eucalyptus* spp., *G. robusta*, *T. orientalis*, *S. campanulata* and *P. cattleianum*.

Notes: *Psidium cattleianum*, *S. terebinthifolius* and *G. robusta* largely removed from this WCA to prevent trees from potentially falling and damaging the fence. Continue *S. terebinthifolius* control also along bottom edge of WCA to avoid trees getting too large and ripping out slope. Continue grass control (*U. maxima*, *M. minutiflora*, and *P. conjugatum*) along fence line to keep trail clear. Target any priority weed taxa such as *A. evecta*, *Heliocarpus popayanensis, S. actinophylla*, *Sphaeropteris cooperi*, *S. terebinthifolius* and *T. orientalis*.

WCA: Pualii-NoMU-01 (Road to trail head)

Veg. Type: Dry-Mesic Forest

OIP/MIP Goal: None

Targets: Weed control along road to trail head. Grass and fallen branches should be removed/maintained.

Notes: Continue grass control (*U. maxima*, *M. minutiflora* and *P. conjugatum*) along road to keep trail clear. Cut and remove any fallen branches or trees. Survey for any new alien/incipient species annually. Partnership with the State Forest Reserve staff (DOFAW) to maintain road as needed.

WCA: Pualii-NoMU-02 (Gulch trail to fenceline)

Veg. Type: Dry-Mesic Forest

OIP/MIP Goal: None

Targets: Weed control along gulch trail from Pualii-NoMU-01/road to Pualii fence enclosure.

Notes: Cut and remove any fallen branches or trees along trail. Survey for any new alien/incipient species when using trails. Spray grass if needed (*U. maxima*, *M. minutiflora* and *P. conjugatum*) along trail to keep trail clear. Sweep gulch for target canopy species, particularly *T. orientalis*, annually.

Small Vertebrate Control

Species: *Rattus rattus* (Black rat), *Rattus exulans*, (Polynesian rat), *Rattus norvegicus* (Norway rat) and *Mus musculus* (House mouse)

Threat level: High

Seasonality/Relevant Species Biology: Trapping during *Hesperomannia oahuensis* reproductive period, which tends to be from March to August. Rodent damage has been seen commonly on *H. oahuensis* during all stages of the reproductive period. Rodent damage is seen on stems, and can be fatal.

Management Objectives:

- Protect *H. oahuensis* flowers, fruits, and stems from damage during reproductive period.
- Observe less than two kills per trap during the January to June period using Goodnature A24 counters.

Strategy and Control Methods:

- Small localized trapping grid around *H. oahuensis* using 4 Goodnature A24s and 24 Victor snap traps.
- Monitor rare plant populations to determine impacts by rodents.

Discussion: Currently rodent control is only around the *H. oahuensis* reintroduction site during the reproductive period. All Victor snap traps will be replaced with Goodnature A24s to protect *H. oahuensis* year-round. OANRP staff will check A24s every 4 months. In addition, A24s may be added around *Drosophila* habitat in order to ensure no rodent damage occurs on native plant host species.

Slug Control

Species: Unknown

Threat level: Low

Seasonality/Relevant Species Biology: Slugs are not known to cause negative impact *Hesperomannia oahuensis*.

Management Objectives:

- During annual rare plant monitoring, look for seedling recruitment and slug herbivory.

Strategy and Control Methods:

- If slug herbivory is observed during rare plant monitoring, Slug Control Areas (SLCAs) will be defined around rare taxa. Prior to any slug control, an experienced malacologist will survey areas for slug densities and native snails during the day and at least one night.
- FerroxxAQ every 6 weeks is applied to these SLCAs. FerroxxAQ is not applied within 20 m of known populations of native snails.

Discussion: Currently, there is no implemented slug control in this MU. Although there are species of the Campanulaceae family present at Pualii, this MU is not a MFS PU for the IPs. In addition, slugs are not known to negatively affect *Hesperomannia oahuensis*. However, slugs have negatively affected *Urera sp*., which are important plant-host species for *Drosophila montgomeryi*. Therefore, SLCA may be implemented. In addition, during annual rare plant monitoring, OANRP staff will inspect plants for herbivory. If present, damage will be noted and the protocols for creating a SLCA will be followed.

Ant Control

Species: *Pheidole megacephala* (Big headed ants)

Threat level: Moderate to High

Seasonality/Relevant Species Biology: Big headed ants have year-round brood production in tropical and sub-tropical areas but are especially active from April-September

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.

Strategy and Control Methods:

- Sample ants at human entry points using the standard survey protocol (see discussion below) 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.
- Sample ants at campsite, LZ, rare taxa sites, DZ, and fencelines to track changes in existing ant densities and to alert OANRP to any new introductions.

Ant Survey Site Table

Site description	**Reason for survey**
Drosophila restoration area	*Drosophila* are preyed upon by ants as larvae, pupae, and adults

Discussion:

Although ants have not been formally surveyed in Pualii MU, Big headed ants were observed historically (in 2006) by TNC staff. Ants have been documented to pose threats to a variety of resources, including native arthropods, plants (via farming of hemipteran pests), and birds. It is therefore important to know their distribution and density in areas with conservation value. Since 2006, we sample ants in high risk areas using the following method:

Standard Survey Protocol: 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.

Big-headed ants were detected in the bottom of North Pualii gulch around *Urera kaalae* outplanting sites in 2016 while surveying for *Drosophila*. This is a widespread tramp ant. Reintroduction of *Drosophila montgomeryi* is anticipated in this area. The infestation was delimited with baits in early 2017 and control planned for summer 2017. Eradication of these ants throughout the MU is not possible, however control of the population in the gulch may prove important for *Drosophila* recovery. Any pesticides used for the ants will be carefully evaluated to ensure *Drosophila* are not impacted.

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 found along the fence line. This site is vulnerable to fires ignited in adjacent agriculture lots located just below the MU.

Management Objectives:

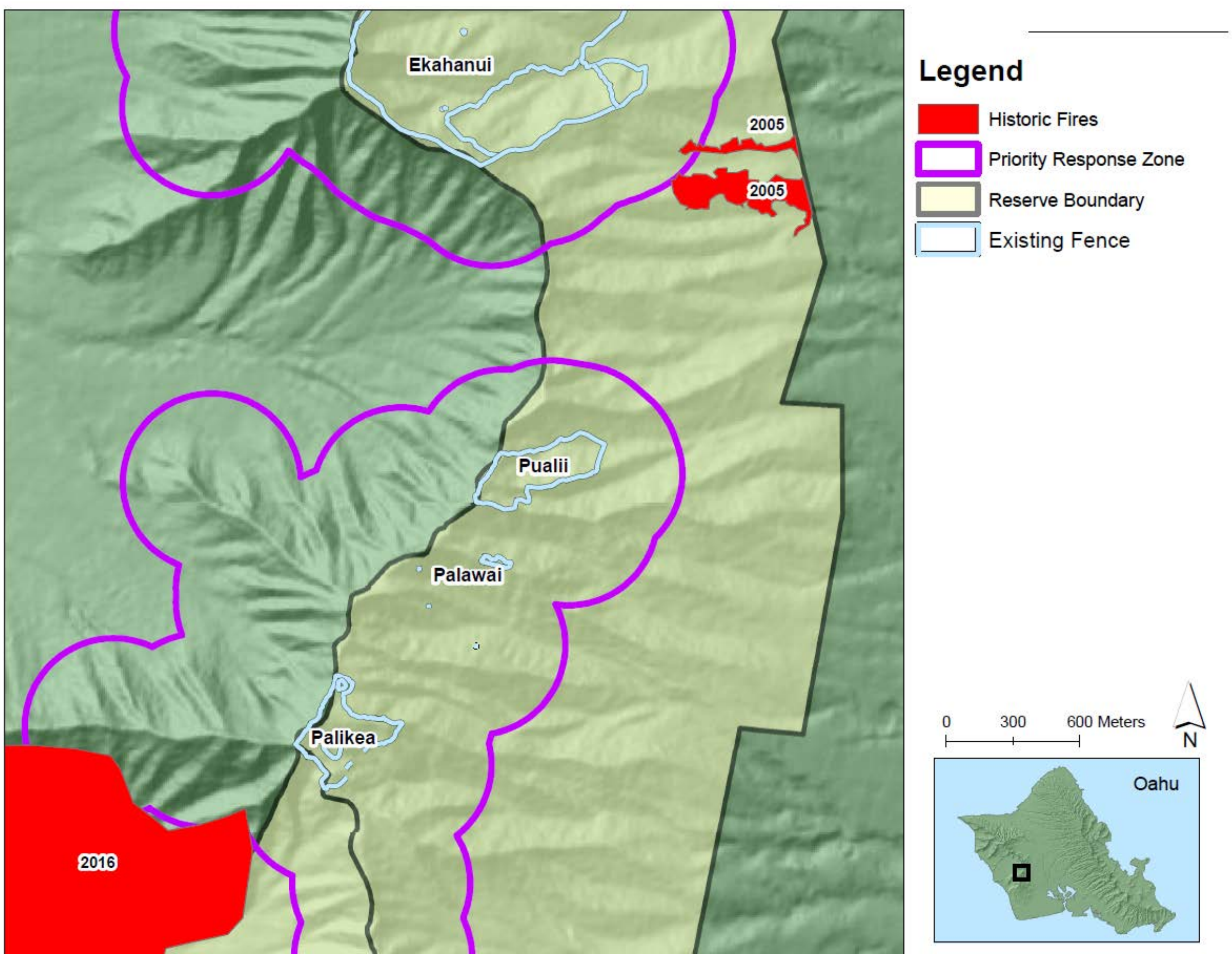
- To prevent fire from burning any portion of the MU at any time.

Strategy and Control Methods:

- Reduce fuel loads along the fence line and road.
- Target *U. maxima* throughout the MU.

Discussion: The threat of fire is high due to the hot and dry climate during the summer, and closely adjacent agriculture lots located near the MU. Additionally, fires have occurred by other closely located MUs. Removal of the most fire prone weed *U. maxima* remains a high priority within the MU and along the fence line as well as the road. Partnership with the State Forest Reserve staff (DOFAW) to maintain road as needed.

Fire Management Map



Action Table

Action Type	Actions	MIP Year 13 Oct 2016-Sept2017				MIP Year 14 Oct 2017-Sept2018				MIP Year 15 Oct 2018-Sept2019				MIP Year 16 Oct 2019-Sept2020				MIP Year 17 Oct 2020-Sept2021			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
General Survey	LZ Survey- Survey South Pualii LZ whenever used, not to exceed once per quarter. If not used, do not need to survey.																				
ICA Pualii-SphCoo-01	Monitor and control SphCoo at site below HesOah reintroduction annually.			■				■				■				■				■	
Pualii-01	Conduct weed sweeps across reintroduction area and native forest patches, focusing on understory/canopy weeds. Sweep 1-2x per year.			■		■		■		■		■		■		■		■		■	
Pualii-02	Conduct weed sweeps across reintroduction area and native forest patches, focusing on understory/canopy weeds. Sweep 1-2x per year.			■		■		■		■		■		■		■		■		■	
	Control weedy grasses along ridge, LZ, fenceline, and across reintroduction zone 2-4 times a year, or as needed. Target all grasses, particularly EhrSti.		■			■		■				■				■				■	
Pualii-03	Conduct weed sweeps across TNC reintroduction area and native forest patches, focusing on understory/canopy weeds. Sweep annually. Focus on GreRob, TreOri, SchTer and Passub.				■				■				■				■				■
	Control under- and mid-story weeds in gulch bottom, from fence to beginning of rare plant reintroductions (Abusan). Always target saplings of TreOri, SchAct, and SchTer. Outreach action.				■				■				■				■				■
	Control weeds along fenceline, as needed.				■				■				■				■				■
Pualii-04	Control weeds along fenceline, as needed.				■				■				■				■				■
PualiiNoMU-01	Control grass/herbaceous weeds, clear downed trees along the Honouliuli contour																				■

Action Type	Actions	MIP Year 13 Oct 2016-Sept2017				MIP Year 14 Oct 2017-Sept2018				MIP Year 15 Oct 2018-Sept2019				MIP Year 16 Oct 2019-Sept2020				MIP Year 17 Oct 2020-Sept2021			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
	road, from the ranch gate to the water catchment, as needed. Use the power sprayer, chainsaw, weedwhack. Alternate this action between teams if significant level of work. Goal: maintain road. Assist with State.																				
PualiiNoMU-02	Sweep gulch for target canopy spp, particularly TreOri, annually. Keep access trail clear.																				
Ungulate Control	Maintain fence integrity																				
	Elimination of any pig ingress into the fence with use of snares and traps.																				
Rodent Control	Implement localized rodent control if determined to be necessary for the protection of rare plants using A24 traps.																				
Ant Control	Conduct surveys for ants at 2 human entry points																				
	Implement control if deemed necessary																				
Slug Control	Monitor slug activity at rare plant population(s)																				
	If slugs found to exceed acceptable levels during monitoring, maintain slug bait at sensitive plant population(s)																				

Ecosystem Restoration Management Plan

MIP Year 14-18, Oct. 2017 – Sept. 2022

MU: Ohikilolo (Lower Makua)

Overall MIP Management Goals:

- Form a stable, native-dominated matrix of plant communities which support stable populations of IP taxa.
- Control fire, ungulate, weed, rodent and slug threats in the next five years to support stable populations of IP taxa.

Background Information

Location: Leeward side of Northern Waianae Mountains, Southern base of Makua valley

Land Owner: U.S. Army Garrison Hawaii

Land Managers: Oahu Army Natural Resources program

Acreage: 676 acres

Elevation Range: 1200-2200 ft.

Description: Ohikilolo (Makua) MU is located in the Makua Military Reservation (MMR). The area is accessed at the mouth of the valley, or by helicopter to LZs throughout the valley. The terrain of the lower portion of the MU includes deep gulches with steep walls, and broad ridges of mixed mesic to dry forest. The upper portion, above the steep sided walls of Makua Valley, is comprised mostly of steep slope to the crest of the ridge.

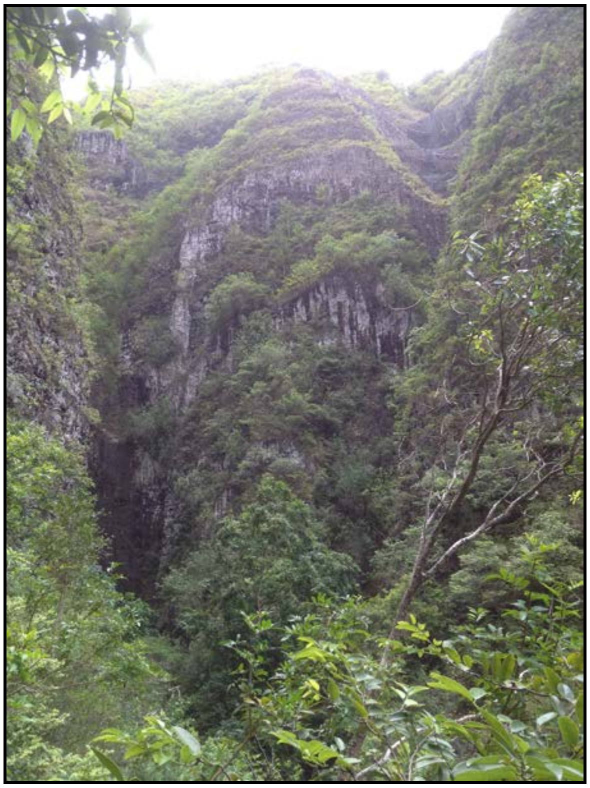
The Ohikilolo Management Unit (MU) is one of the larger MIP MUs. Management for this MU has long been divided informally among OANRP staff as the two following areas; Ohikilolo (Upper) and Lower Makua. The division is useful for management purposes because the access issues to each of the areas vary; large cliffs run approximately along the 2000 ft contour between the two. Due to unexploded ordinance (UXO) issues near the access point at the mouth of the valley the MU can only be accessed via helicopter. Lower Makua also requires contract support from UXO specialists. The two ‘areas’ have been treated separately in past reports because of geographic barriers; therefore, they require different management approaches. In 2012, the ecosystem restoration plan for the area discussed here was referred to as Ohikilolo (Makua)

There are many challenges to management in Makua. Access is limited, and scheduling with Range Control and UXO specialists is required, due to the large amount of UXO present in the valley. Additionally, there are ungulates in the MU, and recently there have been efforts to control animals within the MU, which include, snaring and fence construction. Currently, there are relatively few IP taxa that remain in this MU, in turn, NRS is required to accommodate actions here against actions at other MU’s that contain more IP taxa.

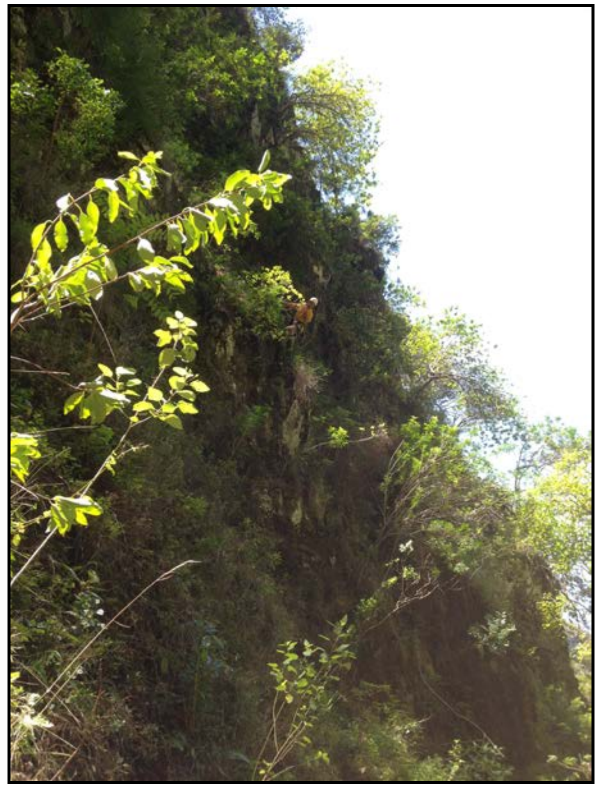
Native Vegetation Types

Wai'anae Vegetation Types	
Dry forest	Canopy includes: *Diospyros* sp., *Psydrax odoratum*, *Nestegis sandwicensis*, *Myoporum sandwicense*, *Erythrina sandwicensis*, *Reynoldsia sandwicensis*, *Rauvolfia sandwicensis*, *Santalum ellipticum*, and *Myrsine lanaiensis.* Understory includes: *Dodonaea viscosa*, *Sida fallax*, *Bidens* sp., *Microlepia strigosa*
NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted.	

Terrain Vegetation Types at Makua



Makua valley floor looking South



Steep cliffs of Ko'iahi gulch looking East towards cliffs above

Photo taken from the Kahanahaiki overlook looking south to Makua

MIP Rare Resources

Organism Type	IP Species	Population Reference Code	Population Unit	Management Designation	Wild/ Reintroduction
Plant	*Alectryon macrococcus* var. *macrococcus*	MMR- A,D,E, F, O-R	Makua	MFS	Wild
Plant	*Flueggea neowawraea*	MMR-C, D, E	Ohikilolo	GSC	Wild
Plant	*Melanthera tenuifolia*	MMR-C, I, J	Ohikilolo	GSC	Wild
Plant	*Neraudia angulata* var. *angulata*	MMR- A, D, E	Makua	MFS	Both
Plant	*Nototrichium humile*	MMR-D,E,H,I	Makua (S. side)	MFS	Both
Bird	*Chasiempsis ibidis*	N/A		Manage	Wild

MFS= Manage for Stability GSC=Genetic Storage Collection

Other Rare Taxa at Ohikilolo MU- Makua

Organism Type	Species	Status
Plant	*Alphitonia ponderosa*	Species of concern
Plant	*Bobea sandwichensis*	Species of concern
Plant	*Bonamia menzesii*	Endangered
Plant	*Ctenitis squamigera*	Endangered
Plant	*Asplenium dielfalcatum*	Endangered
Plant	*Korthalsella degneri*	Endangered
Plant	*Lobelia niihauensis*	Endangered

Plant	*Ocrosia compta*	Endangered
Plant	*Pleomele forbesii*	Endangered
Plant	*Pteralyxia macrocarpa*	Endangered
Plant	*Sideroxylon polynesicum*	Endangered
Bat	*Lasiurus cinereus semotus*	Endangered

Locations of rare resources at Ohikilolo (Lower Makua)

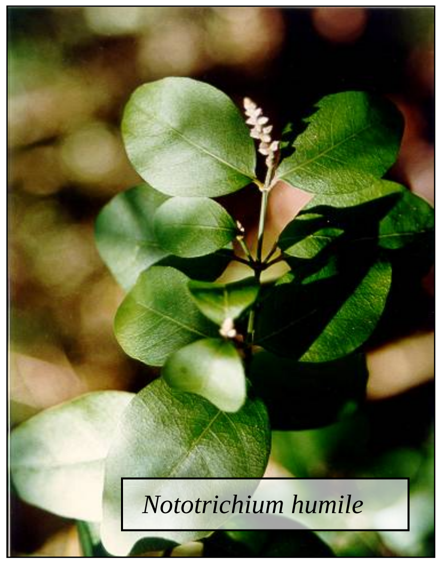
Map removed to protect rare resources

Rare Resources at Makua


Chasiempsis ibidis


Alectryon macrococcus var. *macrococcus* fruit


Flueggea neowawraea


Nototrichium humile


Neraudia angulata var. *angulata*


Sideroxylon polynesicum

MU Threats to MIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2017
Pigs	All	Across MU	Still Present in MU. Ongoing snaring in progress. Extensive removal ongoing.
Goats	All	Across MU	No animals within fence
Weeds	All	Rare taxa sites primarily, across MU secondarily	Regular maintenance required several times per year
Black Rat	*Chasiempis ibidis*, Potential threat to *N. angulata* and *N. humile*	Across MU	There are currently no Elepio pairs in Makua therefore, no control necessary at this time.
Feral Cat	*Chasiempis ibidis*	No control	There are currently no Elepio pairs in Makua therefore, no control necessary at this time.
Mongoose	*Chasiempis ibidis*	No control	There are currently no Elepio pairs in Makua therefore, no control necessary at this time.
Slugs	Potential threat to *N. angulata* and *N. humile*	Affected rare taxa sites only	No control necessary at this time

Management History

- 1929: Army began taking parcels of land for military training.
- 1943: Military gains control of entire valley
- 1995-1997: Ground hunts were started with the use of contract hunters from the U. S. Department of Agriculture Wildlife Services while plans to install a perimeter fence to enclose MMR along the ridge crest were finalized.
- 1996-1997: The first stretch of fencing (3 km) separating MMR from the Keaau game management area was completed by the National Park Service and ~8 km of fencing was erected around the eastern perimeter of the valley.
- 1998: Large fire in Makua, live fire training is halted.
- 1999: Contract and Staff ground hunts continued from 1997-1999 to control numbers of goats. OANRP began to employ neck snares as a management tool.
- 2001: The portion of the fence from Makaleha (3 points) to the Ohikilolo camp was completed by Ranch Services separating the valley from the core populations of goats to the south and OANRP staff employed aerial shooting and "Judas goats" as management tools.
- 2001-2004: Army resumes live fire training on a limited basis.
- 2002: NRS completed a small fence around a single *F. neowawraea* at MMR-C.
- 2003: A breach in the fence allowed at least three goats to cross over from Makaha Valley into Makua Valley. These three goats were subsequently caught and no more sign was observed in the area of the breach. NRS completed a strategic fence (MMR-G) protecting *N. angulata* MMR-D, after which the *N. angulata* MMR-E reintroduction population was established to augment the existing MMR-D population.
- 2004: OANRP with help from Wildlife Services eradicated feral goats from the entire MU.

- 2005: OANRP completed two strategic fences (MMR-H) in the back of Koiahi gulch; they protect *N. angulata.*
- 2006: Four goats breached perimeter fence, all were caught.
- 2009: Last two mating pairs of elepaio observed.
- 2011: Forest tree line mapped from helicopter using GPS to establish accurate weed control boundaries.
- 2013: NRS competed strategic fence (MMR-J) creating protected habitat for outplanting *N. angulata* MMR-I outplanting.
- 2015: Access restricted due to UXO incident and closure of trial from fire break road due to UXO piled up near trail access.
- 2016: Final section of perimeter fence built on Farrington Highway; initiated snaring program within MU.

Ungulate Control

Species: *Sus scrofa* (pig) and *Capra hircus* (goat)

Threat Level: Medium for pigs; Most of the rare taxa affected by pigs are protected by smaller exclosures yet, pigs still pose a threat to broader ecosystem. Medium for goats; Goats have breached the Ohikilolo on occasion, there are numerous goats on the south facing slope of Kea'au. The last capture of goat inside the fenced area was in 2013 near "Ctinitus Ridge".

Management Objectives:

- To maintain all areas of the MU as goat-free and the fenced areas as pig-free.
- An ungulate eradication program has been initiated to remove all ungulates from the Valley. OANRP has started the program by installing snares throughout the Valley. Once RCUH completes an approved firearm use SOP OANRP can begin to use live traps and baiting stations to expand the number of tools in use.

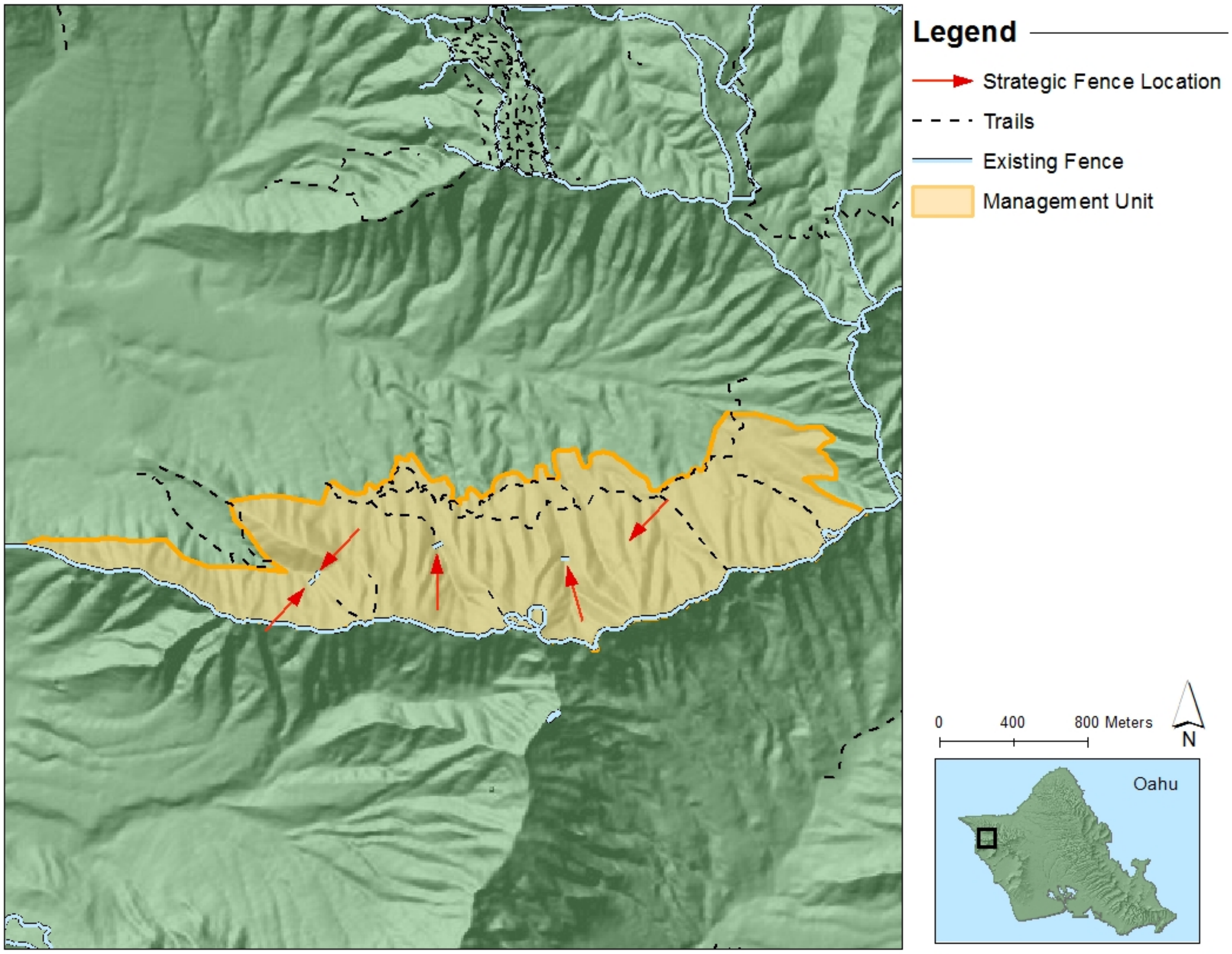
Strategy and Control Methods:

- Maintain MU as goat free, and continue snaring efforts if detection of goats is found.
- Conduct fence checks when access is granted.
- Note any pig sign while conducting day to day actions within fences.
- If any pig activity is detected, work with Ungulate Management/Elepaio Stabilization Coordinator to implement snaring.

Discussion: There are five small fences in this portion of the MU. Given the small sizes of the fence, it is especially important that ungulates do not enter and become trapped in the fence as extensive damage can quickly occur. Checks (including maintenance) on fence integrity will be conducted, as well as, monitoring for ungulate sign during the course of other field activities. The major threats to the fence include falling rocks from steep areas above the units, streams carrying rocks down gulches into the fence, fallen trees, and pigs uprooting areas beneath the fence line. Fences are also checked after extreme weather events.

A pig eradication program has been initiated utilizing neck snares across MU and the greater valley of Makua. Snares a strategically placed near strategic fences, wallows, and water sources. Poachers still hunt the valley illegally and vandalism had been documented in which snares are repeatedly tampered with.

Ungulate Management



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

<u>MU Vegetation Monitoring</u>

As previously discussed, this large MU has been divided into different regions to facilitate management. Vegetation cover across the Ohikilolo (Upper) section was monitored in 2010 and again on 2016. The steep cliffs dividing Ohikilolo (Upper) from Ohikilolo (Makua) cannot be monitored for vegetation cover at the current time. Remote monitoring technologies are being considered and if a feasible methodology becomes available, vegetation cover monitoring may take place in this cliff community. Installing gigapan stations at the Makua lookout at Kahanahaiki will be explored to guide *T. ciliata, G. robusta,* and other low numbered weed taxa to guide management. This document focuses on the lowest elevation section of the MU, Ohikilolo (Makua). As defined by the MIP, the major vegetation cover goals are as follows:

Primary Management Objective:

- Assess if the percent cover for both the alien understory and canopy is 50% or less across the entire management unit (Oahu Implementation Team *et al*. 2008). If alien species cover is not below the 50% goal, use repeated MU monitoring to determine whether or not the value of alien species is decreasing significantly toward that goal.

Secondary Management Objective:

- Assess if the percent cover for both the native understory and canopy is 50% or more across the entire management unit (Makua Implementation Team *et al*. 2003). If native species cover is not above the 50% threshold, use repeated MU monitoring to determine whether or not the value of native species is increasing significantly toward that goal.

Sampling Objective:

- Be 95% confident of detecting a 10% change in both non-native and native understory vegetation in the understory and canopy.
- The acceptable level of making a Type 1 error (detecting a change that did not occur) is 10% and a Type 11 error (not detecting a change that did occur) is 20%.
- Minimum detected change between two samples being compared is 10% over the sampling period.

Given the low number of MIP taxa (5) located in the Makua portion of the MU, OANRP has decided that investigating the primary and secondary management objectives at this time is not the highest priority for monitoring staff. Also, since Makua is entirely in an UXO area and entry requires an UXO escort, ground-based monitoring would be very expensive.

Surveys

Potential Vectors: Army Training, OANRP staff, pigs, poachers, wind.

Management Objective:

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

Strategy and Control Methods:

- Survey LZs and Campsites used in the course of field work, not to exceed once per quarter.
- Note unusual, significant, or incipient alien taxa during the course of regular field work, particularly *Cenchrus setaceus*
- Map and complete Target Species form to document sighting.

Management Responses:

- 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)

Surveys are designed to be the first line of defense in locating and identifying potential new weed species. Landing zones, fencelines, and other highly trafficked areas are inventoried regularly; (Army roads are covered by the Lower Ohikilolo ERMUP) LZs are surveyed annually and transects are surveyed at least annually, while all other sites are surveyed quarterly or as they are used. At Makua, only landing zones and transects are currently surveyed regularly.

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:

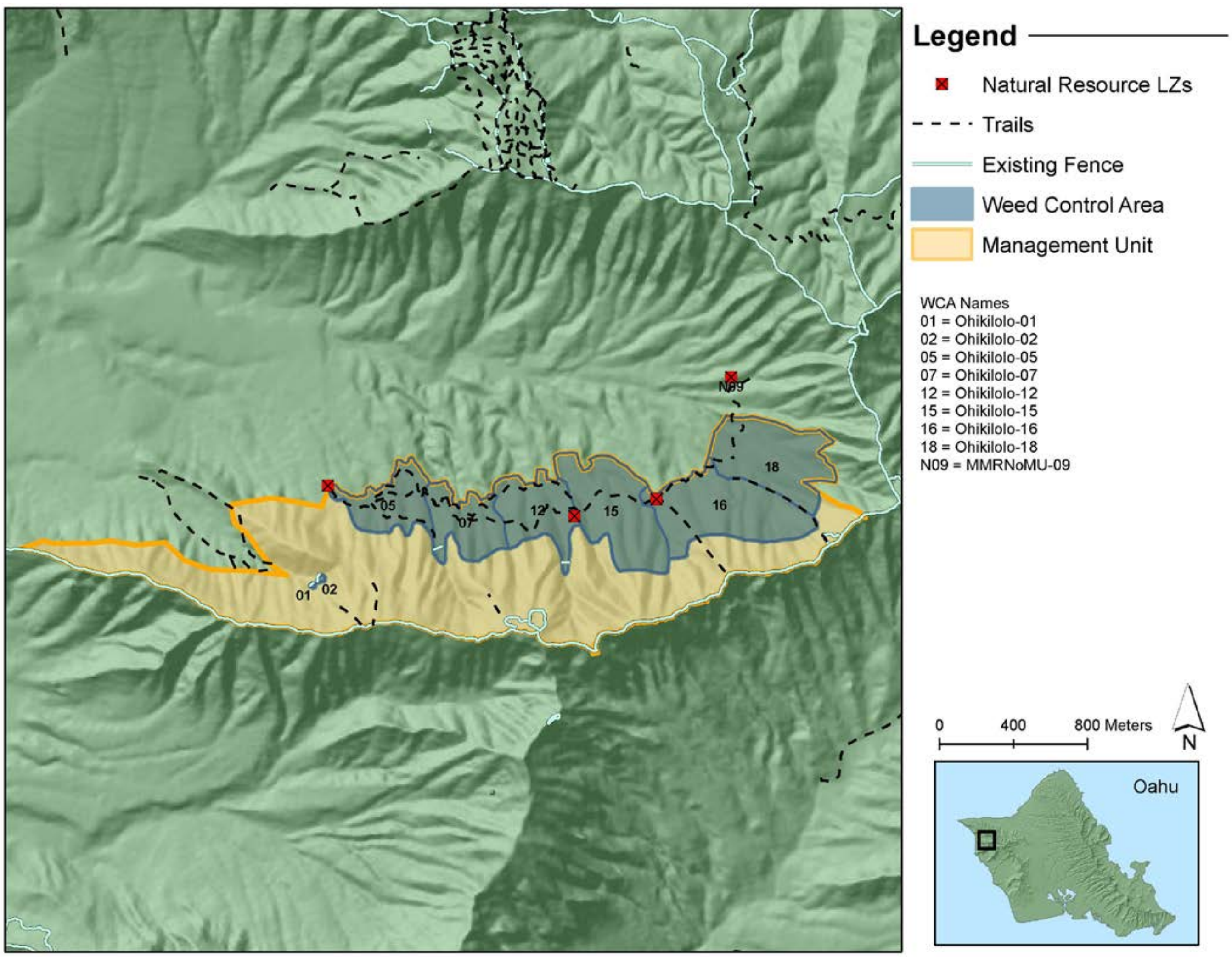
- Species and ICAs are listed in the table below. History and strategy is discussed for each species.
- Monitor the progress of management efforts, and adjust visitation rates to allow staff to treat plants before they mature. Remember that one never finds 100% of all plants present.

- Use aggressive control techniques where possible. These include power spraying, applying pre-emergent herbicides, clearcutting, aerial spraying, and frequent visits.

There is only one incipient species identified by OANRP in the MU, but due access challenges the ICA is not visited frequently. OANRP will continue to monitor and conduct incipient control when appropriate.

Taxon	ICA Code	Control Discussion
Sideroxylon persimile	MMR-Sidper-01	*S. persimile* is found in abundance just to the south of the Makua MU in lower stretches of Makaha valley. The ICA is located at Makua Well site, at bottom of NerAng gulch. One immature tree found in 2013. Tree was cut down at that time, but staff did not have herbicide. NRS have not been back to monitor due to Range entry restrictions around UXO stockpile.

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 except where alien removal 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:

- In lieu of any vegetation monitoring, goal is to focus efforts within 50m of rare taxa and through forest patches, and in these areas work towards reducing alien cover to 50% or below.
- No monitoring is in place for any of the MIP goals for this portion of the MU. Instead, gigapan photo points will be installed to detect novel alien canopy weeds, which will be a priority for control.
- If monitoring for any MIP goal is installed, and if results suggest goals are not being met, staff will increase/expand weeding efforts.

The Lower Makua dry forest is unique, with impressively tall native canopy and numerous *Ochrosia compta*. There are large groves of native-dominated dry forest, and qualitative observations of weeded areas suggest that these areas are recovering well. However, there is continued pressure at the forest edge from encroaching alien grasses.

WCAs are divided by a series of ridges and gulches and need to be GPSed to aid weed data tracking. The WCA numbers are not sequential as Ohikilolo (Makua) and Ohikilolo (Upper) together make up the Ohikilolo MU. WCAs are prioritized based upon rare resources and the status of each WCA based upon staff observations. WCAs closer to the campsite will be a higher priority for conducting large scale canopy sweeps. During the next five years NRS will be rotating between Ohikilolo-12, Ohikilolo-15, and Ohikilolo-16, focusing on one WCA per year. Large scale weed sweeps often include the use of chainsaws to girdle large trees before applying herbicide. Incision Point Application (IPA) will be used to on bigger trees during target canopy sweeps.

UXO is a major safety concern. If an area is deemed unacceptably dangerous, NRS will not conduct weed management in it. This is particularly true for specific types of UXO that can be obscured by dense grass, and areas where dense grass obscures the ground.

Summary of Target Taxa

Taxa	Distribution	Notes
Araucaria columnaris	Restricted	No *A. columnaris* is known from the Makua portion of the MU, but it is known from Ohikilolo (Upper). It has wind-dispersed seed, and immature trees have been found more than 300m from the now-dead source tree. If found in Makua, it should be controlled. No herbicide is required for control of immature; they can be pulled or simply cut down. Bigger trees can be controlled utilizing IPA methods.
Blechnum appendiculatum	Widespread	This invasive fern should be target in areas directly around rare taxa. It forms thick mats that may inhibit successful establishment of seedlings

Caesalpinia decapetala	Restricted	This thorny vine, once established, is horrendous to walk through and control. Any locations found should be GPSed, controlled, and possibly designated as ICAs.
Cenchrus setaceus	Restricited	Highly invasive, there is an infestation of this grass to the south on Ohikilolo ridge. This is a high priority for control everywhere on the Waianae coast. No plants are currently known from this MU, but staff will be vigilant in looking for new incursions of this taxon.
Coffea arabica	Widespread	While common in Koiahi gulch, *C. arabica* is not known from areas east of Koiahi ridge. It should be a priority for early detection and rapid control. Can be controlled utilizing IPA methods.
Fraxinus uhdei	Restricted	One large mature tree was known from Ohikikilolo (Upper), but none are currently known from Makua. If found, this is a high priority for control.
Grevillea robusta	Widespread	*G. robusta* has wind dispersed seeds, colonizes cliffs, and is alleleopathic. It should be controlled during WCA sweeps. Can be controlled utilizing IPA methods.
Heliocarpus popayensis	Restricted	Uncommon in the MU, *H. popayensis* was seen and controlled once in the past 10 years. Trees are large, soft-wooded, with wind-dispersed seed. It can form large stands. This is a high priority target. Can be controlled utilizing IPA methods.
Leucaena leucocephala	Widespread	Common in the MU, this is a target whenever seen near native forest patches. It is best controlled with Garlon 4 in a 40% mix or with IPA Milestone.
Melia azedarach	Widespread	This tree is widespread, but not very common. It is a target in WCAs.
Melinis minutiflora	Widespread	Grasses are a high priority target for control in WCAs, particularly (but not only) around native forest.
Montanoa hibiscifolia	Scattered	This shrubby tree grows quickly, thrives in dry, steep habitats, and produces wind-dispersed seed. It should be controlled wherever seen.
Morella faya	Restricted	One *M. faya* was controlled in Ohikilolo (Upper) years ago. If any plants are found, they should be controlled immediately and monitored as an ICA. Can be controlled utilizing IPA methods.
Psidium cattleianum	Widespread	By far the most common canopy weed, *P. cattleianum* is the primary target of WCA control. Trees in and near native forest patches are highest priority. Care should be taken not to open large stands of *P. cattleianum*, creating light gaps optimal for grasses. Can be controlled utilizing IPA methods.
Schinus terebinthifolius	Widespread	Widespread across the MU, *S. terebinthifolius* becomes the dominant vegetation as the ridges climb in elevation. Not a priority in the upper regions but will be controlled on target sweeps in lower elevations; not a priority. Can be controlled utilizing IPA methods.
Spathodea campanulata	Scattered	While this tree has a wide distribution, it is not common in the MU. It should be treated wherever seen. Can be controlled utilizing IPA methods.
Sphaeropteris cooperi	Restricited	Found only a few in nearby gulches. Zero tolerance for this species. Control shall be recorded in WCAs.
Syzygium cumini	Widespread	With its thick bark, *S. cumini* is difficult to control. Chainsaw girdling and Garlon application are most effective. IPA is not effective on this species. Need more trials to determine what herbicide works. This tree should be targeted around native forest patches.
Toona ciliata	Scattered	No large monoculture stands of *T. ciliata* are currently known from Makua. If left unchecked, this tree would likely behave as it has in Makaha and Kaluaa. It is a priority target and should be controlled whenever seen. IPA with Milestone and Polaris is effective.
Triumfetta semitrilobata	Widespread	This shrub should be controlled around rare taxa and along trails.
Urochloa maxima	Scattered	Formerly *Panicum maximum*. This grass has a very high burn index. Any patches in/near native forest patches are a high priority for control.

WCA: Ohikilolo-01 (Koiahi, South Nerang)

Veg Type: Dry forest

MIP Goal: Less than 25% non-native cover

Targets: *S. campanulata, T. ciliata, Ageratina adenophora, Buddleia asiatica, Melinis minutiflora*

Notes: This area is degraded with few native species remaining, and work is focused tightly around plants/base of cliff in hopes of fostering recruitment. *N. angulata* are present at the back of the gulch on cliffs. There are a few *N. humile* at the foot of the cliffs. Fence repairs are periodically needed due to large boulders washing down the gulch and cliffs above. Weeding should be prioritized around *Microlepia strigosa* as it fills in after weed removal and provides a dense understory. Invasive grasses and ferns can be controlled around native plants.

WCA: Ohikilolo-02 (Koiahi, North Nerang)

Veg Type: Dry forest

MIP Goal: Less than 25% non-native cover

Targets: *M. minutifolia, Blechnum appendiculatum, A. adenophora, Psidium cattleianum*

Notes: This area is degraded with few native species remaining, and work is focused tightly around *N. angulata* plants at the base of the cliff they occur to encourage favorable habitat for recruitment. There are a few *N. angulata* at the foot of the cliffs but the majority of the plants are located on the inaccessible cliffs. Fence repairs are periodically needed due to large boulders falling from cliffs above. Weeding should be prioritized around *Microlepia strigosa* as it fills in after weed removal and provides a dense understory. Invasive grasses can be hand pulled around native plants, but eliminating large patches of grass is difficult because water has to be hiked in for herbicide.

WCA: Ohikilolo-05 (Firebreak Road to Banana Gulch)

Veg Type: Dry forest

MIP Goal: Less than 25% non-native cover

Targets: *S. campanulata, Montanoa hibiscifolia, Melia azedarach, Syzygium cumini, P.cattleianum*

Notes: Currently this WCA is difficult to access due to the UXO stock pile near trailhead. Therefore, actions are not scheduled until issues are resolved. Two populations of *Bobea sandwichensis* are present in this gulch. Continued non-native canopy removal may help with the re-establishment of native seedlings. Grass control is needed on the western end of the WCA to minimize ingress into the native forest. *M. strigosa* was noted filling in the gaps after weed control. Spraying grass below *Dodonaea viscosa* at the top of ridges will perhaps aid native recruitment. Some gulches are fairly native-dominated in the understory and canopy, with *Diospyros sandwicensis* being the most common species. Large overstory of invasive trees like *Aleurites moluccana* and *Syzygium cumini* are encroaching into gulch areas and towards the base of cliffs. The ridges are largely unforested at the north end of the WCA, where the grass encroaches to the forest edge. At the edge of the grassy ridges there is a border of *P.cattleianum* that prevents grass from moving upslope of the gulch. Most weeding efforts are concentrated on the eastern part of the WCA, close to the border of WCA 7, due to the presence of native-dominated forest nearby.

WCA: Ohikilolo-07 (Nerang to Well Ridge)

Veg Type: Dry forest

MIP Goal: Less than 25% non-native cover

Targets: *B. appendiculatum, M. hibiscifolia, T. ciliata, S. terebinthifolius, A. adenophora*

Notes: The majority of weeding efforts in this WCA occur in an area known as "Banana gulch", where populations of *Melanthera tenuifolia, Nototrichium humile,* and *Neraudia angulata* are located. They are protected by a small strategic fence in the back of a slot gulch on the west end of the WCA. *N. angulata* was reintroduced but there was a low survival rate, therefore there are no scheduled actions to weed within this area for the next five years. Target sweeps will be focused in Ohikilolo-12 and Ohikilolo-15 due to their close proximity to camp. In the past, weeding efforts have been focused along the trails within this WCA. Continued non-native canopy removal may help native seedlings establish. Large overstory invasive trees like *Aleurites moluccana* and *Syzygium cumini* are encroaching on gulches and farther back into slot gulches towards the base of cliffs. The ridges are largely unforested at the north end of the WCA where the grass encroaches to the forest edge.

WCA: Ohikilolo-12 (Ron's Rock to Dividing Ridge)

Veg Type: Dry forest

MIP Goal: Less than 25% non-native cover

Targets: *P. cattleianum, G. robusta, S. campanulata, T. ciliata, S. cumini, S. terebinthifolius*

Notes: A small fence was built in the back of the main gulch of this WCA and *N. angulata* was reintroduced. Priority is to maintain the weeds around the *N. angulata* and clear the fence. Continued non-native canopy removal may help native seedlings re-establish in the gulches. Large overstory of invasive trees like *Aleurites moluccana* and *Syzygium cumini* are encroaching into gulches and farther back into slot gulches towards the base of cliffs. The ridges are largely unforested at the north end of the WCA where the short grasses encroach to the forest edge. At the edge of the grassy ridges, there is a border of *P. cattleianum* to slow its progress further into the slopes of the gulch. This WCA is somewhat unique, in that there are archeological sites as well as *Sideroxylon polynesicum*, a rare tree/shrub found in dry forest areas.

WCA: Ohikilolo-15 (Dividing Ridge to Campsite)

Veg Type: Dry forest

MIP Goal: Less than 25% non-native cover

Targets: *P. cattleianum, G. robusta, S. campanulata, T. ciliata, S. cumini, S. terebinthifolius*

Notes: This is one of the largest WCAs in Makua. Due its location, just a few ridges over and west of the Lower Makua Campsite DZ, accessibility allows for more frequent plant monitoring and weeding. This large area is home to several managed taxa including *F. neowawraea* (fenced), *A. macrococcus,* and *B. sandwicensis*. Additional native plants present in this area include *D. sandwichensis*, *P. odoratum*, *Sapindus oahuensis, Nestegis sandwicensis*, and the rare *Alphitonia ponderosa;* it is a high priority for WCA canopy sweeps. Continued non-native canopy removal may help native and endangered seedlings re-establish. Luckily there is not much grass under the very tall native and non-native canopy. Preventing grass on the ridge from entering the gulches is a priority, so leaving monotypic stands of *P. cattleianum* is necessary to form a barrier to grass ingress. There is an increasing population of *Toona ciliata* in the western most gulch and scattered throughout the WCA. Sweeps targeting *T. ciliata* will be conducted in order to prevent this species from establishing in gulches.

WCA: Ohikilolo-16 (Campsite to Arch site)

Veg Type: Dry forest

MIP Goal: Less than 25% non-native cover

Targets: *P. cattleianum, G. robusta, S. campanulata, T. ciliata, S. cumini, S. terebinthifolius*

Notes: Commonly referred to by staff as "The Nicest Patch Ever," this is WCA contains an abundance of common and rare natives, as well as endangered taxa including, Elepaio. Care must be taken to not impact trees that Elepaio nests and fledglings are found. Future efforts will focus on sweeps up towards steep cliffs, due to the close proximity of Campsites/LZs to weeding areas. Large, monotypic stands of *P. cattleianum* will be avoided, and weeding will focus on chainsaw girdling and herbicide application to *P. cattleianum* that is intermixed with natives. Although the highest concentrations of *Alectryon macrococcus* var. *macrococcus* reside here, there has been a steady decrease possibly due to rat predation, disease, and black twig borer (*Xylosandrus compactus*) damage. In the past, extensive weed control focused on this intact native forest due to the presence of native tree canopy. The WCA is responding well to weeding efforts, with increasing amounts of native understory plants. Continued follow-up weeding will prevent alien overstory species from establishing.

WCA: Ohikilolo-18 (CteSqu to FluNeo)

Veg Type: Dry forest

MIP Goal: Less than 25% non-native cover

Targets: *G. robusta, S. campanulata, T. ciliata, P. cattleianum, S. cumini, M. hibiscifolia*

Notes: This WCA contains Elepaio, as well as rare and endangered taxa such as, *A. macrococcus* var. *macrococcus*, *Pteralyxia macrocarpa*, *A. ponderosa*, and *Ctenitis squamigera*, but weed control here is a low priority. Continued non-native canopy removal may help native seedlings re-establish. There are several native patches within this area that are threatened by dense stands of *P. cattleianum.* One the most effective weed control efforts to combat this weed involves chainsaw girdling. Trials are still in place to test the efficacy of IPA methods on *P. cattleianum*. In doing so, it is important to prevent large light gaps that could allow invasive weeds to establish in the understory. The priority for this WCA is to concentrate weeding efforts in the flat area below *A. ponderosa.*

WCA: MMRNoMU-09 (Elepaio 15 LZ)

Veg Type: Dry forest

MIP Goal: None

Targets: *G. robusta, S. campanulata, T. ciliata*

Notes: This LZ was created to assist the monitoring of Elepaio in the gulches upslope. This small area is rarely used. It was cleared of weeds and overhanging vegetation in 2016 to ensure a safe and appropriate LZ and has been maintained as needed. If access to this part of the valley is needed in future, additional maintenance be performed.

Small Vertebrate Control

Species: *Rattus rattus*, *Mus musculus*

Threat level: Low

Seasonality/Relevant Species Biology: Year round.

Management Objectives:

- Monitor rare taxa populations of *N. angulata* for rat damage; promptly initiate control if damage is noted.

Strategy and Control Methods:

- Monitor *N. angulata* populations, as well as other native species to determine impacts by rodents.

Discussion: Currently no rodent control is conducted by OANRP at Lower Makua since rodents are not deemed a threat at this time. If rare plants are determined to be impacted adversely by rodents, OANRP will evaluate the use of localized rodent control for the protection of these species. Given the small size and dry habitat, a grid of A-24 traps might effectively reduce rat numbers to allow for even greater regeneration of fruiting canopy species like *Diospyros spp.* which already recruits more readily than other native canopy species.

Slug Control

Species: *Deroceras laeve*, *Limax maximus*

Threat level: Low

Seasonality/Relevant Species Biology: Tend to be more active in the wet season

Management Objectives:

- Note any feeding damage to *Neraudia angulata* and *Nototrichium humile* suspected to be caused by slugs.
- If damage is observed, determine slug abundance in the area and potentially initiate molluscicide application.

Slugs have not, to date, been observed feeding on *Neraudia angulata* and *Nototrichium humile*. Both taxa occur in habitat frequented by slugs making contact possible. Additionally, slugs are not abundant in dry forest. They are not a high threat to any rare taxa in this area.

Ant Control

Species: *Plagiolepis alludi*, *Anoplolepis gracilipes*

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

Management Objectives:

- Eradicate incipient ant invasions and control established populations when densities are high enough to threaten rare resources.
- Sample ants at human entry points a minimum of once a year. Use samples to track changes in existing ant densities and to alert NRS to any new introductions.

Strategy and Control Methods:

- If incipient species are found and deemed to be a high threat and/or easily eradicated locally (<0.5 acre infestation) begin control.
- Determine extent of *A. gracilipes* infestation, if small, eradicate locally using Safari 20 SG
- Ant populations will be kept to a determined acceptable level across the MU to maintain ecosystem health.

Ants have been documented to pose threats to a variety of resources, including native arthropods, plants (via farming of Hemipterian pests), and birds. The distribution and diversity of ant species across the lower Makua MU has not yet been sampled.

Black Twig Borer Control

Species: *Xylosandrus compactus*

Threat level: High

Seasonality/Relevant Species Biology: Peaks have been observed from October to January on Oahu

Management Objectives

- Reduce BTB populations to a level optimal for *Flueggea neowawraea* survival.
- Annual or every other year census monitoring of *Flueggea neowawraea* populations to determine BTB damage.

Strategy and Control Methods:

- During the last survey efforts there were no report of any live *Alectryon macrococcus* var. *micrococcus.* There are no effective control methods available. Heavy watering and fertilization of targeted plants has been successful at reducing BTB damage in agricultural settings, but is not practical here on the wild plants, and there are currently no reintroductions planned. NRS maintain contact with BTB research community and will investigate any new techniques that appear to be applicable to forestry settings.

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. Invasive grass has a high fire index, and surrounds the MU. There have been numerous fires in Makua valley, both from fires set by the military and by arsonists along Farrington Hwy.

Management Objective:

- To prevent fire from burning any portion of the MU at any time.

Strategy and Control Methods:

- 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 with native species.

Discussion: The Makua portion of the Ohikilolo MU is at high risk from fire. The Army has instituted several control measures to reduce the likelihood of fires starting in the valley during training exercises. These include regular maintenance of the firebreak road, limitation of training to within the firebreak road, and the establishment of a weather-based index to guide training activities. The index evaluates rainfall, temperature and wind conditions to produce a color-coded fire condition rating. Live fire-training may occur during 'green' conditions, but not during 'amber' or 'red' conditions. In addition, the Army maintains an Army Wildland Fire crew who are trained in fighting wildfires, and has two dip ponds on site. The Army has a grass cutting contract to maintain low fuels around select areas within the firebreak road, and has also conducted controlled burns to reduce fuel loads.

In 2010-2011, OANRP participated in fuels management work conducted by CALIBRE. This project, funded through the Garrison, looked at novel herbicide combinations, aerial spraying, and remote fuel breaks. Through this project, some remote fuel breaks were sprayed outside of the firebreak road, adjacent to several different MUs in MMR, including Ohikilolo (Makua). If CALIBRE obtains further funding, OANRP will continue to collaborate with them.

No live-fire training has occurred in the past ten years, but arson fires and out-of-prescription burns have threatened portions of the MU. Live-fire training appears unlikely to resume in the next five years.

OANRP will continue to focus on maintaining good communication with the interagency Wildland Fire Working Group to facilitate positive on-the-ground fire response throughout the Waianae range. OANRP will support fire fighting with helicopters and staff. In WCAs, grass patches no canopy weeding will be done on the edge of the grass/forest line to suppress grass incursion into forested areas.

In the future, staff will continue to consider whether any of the following fuel suppression options are feasible, productive, and cost-effective for the grassy slopes between the forest line and the firebreak road: aerial spraying of grass, fuel suppression via planting of trees that produce heavy shade (such as mango), and fuel suppression via planting of common natives (such as *Dodonea viscosa* or *Osteomeles anthyllidifolia*).

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 filled with hatch marks 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 Type	Actions	MIP Year 14 Oct 2017-Sept2018				MIP Year 15 Oct 2018-Sept2019				MIP Year 16 Oct 2019-Sept2020				MIP Year 17 Oct 2020-Sept2021				MIP Year 18 Oct 2021-Sept2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
General Survey	LZ-MMR-08: Survey Lower Makua campsite (08) 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
	LZ-MMR-69: Survey Upper Lower Makua LZ (69) 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
	LZ-MMR-75: Survey Lower Makua trailhead 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
	LZ-MMR-146: Survey Arch Camp LZ (#146) 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
	LZ-MMR-147: Elepaio 15 LZ (#147) 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
	LZ-MMR-188 Survey Luna Skeet LZ (#188) 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
	WT-Ohikilolo-01: Install weed transect along Koiahi access trail. GPS trail and mark route in field to ensure same trail can be walked in future years.			X																	
	WT-Ohikilolo-01: Survey Koiahi transect annually; transect begins at trailhead and ends at Neraudia fences.			X				X				X				X				X	

Action Type	Actions	MIP Year 14 Oct 2017-Sept2018				MIP Year 15 Oct 2018-Sept2019				MIP Year 16 Oct 2019-Sept2020				MIP Year 17 Oct 2020-Sept2021				MIP Year 18 Oct 2021-Sept2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
ICA	Monitor/control SidPer at Makua Well every 6 months/yearly. Survey entire ICA. Pick and remove from field any potentially mature fruit. On first visit, survey surrounding area widely to locate any additional plants.																				
Ohikilolo-01 (South Nerang)	Conduct understory and canopy weed control across WCA annually. Focus around Nerang and native species patches. Target understory weeds, Spacam, gradual control of canopy weeds.																				
	Control alien grasses across WCA, annually, or as needed.																				
Ohikilolo-02 (North Nerang)	Conduct understory and canopy weed control across WCA annually. Focus around Nerang and native species patches. Target understory weeds, Spacam, gradual control of canopy weeds.																				
	Control alien grasses across WCA, annually, or as needed.																				
***Ohikilolo-05 (Firebreak Road to Nerang Gulch)**	Control canopy weeds and selected understory weeds across WCA. Focus on native forest patches as first priority. Target TooCil, MonHib, Grerob, SzyCum, PsiCat, etc. Avoid creating large light gaps. Avoid killing thick Psicat/weed stands on edge of grass, as don't want to open more areas to grass. Sweep entire WCA once every 3-5 years. Always GPS weeding areas.																				

Action Type	Actions	MIP Year 14 Oct 2017-Sept2018				MIP Year 15 Oct 2018-Sept2019				MIP Year 16 Oct 2019-Sept2020				MIP Year 17 Oct 2020-Sept2021				MIP Year 18 Oct 2021-Sept2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
***Ohikilolo-07 (Nerang to Well Ridge)**	Control canopy weeds and selected understory weeds across WCA. Focus on native forest patches as first priority. Target TooCil, MonHib, Grerob, SzyCum, PsiCat, etc. Avoid creating large light gaps. Avoid killing thick Psicat/weed stands on edge of grass, as don't want to open more areas to grass. Sweep entire WCA once every 3-5 years. Always GPS weeding areas.																				
	Control all weeds within fenced Nerang zone every 6 months. Focus around Nerang/Nothum plants and potential reintro spots. Target Bleapp, Agerip, Chrsp, Monhib, Helpop, understory weeds. Remove canopy weeds gradually.																				
	Control weedy grasses within Nerang exclosure every 6 months, as needed. Exercise care when working around rare taxa.																				
Ohikilolo-12 (Ron's Rock to Dividing Ridge)	Control canopy weeds and selected understory weeds across WCA. Focus on native forest patches as first priority. Target TooCil, MonHib, Grerob, SzyCum, PsiCat, etc. Avoid creating large light gaps. Avoid killing thick Psicat/weed stands on edge of grass, as don't want to open more areas to grass. Sweep entire WCA once every 3-5 years. Always GPS weeding areas.																				
	Control weedy grasses within Nerang reintro/exclosure every 6 months, as needed. Exercise care when working around rare taxa.																				
	Prep reintro zone. Control all weeds within fenced Nerang reintro zone every 6 months. Focus around potential reintro spots. Target																				

Action Type	Actions	MIP Year 14 Oct 2017-Sept2018				MIP Year 15 Oct 2018-Sept2019				MIP Year 16 Oct 2019-Sept2020				MIP Year 17 Oct 2020-Sept2021				MIP Year 18 Oct 2021-Sept2022			
		4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
	Bleapp, Agespp., Chrsp, Monhib, Helpop, understory weeds. Remove canopy weeds gradually.																				
Ohikilolo-15 (Dividing Ridge to Campsite)	Control canopy weeds and selected understory weeds across WCA. Focus on native forest patches as first priority. Target TooCil, MonHib, Grerob, SzyCum, PsiCat, etc. Avoid creating large light gaps. Avoid killing thick Psicat/weed stands on edge of grass, as don't want to open more areas to grass. Sweep entire WCA once every 3-5 years. Always GPS weeding areas.																				
Ohikilolo-16 (Campsite to Arch site)	Control canopy weeds and selected understory weeds across WCA. Focus on native forest patches as first priority. Target TooCil, MonHib, Grerob, SzyCum, PsiCat, etc. Avoid creating large light gaps. Avoid killing thick Psicat/weed stands on edge of grass, as don't want to open more areas to grass. Sweep entire WCA once every 3-5 years. Always GPS weeding areas.																				
***Ohikilolo-18 (Ctesqu to Fluneo)**	Control canopy weeds and selected understory weeds across WCA. Focus on native forest patches as first priority. Target TooCil, MonHib, Grerob, SzyCum, PsiCat, etc. Avoid creating large light gaps. Avoid killing thick Psicat/weed stands on edge of grass, as don't want to open more areas to grass. Sweep entire WCA once every 3-5 years. Always GPS weeding areas.																				
MMRNoMU-09 (Elepaio 15 LZ)	Clear and maintain LZ as needed.																				
Ungulate Control	Conduct post-storm fence monitoring trips.																				
	Monitor Lower MakuaPU fences MMR-H and																				

Action Type	Actions	MIP Year 14 Oct 2017-Sept2018				MIP Year 15 Oct 2018-Sept2019				MIP Year 16 Oct 2019-Sept2020				MIP Year 17 Oct 2020-Sept2021				MIP Year 18 Oct 2021-Sept2022			
		4	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**
	G. Other small fences in PU are low priority.																				
Ant Control	Conduct survey for ants at lower Makua Landing Zone																				
	If any high risk species are present begin control																				
Slug Control	Monitor rare plants for signs of slug damage																				
	If slugs found to exceed acceptable levels during monitoring, maintain slug bait at sensitive plant population(s)																				
Fire Control	Maintain LZs																				

*Low priority, few rare taxa in area or partially closed by range control.

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, 2015—September 30, 2016

Devil weed (Chromolaena odorata) "hotspot" flagged off for later treatment

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 Oʻahu 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.

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 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.

All crew decontaminate at the end of each day and wear dedicated gear for devil weed operations to avoid spreading seeds to other worksites.

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, 2015—September 30, 2016.

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:

- OISC spent 1871 hours and conducted survey sweeps over 1,567 acres in the Kahuku Training Area.

- Treated a total of 706 mature and 5627 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.

OISC crewmember climbing one of the rock walls frequently encountered at KTA

One camp trip had to be cut short due to an intern that would not follow the instructions of OISC field leaders and had to be delivered back to OISC's baseyard. OANRP staff were informed of the incident by phone as soon as it happened. Other camp trips were postponed due to training exercises. Despite this, the crew was still able to sweep all the subunits they were assigned twice. OISC finished early and added the extra activity of treating hotspots OISC 022, 024 and 080.

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. However, the crew's observations indicate that the treated hotspots show little or no recruitment and that the partnership between OANRP and OISC is working to eradicate *C. odorata* from the Kahuku Training Area. The crew saw some recruitment in areas that had been treated, but they have described other hotspots as "crispy" and saw no plants in these locations. At some hotspots the herbicide appeared to have not penetrated the canopy and in some hotspots just a few plants survived on the outskirts of the treatment area. In these cases, the field crew pulled these plants. Unfortunately, some new hotspots were found this year in Kaunala Gulch.

An ongoing project of the OISC field crew has been to map guinea grass. These areas are difficult to survey because visibility is extremely low when moving through grass that is taller than the average person. OISC is also noting cliff areas that may be difficult to survey on foot but might be good candidates for gigapan imagery.

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. In addition staff did the following:

- Obtained permission from a private landowner adjacent to KTA that facilitated OANRP's access into hotspots OISC 022, 024 and 080.
- Organized meeting with environmental staff of Marine Corps Base Hawaiʿi, OANRP and OISC to coordinate treatment efforts and begin discussions to coordinate biocontrol research.
- OISC and OANRP met to ensure the Google Docs Hotspot Spreadsheet was communicating the information necessary to both organizations. Staff decided to keep OISC's monitoring notes for the past 4 visits so the history of 2 years (each hotspot is surveyed twice in one year). This ensures the information needed to evaluate whether a hotspot should be deactivated or not will be displayed. OISC will strive to merge adjacent hotspots together. OANRP may combine further if it makes treatment easier.
- OISC and OANRP met with the Hawaiian Electric Company (HECO) to discuss the transmission lines that run through the *C. odorata* survey area. HECO said that we did not need to seek permission from them to survey or treat along transmission lines. We provided brochures for their staff and discussed the necessity of washing boots, gear and trucks after working in areas infested with *C. odorata.*
- OISC is working with the state trails program, Na Ala Hele, to ensure that the contractors building a fence around the area used for motorcross will clean all their equipment once the project is finished to avoid spreading *C. odorata* to a new area.

Challenges:

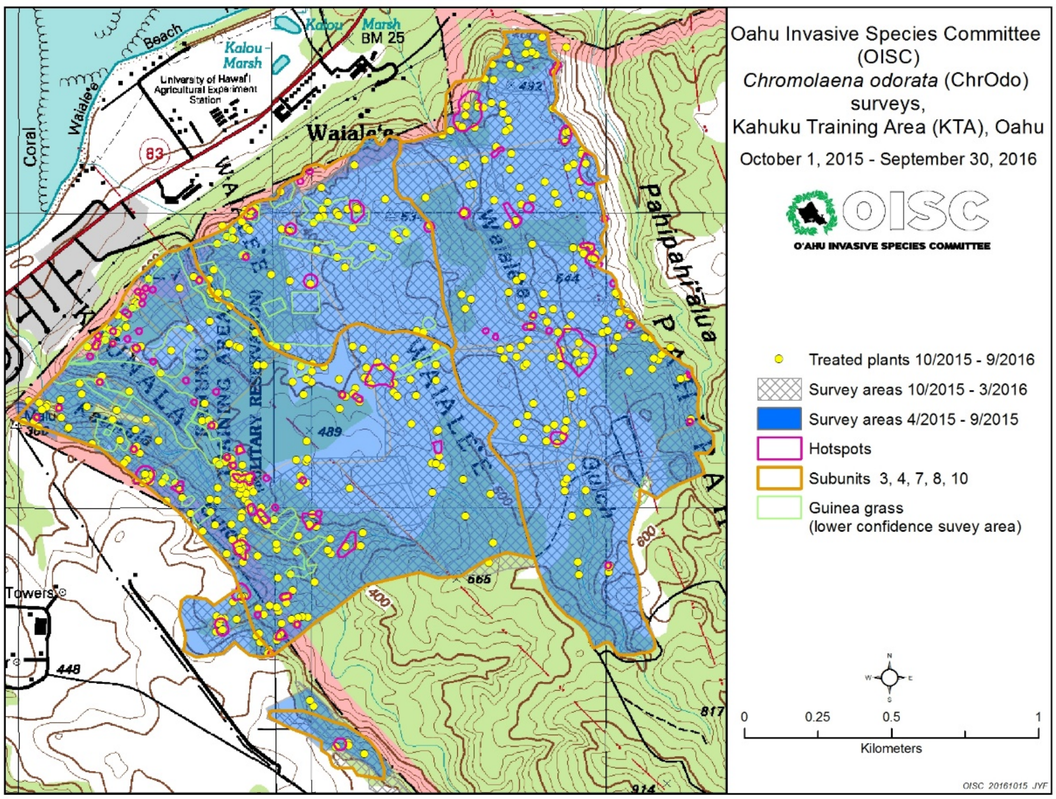
The dirt road into the survey area was extremely degraded and after a rainy spell, OISC's 4WD trucks got stuck. The road has since been re-graded making entry much easier. The crew saw many plants in Pahipahiʿālua gulch that were inaccessible by foot because of the steep terrain. A new hotspot was found in Kaunala Gulch that may be difficult to access to treat. Aerial sprays may be necessary here for both areas and individual outlier plants.

Motorcross activities continue to spread plants. While surveying, the crew saw plants along the motorcross trails used by the public on the weekends. The crew noted an area where earth had been mounded and disturbed, presumably to create a more exciting trail. A *C. odorata* was found in in the mound. Guinea grass is a continuing challenge. It is difficult to see when surveying through guinea grass and these areas are therefore labeled with a lower confidence level. At KTA, small ledges that present a safety hazard are hidden throughout guinea grass areas.

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	1519.99	705	5547	6252	
KTA Subunits 8	21.85	1	35	36	
KTA Subunits 10	25.36	0	45	45	
Total	**1567**	**706**	**5627**	**6333**	**1740**

Figure 1: OISC *Chromolaena odorata* Work Effort in Kahuku Training Area October 1, 2015 – September 30, 2016



***C. odorata* activites Supported with Other Funds:**

Public Education & Outreach:
The OISC manager talked to the Oʻahu Pig Hunters Association about *C. odorata* as well as *Miconia calvescens* and Rapid ʻŌhiaʻa Death. OISC also printed *C. odorata* pest alert rack cards to give out at events and presentations. OISC's outreach specialist provided educational materials at the Hawaiʻi Motorcross Association's (HMA) July 4th festival. The HMA uses KTA on weekends. Information about *C. odorata* is a prominent part of OISC's educational booth which is displayed at numerous events.

Surveys and Control for *C. odorata* outside of the Kahuku Training Area (KTA):
ʻ**Aiea:** OISC conducted a 697-acre aerial survey in ʻAiea and did not see any large patches. We do not expect to see small individual plants on an aerial survey. The survey was primarily for *Miconia calvescens,* which was also not seen. At Camp Smith, the crew treated several large *C. odorata* and conducted additional surveys and treatment. Marine Corps Base Hawaiʻi Environmental staff assisted with access onto Camp Smith and bought us the parts to resurrect our power sprayer, which made treating the large patches at Camp Smith much more efficient. The crew also treated a large hotspot along the ʻAiea Loop Trail. Delimiting and treatment in ongoing at Camp Smith and in ʻAiea.

Kahana: OISC met with the Ahupuaʻa ʻO Kahana park manager to discuss aerial treatment options. The field crew also conducted limited control work. OISC plans to aerially spray in Kahana in October of 2016.

Kaukonahua (Wahiawā): Portions of Schofield Barracks fall inside OISC's search area for *Miconia calvescens* and was up for survey for that species. Since the area is suitable habitat and used by the military there seemed to be a reasonable probability that *C. odorata* had been dispersed here so the crew surveyed for both species. None was found.


Treatment area along ʻAiea Loop Trail

Keamanea and ʻŌʻio (Haleʻiwa): The OISC crew usually surveys portions of these two watersheds for fireweed (*Senecio madagascariensis*) before the KTA camp trips. One mature and one immature were found in the portion of the wind farm that is located in Keamanea watershed.

Public Reports and Early Detection Surveys:
OISC conducted numerous early detection surveys outside KTA. OISC received a report from a motorsports enthusiast of *C. odorata* in Waiawa Valley, behind the prison. OISC was able to get

access from the prison to look at the area, but did not find any plants. There was a very similar looking species in the spot described. OISC also surveyed for devil weed while checking out a public report of *Miconia calvescens* along the Pupukea Loop Trail. Neither species was found. Because there is so much *C. odor* at Camp Smith, the crew conducted a presence/absence survey around Joint Base Pearl Harbor Hickam thinking it could be dispersed there by vehicles or landscapers. No *C. odorata* was found.

Table 2: OISC *Chromolaena odorata* Work Effort Summary on non-KTA lands. October 1, 2015–September 30, 2016:

Location	Aerial Acres Surveyed	Ground Acres Surveyed	Mature Plants Treated	Immature Plants Treated	Total Plants Treated	Effort (Hours)
ʻAiea	2094.986	1044.023	624	6671	7295	1650.50
Hālawa		200.875	0	0		12
Heʻeia		100.976	0	0		32
Kaʻelepulu		50.987	0	0		110
Kahana		11.591	1067	1897	2964	72
Kaukonahua (Wahiawā)		64.980	0	0	0	21
Keamanea		371.440	1	0	1	405
ʻŌiʻo (Haleʻiwa)		74.232	0	0	0	56
Paumalu (non-KTA)		369	13	16	29	333
Marine Corps Base Hawaiʻi.		63.213	0	0	0	16
Waiawa		2.473	0	0	0	4
Total	**2094.986**	**2353.790**	**1705**	**8584**	**10,289**	**2711.50**

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, Oʻahu, Hawaiʻi

Annual Progress Report
October 1, 2016—March 31, 2017

Clipping off the flowering heads of C. odorata to prevent further seed spread.

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 and is under some type of control program in several different countries including Australia and South Africa. It is widespread on Guam and other Pacific territories. The ability of this weed to form dense thickets and crowd out native plants means that it could be a disturbance weed. *C. odorata* is currently known from three locations on Oʻahu: the Kahuku Training Area, Kahana State Park and Camp H.M. Smith in Hālawa with Kahuku Training Area being the point of introduction.

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.

Surveying in steep parts of Kahuku Training Area

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 the other locations where *C. odorata* has been found.

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.

Project Accomplishments: October 1, 2016—March 31, 2017.

OISC conducted four multi-day trips to control *C. odorata* for a total of 884 fieldwork hours. During the worktrips the crew:

- Conducted survey sweeps over 641 acres.
- Marked hotspots with flagging or something equivalent for later aerial or ground treatment by OANRP staff.
- Treated a total of 220 mature and 1,996 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 due to low visibility.

Using the wash station at Kahuku Training Area

During the surveys, the crew observed that some of the mature plants they found were on the outer edges of the hotspots, validating that it is useful to do sweeps after hotspot aerial treatments. The field crew seems to be able to do the sweeps fairly quickly, but we will use the extra time to control the plants in the extremely steep sections of Kaunala gulch. As part of this effort, OANRP staff took GigaPan (extremely high-resolution panoramic photographs) images of a cliff that is too steep to survey in a traditional sweep line for OISC. The OISC crew may be able to reach some plants by hiking directly to the point. OISC staff reviewed the images and found points that could be reached directly. The crew will attempt this sometime in the next six months. The area reviewed by GigaPan equaled approximately 16 acres.

Data Management and 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. The GIS Specialist assisted staff with the review of the GigaPan photos. She also worked with OANRP staff to ensure the hotspot spreadsheet makes sense to both organizations.

Challenges:

During one survey operation, OANRP was also conducting aerial sprays, so the crew had to adjust the area they were surveying. Guinea grass over cliffs is a constant issue, during this reporting period, the crew observed some 40-foot cliffs hidden under guinea grass.

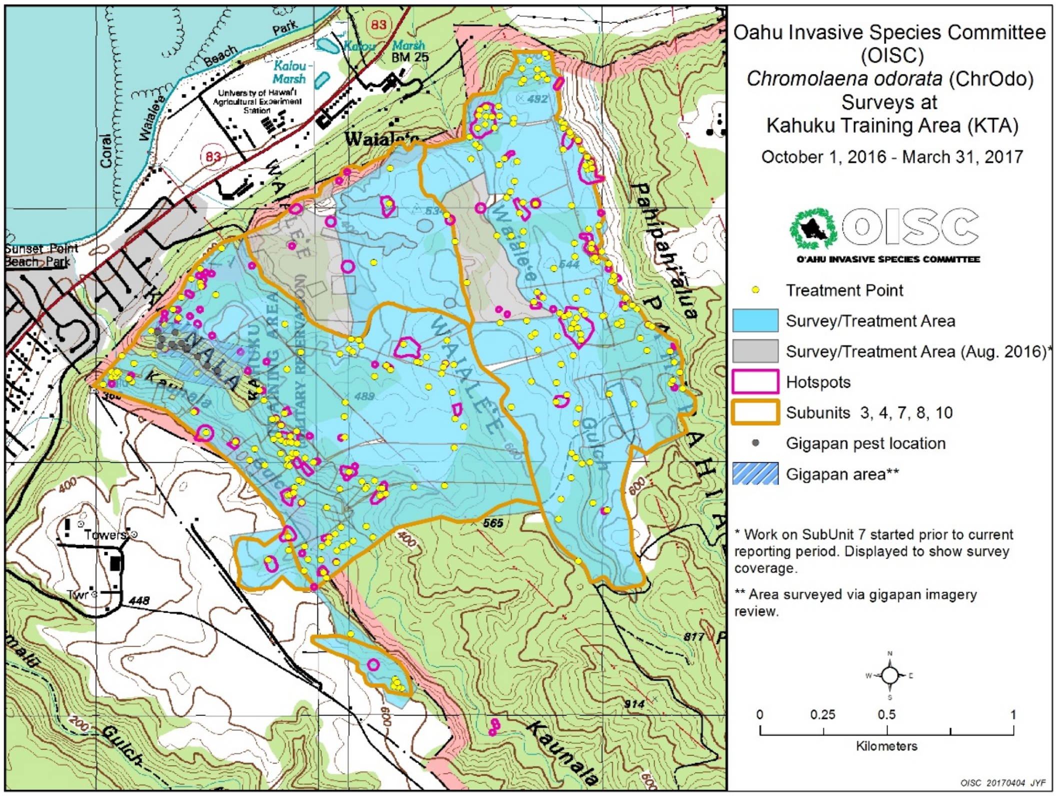
Table 1: OISC *Chromolaena odorata* Work Effort Summary at Kahuku Training Area October 1, 2016-March 31, 2017

Location	Acres Surveyed	Mature Plants Treated	Immature Plants Treated	Total Plants Treated	Effort (Hours)
KTA Subunits 3, 4, 7, 8, 10	641	220	1996	2,216	884*

This number is higher than the time summary spreadsheets; work on subunits 8 and 10 was not included in the time summary spreadsheets and a mistake in the amount of 2 hours was made in the amount of work done in October.

Top: Bagging flowers and seed heads to prevent seed spread.
Bottom: C. odorata seeds attached to flagging.

Figure 1: OISC *Chromolaena odorata* Work Effort in Kahuku Training Area
October 1, 2016 – March 31, 2017



***C. odorata* Activites Supported with Other Funds:**

Surveys and Control for *C. odorata* outside of the Kahuku Training Area (KTA)
OISC conducted 567 acres of ground surveys in ʿAiea, removing 657 immature and 70 mature plants. Unfortunately, much of the surveys need to be done on private property and acquiring access permission is time-consuming.

OANRP allowed OISC to use the sprayer they built to treat the *C. odorata* in Kahana Valley. OISC paid for the helicopter time. Although the operation was delayed several times due to weather, the spray finally happened in December and monitoring took place in February. The spray was efficient and effective. It only took a day to treat every hotspot and during a subsequent monitoring trip only a few plants were found on the edges of the spray area and in between patches.

OISC crew conducted road surveys in North Shore neighborhoods and the residential area around Camp Smith in Hālawa. OISC joined an interagency team on an annual fountain grass survey of the Bellows Air Force Station in Waimānalo and surveyed for *C. odorata* since one was found in the adjacent neighborhood of Lanikai by an off-duty OANRP employee.

Table 2: OISC *Chromolaena odorata* Work Effort Summary on non-KTA lands. October 1, 2016 – March 31, 2017:

Location	Ground Acres Surveyed	Mature Plants Treated	Immature Plants Treated	Total Plants Treated	Effort (Hours)
ʻAiea	567	70	657	727	602
Hālawa	42.87	0	0	0	12
Kahana Valley*	54.66	26	397	423	261.5
Kālunawaikaʻala (N. Shore Road Survey)	116.79	0	0	0	24
Keamanea	30.63	0	0	0	32
ʻŌiʻo (Haleʻiwa)	77.71	0	0	0	90
Non-KTA Paumalu	168	5	180	185	1101
Waiawa	32.48	0	0	0	24
Waimanālo (Bellows Survey)	1201	0	0	0	8
Total	**2291.14**	**101**	**1,284**	**1,335**	**2,154.5**

**These are the combined numbers from surveys before and after the aerial spray, counts were not taken during the aerial spray as the pilot was the only person in the helicopter.*

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.

OAHU ARMY NATURAL RESOURCES PROGRAM
MONITORING PROGRAM

VEGETATION MONITORING AT OHIKILOLO UPPER MANAGEMENT UNIT, 2016

INTRODUCTION

Vegetation monitoring was conducted at Ohikilolo Upper Management Unit (MU) in priority areas 1 and 2 in May and June of 2016 in association with Implementation Plan (IP) requirements for long term monitoring of vegetation composition and change over time (OANRP 2008) (Figure 1). Priority area 1 includes portions of the MU which receive the majority of management actions. The remainder of the MU, priority area 2, receives relatively less management. 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. Ohikilolo Upper MU vegetation monitoring occurs on a on a three-year interval for priority area 1, and on a six-year interval for priority area 2. Monitoring took place twice previously for priority area 1 (in 2010 and 2013), and once for priority area 2 (in 2010) (OANRP 2010 and 2013). Previous monitoring indicated that cover goals were met for only the non-native canopy. The Ohikilolo ridge line fence was completed, and ungulates removed, in 2001.

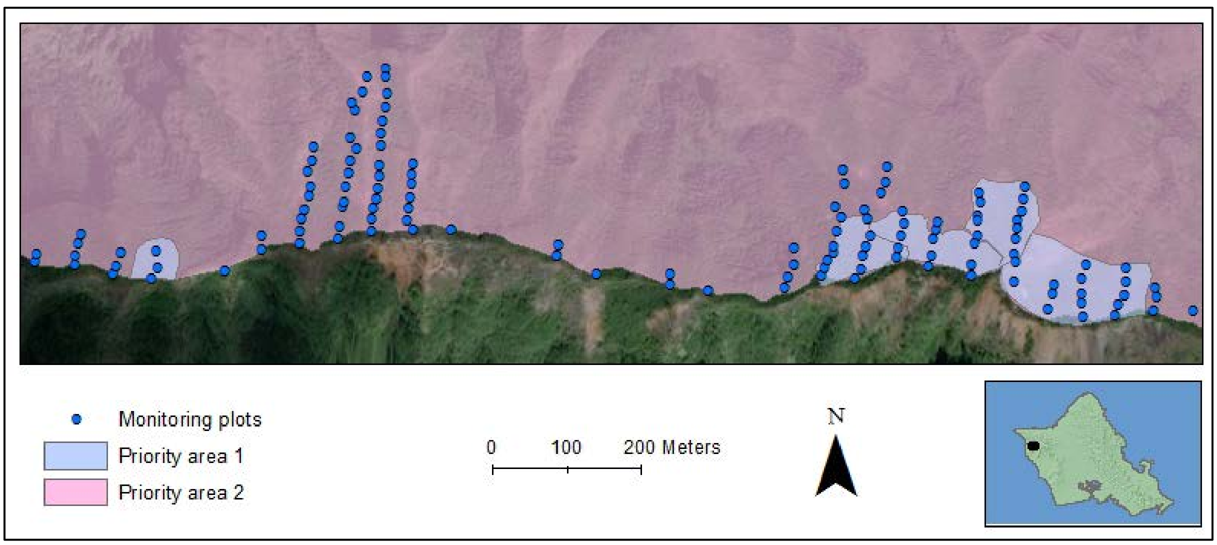


Figure 1. Ohikilolo Upper MU vegetation monitoring plot locations.

METHODS

In May and June of 2016, 133 plots (51 in priority area 1, and 82 in priority area 2) in 27 transects were monitored at Ohikilolo Upper MU. Plots measuring 5 x 10 m were generally located every 20 m along transects. Transects were located in accessible areas (as the majority of the MU is too steep to access), spaced approximately 50 m apart. 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 2016, but only documented once previously for priority area 1 in 2013. Monitoring results for both priority areas combined were compared with data from 2010. Monitoring results specifically for priority area 1 were compared with data from 2010 and 2013. Based on MIP 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 and Friedman's tests with Bonferroni adjusted post-hoc pairwise comparisons for cover data, paired t tests and repeated measures ANOVA for species richness data, and McNemar's tests for frequency data.

RESULTS

PRIORITY AREAS 1 AND 2

Understory and canopy cover categories

Management objectives of having < 50% non-native understory and canopy and > 50% native understory and canopy cover were met only for the non-native canopy in 2016, as cover remained low (15% median value)(Table 1). Native understory and canopy cover was low (35% and 7.5% median values, respectively), and non-native understory cover was moderately high (65% median value). There were several significant changes in percent cover of vegetation from previous monitoring results. However, only a subset of those met the 10% standard for recognized change in cover. These included ≥ 10% decreases in cover for native grass/sedges, total native understory, and non-native shrubs, as well as a 10% increase in total canopy (Figure 2). In 2016, locations of low to high native understory percent cover were patchily distributed across the MU, though cover was more consistently moderate to high in the upper elevations of priority area 1 (Figure 3). High native canopy cover occurred primarily in priority area 1, while cover in priority area 2 was almost always low. Non-native understory and canopy cover were typically low in priority area 1, and high in priority area 2. Locations where beneficial and worsening cover changes occurred were patchily distributed, particularly in priority area 1 (Figure 4). Beneficial changes occurred mostly in priority area 1, while priority area 2 generally had either no change or worsening conditions in the non-native understory and canopy as well as the native canopy.

Table 1. Percent cover of native and non-native vegetation categories in the canopy and understory at Ohikilolo MU in priority areas 1 and 2 from 2010 to 2016. Median values are represented (n = 133). 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 (Wilcoxon signed-rank test). Arrows indicate increase (↑) or decrease (↓) in cover.

	2010	2016	p	Z	Management objective currently met?
Understory					
Native shrubs	7.5	7.5	0.003 ↓	-2.92	
Native ferns	7.5	3	< 0.001 ↓	-4.624	
Native grass/sedges	15	3	**< 0.001** ↓	-5.633	
Total native understory	45	35	**< 0.001** ↓	-5.368	No, and getting worse
Non-native shrubs	25	15	**0.002** ↓	-3.143	
Non-native ferns	7.5	7.5	0.001 ↓	-3.444	
Non-native grass/sedges	15	7.5	0.884	-0.145	
Total non-native understory	65	65	0.115	-1.574	No
Bare ground	3	3	0.217	-1.235	
Canopy					
Native canopy	3	7.5	< 0.001 ↑	-4.087	No, but possibly getting better
Non-native canopy	15	15	0.217	-1.234	Yes
Total canopy	45	55	**< 0.001** ↑	-3.992	

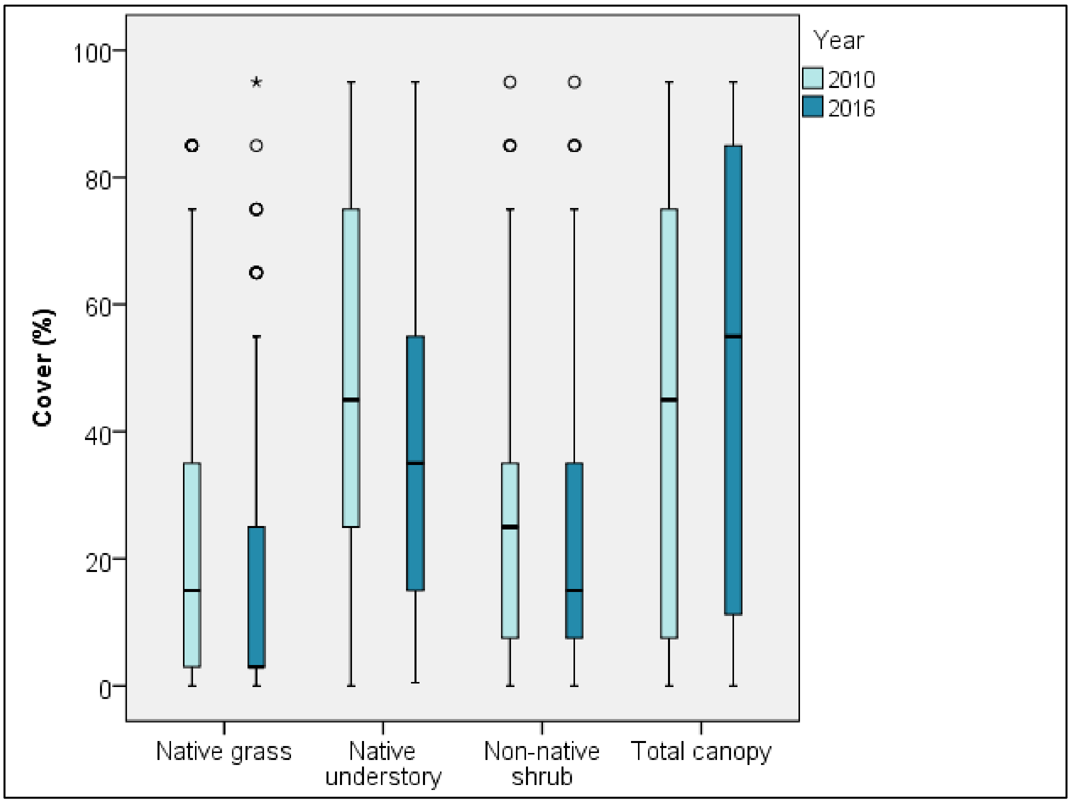


Figure 2. Boxplots for vegetation categories with significant change in percent cover that meet 10% standard for recognized change in cover between years 2010 and 2016 in Ohikilolo Upper MU, priority areas 1 and 2. [*Note: The boxes depict 50% of the data values, and the horizontal line inside the box 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.*]

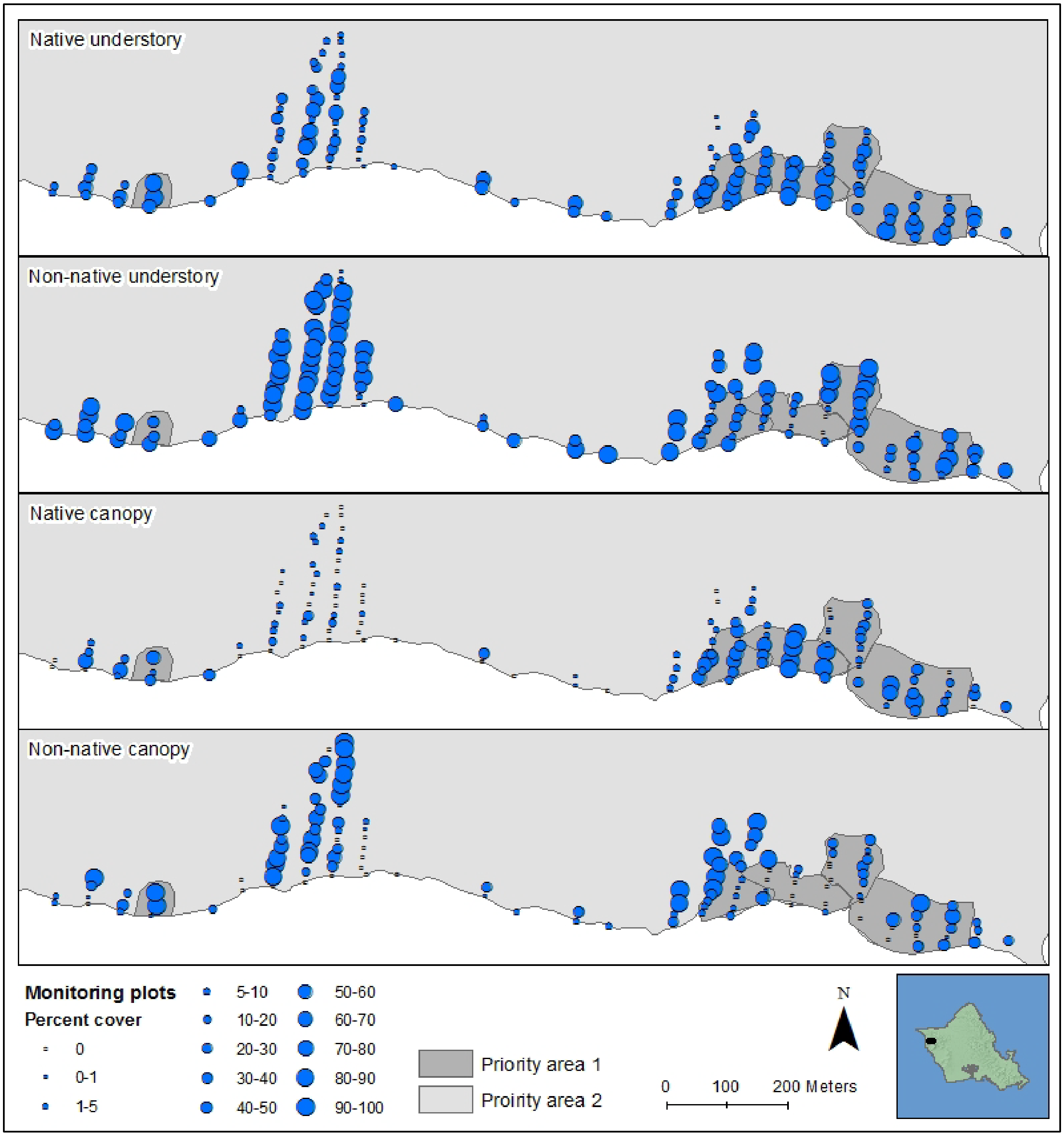


Figure 3. Locations of low to high percent cover of native and non-native understory and canopy vegetation among monitored plots at Ohikilolo Upper MU in priority areas 1 and 2 in 2016. Larger circles denote higher percent cover, while smaller circles represent lower cover.

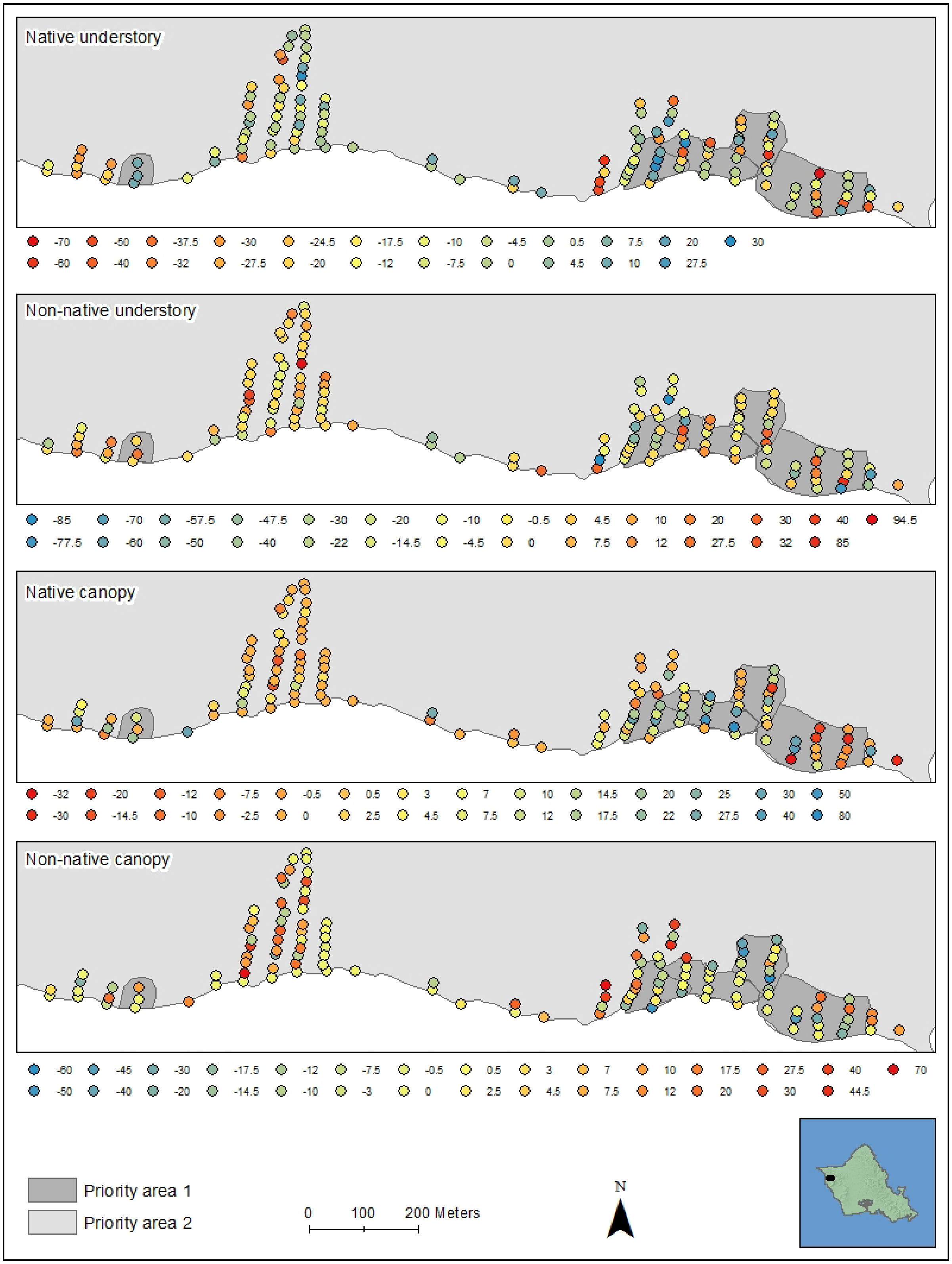


Figure 4. Locations of change in native and non-native percent cover for the understory and canopy vegetation in monitored plots in Ohikilolo Upper MU between 2010 and 2016. Color gradients are inverted for native and non-native vegetation, such that blue indicates beneficial change, red depicts worsening conditions. Cover change of 0 indicates there was no change in percent cover.

Species richness

During monitoring in 2016, 150 species were recorded in the understory (54% native taxa), and 39 were identified in the canopy (77% native). Most species present in the canopy were also represented in the understory, with the exception of one native species (*Bobea elatior*). Locations of high and low species richness for the native and non-native understory and canopy generally corresponded with priority area designations. Priority area 1 typically had higher native richness and lower non-native richness than priority area 2. (Figure 5). Species richness differed significantly between the years monitored, with small increases in native and non-native understory and canopy taxa within plots (Table 2). The significant increases in richness among plots was paired with increases in overall diversity for the MU, with the exception of native canopy, which had slightly less overall diversity for the MU in 2016. Twenty-four newly recorded species (63% non-native) were found in plots in 2016, while 19 species (58% native) were recorded in 2010 but not observed in 2016 (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 2016 were uncommon in 2010, with frequencies less than 4%. Most species newly recorded in 2016 had frequencies less than 5%, with the exception of *Clidemia hirta* (in 6% of plots), and *Cyperus brevifolius* (in 15.8% of plots), which was possibly identified in 2010 as *Cyperus mindorensis* (in 6% of plots in 2010, and in 1.5% of plots in 2016). Due to taxonomic uncertainties, those two species were lumped as *Cyperus* spp. in the current analysis.

Species frequency

Non-native species that occurred most frequently in plots (present in more than half the plots) in the understory included *Blechnum appendiculatum, Melinis minutiflora, Schinus terebinthifolius, Stachytarpheta australis, Ageratina adenophora,* and *Ageratina riparia,* while *S. terebinthifolius* occurred most commonly in the canopy (Table 4). The most frequent native understory species (in at least 40% of the plots) included *Carex meyenii*, *Dodonaea viscosa*, *Pteridium aquilinum, Metrosideros tremuloides, Metrosideros polymorpha* and *Myrsine lessertiana*. *Metrosideros tremuloides*, *M. polymorpha,* and *D. viscosa* were the most commonly occurring native taxa in the canopy (in at least a quarter of the plots). Three out of the nine MIP/OIP rare taxa at Ohikilolo Upper MU were recorded in plots during monitoring of priority areas 1 and 2 in 2016, including *Dubautia herbstobatae*, *Kadua parvula,* and *Pritchardia kaalae.* Three out of seven additional non-MIP/OIP rare taxa known from the MU (*Chrysodracon forbesii*, *Melicope makahae,* and *Platydesma cornuta* var. *decurrens*) were also recorded. Analysis of frequency change (McNemar's test) was limited to taxa with at least ten percent change between 2010 and 2016. These included five non-native taxa in the understory (*A. riparia, Conyza bonariensis, Cyperus spp.*, *Rubus rosifolius* and *Youngia japonica*), one native species in the understory (*Lepisorus thunbergianus*), and one native species in the canopy (*D. viscosa*), all of which had significant increases in frequency, with the exception of *A. riparia,* which decreased on frequency (Table 5).

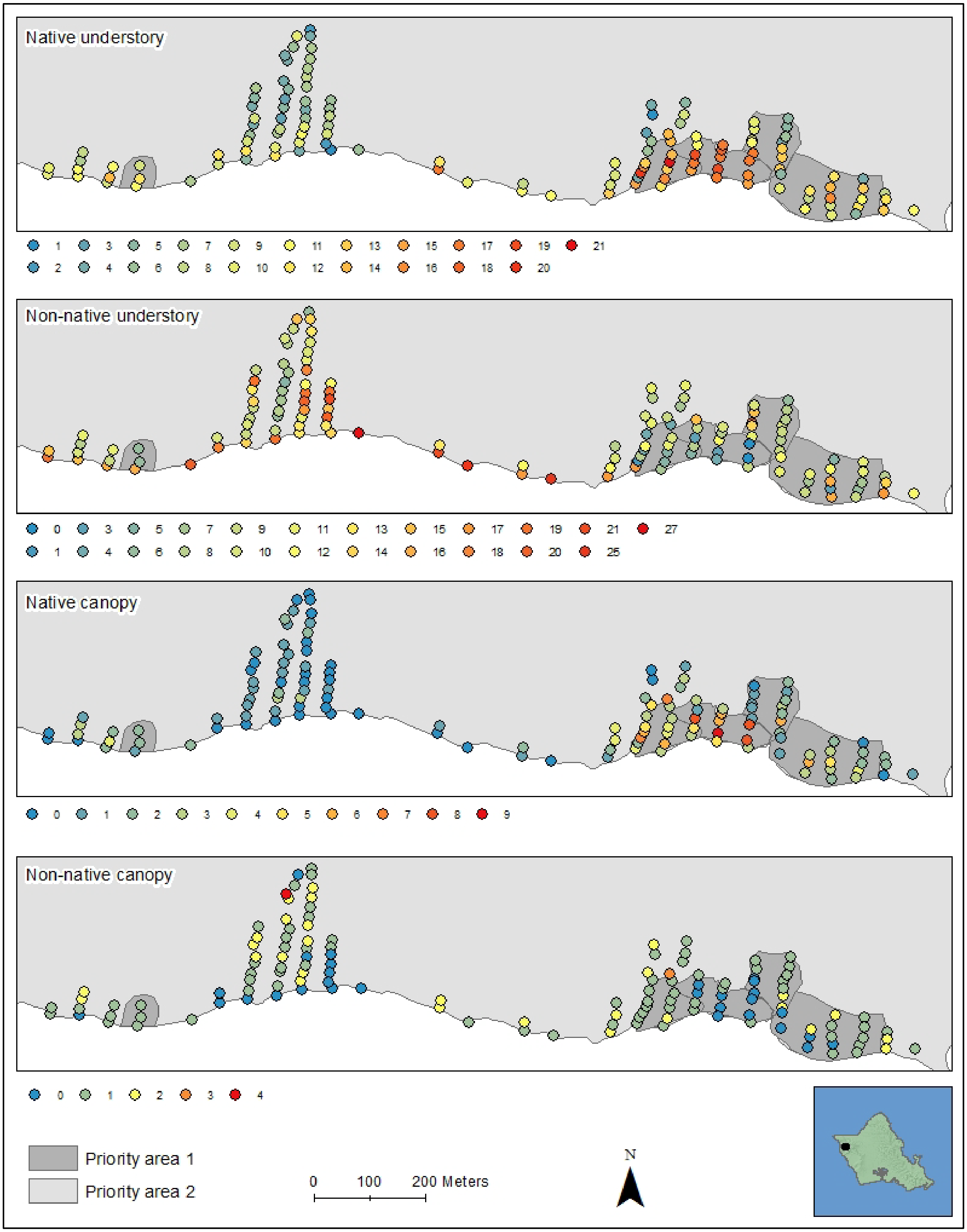


Figure 5. Locations of low to high species richness among plots in the native and non-native understory and canopy in Ohikilolo Upper MU in priority areas 1 and 2, 2016. Color gradients of blue to red indicate low to high values, respectively, of the number of species occurring in plots (i.e., blue indicates low diversity, while red indicates relatively higher diversity).

Table 2. Ohikilolo Upper MU understory and canopy species richness from 2010 to 2016 in priority areas 1 and 2. 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 = 133). P-values obtained from paired t tests. Statistically significant values are in boldface. Arrows indicate increase (↑) or decrease (↓) in richness.

	2010	2016	p	t
Native understory	9.23 (79)	9.60 (80)	**0.045** ↑	2.021
Non-native understory	10.41 (62)	11.10 (69)	**0.007** ↑	2.735
Native canopy	1.59 (31)	2.05 (30)	< **0.001** ↑	4.731
Non-native canopy	0.91 (5)	1.03 (9)	**0.009** ↑	2.654

Table 3. Newly recorded, and no longer present, species from 2016 Ohikilolo Upper MU monitoring in priority areas 1 and 2, in the understory and/or canopy. Native taxa are in boldface.

New species recorded in 2016	Freq. 2016	Species found in plots in 2010 but not recorded in 2016	Freq. 2010
Arundina gramminifolia	0.8	***Adenophorus tenellus***	3.8
Bidens alba	0.8	*Cerastium fontanum*	1.5
Boehmeria grandis	0.8	*Cordyline fruticosa*	0.8
Castilleja arvensis	4.5	***Elaphoglossum alatum***	0.8
Clidemia hirta	6.0	***Elaphoglossum sp.***	0.8
Cyperus brevifolius	15.8	***Euphorbia multiformis***	0.8
Desmodium sandwicense	0.8	***Myrsine lanaiensis***	0.8
Ehrharta stipoides	0.8	***Perrottetia sandwicensis***	0.8
Epidendrum x obrienianum	1.5	*Pluchea carolinensis*	0.8
Erechtites valerianifolia	0.8	***Psydrax odorata***	0.8
Euphorbia celastroides* var. *amplectens	0.8	***Pteris irregularis***	0.8
Kadua parvula	0.8	*Rhynchospora sp.*	0.8
Melicope kaalaensis	0.8	***Sadleria pallida***	1.5
Neraudia melastomifolia	0.8	*Salvia occidentalis*	0.8
Opuntia cochenillifera	0.8	*Santalum album*	0.8
Phaius tankervilleae	0.8	***Smilax melastomifolia***	0.8
Phyllanthus distichus	0.8	*Syzygium cumini*	0.8
Polystachya concreta	1.5	*Trianthema portulacastrum*	0.8
Pteris cretica	1.5	***Zanthoxylum dipetalum* var. *dipetalum***	0.8
Sadleria cyatheoides	2.3		
Santalum ellipticum	0.8		
Sida rhombifolia	0.8		
Spathodea campanulata	0.8		
Stapelia gigantea	0.8		

Table 4. Species frequency among plots (percent of plots in which a given species occurs) during 2016 monitoring in priority areas 1 and 2 (n= 133), in order of most to least frequent. Native species are in bold print. *Rare taxa. **Ohikilolo Ecosystem Restoration Management Unit Plan (ERMUP) target weed taxa.

Taxon	Freq.	Taxon	Freq.
Understory			
*Blechnum appendiculatum***	90.2	***Elaeocarpus bifidus***	10.5
Carex meyenii	88.0	*Emilia sonchifolia*	10.5
Melinis minutiflora	82.0	***Luzula hawaiiensis***	10.5
Schinus terebinthifolius	79.7	***Doryopteris decipiens***	9.8
Stachytarpheta australis	78.2	*Linum trigynum*	9.8
Ageratina adenophora	74.4	***Osteomeles anthyllidifolia***	9.8
Ageratina riparia	65.4	***Pritchardia kaalae****	9.8
Dodonaea viscosa	60.2	***Psychotria mariniana***	9.8
Pteridium aquilinum	50.4	***Viola chamissoniana* subsp. *tracheliifolia***	9.8
Metrosideros tremuloides	48.9	***Antidesma platyphyllum***	9.0
Metrosideros polymorpha	47.4	*Chamaecrista nictitans*	9.0
Kalanchoe pinnata	43.6	***Dryopteris fusco-atra***	9.0
Myrsine lessertiana	42.1	***Dryopteris glabra***	9.0
Cocculus orbiculatus	39.1	*Pityrogramma austroamericana*	9.0
Conyza bonariensis	39.1	***Elaphoglossum paleaceum***	8.3
Doodia kunthiana	36.8	***Psychotria hathewayi***	8.3
Lythrum maritimum	36.8	*Paspalum conjugatum*	7.5
Erigeron karvinskianus	34.6	*Adiantum hispidulum*	6.8
Sphenomeris chinensis	33.8	*Clidemia hirta*	6.0
Setaria parviflora	30.8	***Kadua acuminata***	6.0
Andropogon virginicus	30.1	***Athyrium microphyllum***	5.3
Centaurium erythraea	29.3	***Lysimachia hillebrandii***	5.3
Coprosma foliosa	29.3	*Psidium cattleianum*	5.3
Youngia japonica	29.3	*Triumfetta semitriloba*	5.3
Carex wahuensis	28.6	***Acacia koa***	4.5
*Grevillea robusta***	28.6	*Ageratum conyzoides*	4.5
Lantana camara	27.1	*Castilleja arvensis*	4.5
Alyxia stellata	25.6	***Deparia prolifera***	4.5
Rubus rosifolius	25.6	*Emilia fosbergii*	4.5
Bidens torta	23.3	***Kadua affinis***	4.5
Gamochaeta purpurea	23.3	***Melicope oahuensis***	4.5
Lepisorus thunbergianus	23.3	*Verbena litoralis*	4.5
Selaginella arbuscula	23.3	*Cuphea carthagenesis*	3.8
Dryopteris sandwicensis	22.6	***Dianella sandwicensis***	3.8
Oxalis corniculata	21.8	***Gahnia beecheyi***	3.8
Eragrostis grandis	20.3	***Paspalum scrobiculatum***	3.8
Wikstroemia oahuensis* var. *oahuensis	19.5	***Pipturis albidus***	3.8
Lachnagrostis filiformis	18.0	*Psidium guajava*	3.8
Melinis repens	18.0	***Diospyros sandwicensis***	3.0
Nephrolepis exaltata* subsp. *hawaiiensis	18.0	*Oplismenus hirtellus*	3.0
Freycinetia arborea	17.3	*Toona ciliata*	3.0
Microlepia strigosa	17.3	*Adiantum radianum*	2.3
Festuca bromoides	16.5	*Bidens pilosa*	2.3
Cheilanthes viridis	15.8	*Buddleja asiatica*	2.3
Cyclosorus parasiticus	15.8	*Cyclosorus dentatus*	2.3
Cyperus brevifolius	15.8	***Cyrtandra waianaeensis***	2.3
Lysimachia arvensis	12.8	***Dicranopteris linearis***	2.3
Psilotum nudum	12.0	***Nestegis sandwicensis***	2.3
Cibotium chamissoi	11.3	*Passiflora suberosa***	2.3
Sporobolus indicus	11.3	***Sadleria cyatheoides***	2.3

Table 4, continued

Taxon	Freq.	Taxon	Freq.
Understory, cont.			
Sonchus oleraceus	2.3	*Ehrharta stipoides***	0.8
*Araucaria columnaris***	1.5	*Erechtites valerianifolia*	0.8
*Axonopus fissifolius***	1.5	***Euphorbia celastroides* var. *amplectens***	0.8
Chrysodracon forbesii*	1.5	*Indigofera spicata*	0.8
Cyclosorus cyatheoides	1.5	***Kadua parvula****	0.8
Cyperus mindorensis	1.5	*Leucaena leucocephala*	0.8
Epidendrum x obrienianum	1.5	***Melicope kaalaensis***	0.8
Korthalsella complanata	1.5	*Mesosphaerum pectinatum*	0.8
Melicope makahae*	1.5	***Neraudia melastomifolia***	0.8
Planchonella sandwicensis	1.5	*Opuntia cochenillifera*	0.8
Platydesma cornuta* var. *decurrens*	1.5	***Panicum nephelophilum***	0.8
Plectranthus parviflorus	1.5	***Peperomia membranacea***	0.8
Polypodium pellucidum* var. *pellucidum	1.5	*Phaius tankervilleae*	0.8
Polystachya concreta	1.5	*Phlebodium aureum*	0.8
Pteris cretica	1.5	***Phyllanthus distichus***	0.8
Salvia coccinea	1.5	***Santalum ellipticum***	0.8
Scaevola gaudichaudiana	1.5	*Sida rhombifolia*	0.8
Artemisia australis	0.8	*Spathodea campanulata*	0.8
Arundina gramminifolia	0.8	*Stapelia gigantea*	0.8
Asplenium caudatum	0.8	***Syzygium sandwicense***	0.8
Bidens alba	0.8	***Tectaria gaudichaudii***	0.8
Boehmeria grandis	0.8	***Vaccinium reticulatum***	0.8
Ctenitis latifrons	0.8	***Waltheria indica***	0.8
Desmodium sandwicense	0.8	***Xylosma hawaiiense***	0.8
Dubautia herbstobatae*	0.8		
Canopy			
Schinus terebinthifolius	72.2	***Kadua affinis***	1.5
Metrosideros tremuloides	37.6	*Lantana camara*	1.5
Metrosideros polymorpha	33.1	***Melicope oahuensis***	1.5
Dodonaea viscosa	24.1	***Planchonella sandwicensis***	1.5
*Grevillea robusta***	22.6	*Psidium cattleianum*	1.5
Freycinetia arborea	12.8	***Sadleria cyatheoides***	1.5
Myrsine lessertiana	12.0	***Syzygium sandwicense***	1.5
Alyxia stellata	9.8	***Bobea elatior***	0.8
Cibotium chamissoi	8.3	***Boehmeria grandis***	0.8
Coprosma foliosa	8.3	***Cyrtandra waianaeensis***	0.8
Elaeocarpus bifidus	8.3	***Korthalsella complanata***	0.8
Acacia koa	7.5	***Pipturis albidus***	0.8
Lepisorus thunbergianus	7.5	*Rubus rosifolius*	0.8
Psychotria hathewayi	6.0	***Santalum ellipticum***	0.8
Psychotria mariniana	4.5	***Scaevola gaudichaudiana***	0.8
Antidesma platyphyllum	3.8	*Stachytarpheta australis*	0.8
Nestegis sandwicensis	3.0	*Toona ciliata*	0.8
Diospyros sandwicensis	2.3	*Triumfetta semitriloba*	0.8
Melinis minutiflora	2.3	***Wikstroemia oahuensis* var. *oahuensis***	0.8
Pritchardia kaalae*	2.3		

Table 5. Species frequency change at Ohikilolo MU priority areas 1 and 2 between 2010 and 2016. Only taxa with at least 10% change in frequency were analyzed. Frequency values represent the proportion of plots in which species are present (n = 133). Native species are in boldface. P-values obtained from McNemar's test. Arrows indicate increase (↑) or decrease (↓) in frequency.

Species	Frequency 2010	Frequency 2016	% change	p
Understory				
Ageratina riparia	75.9	65.4	-10.5	**0.022[a]**↓
Conyza bonariensis	25.6	39.1	13.5	**0.001[a]**↑
*Cyperus spp.**	6.0	17.3	11.3	**0.001[b]**↑
Lepisorus thunbergianus	7.5	23.3	15.8	**<0.001[a]**↑
Rubus rosifolius	12.8	25.6	12.8	**<0.001[b]**↑
Youngia japonica	10.5	29.3	18.8	**<0.001[a]**↑
Canopy				
Dodonaea viscosa	11.3	24.1	12.8	**<0.001[b]**↑

**Cyperus brevifolia* and/or *C. mindorensis*
[a]Asymptotic significance
[b]Exact significance

Species cover

Species with frequencies > 0.20 (present in at least 27 plots) in 2010 and/or 2016 were subjected to analysis of cover change (Wilcoxon signed-rank test). Significant increases in percent cover occurred for two native understory taxa (*L. thunbergianus* and *Selaginella arbuscula*), four non-native understory species (*C. bonariensis, Erigeron karvinskianus, R. rosifolius,* and *Y. japonica*), two native canopy taxa (*D. viscosa* and *M. tremuloides*), and one non-native canopy species (*Grevillea robusta*) (Table 6 and Figure 6). Decreases in percent cover occurred for six native understory species (*C. meyenii, Carex wahuensis, D. viscosa, M. polymorpha, P. aquilinum,* and *Sphenomeris chinensis)*, and six non-native understory species (*A. riparia, B. appendiculatum, Festuca bromoides, Lantana camara, S. terebinthifolius,* and *Setaria parviflora*) (Figure 7). The median change in percent cover was 0.0% for all species (as most taxa were absent from more than half of the plots during both years, most plots maintained 0% cover, or cover otherwise remained unchanged) with the exception of *C. meyenii* (median change of -2.5%). Cover changes noted above were generally small, with the exception of the increased cover for *E. karvinskianus*, *R. rosifolius*, and *M. tremuloides*, and the decreased cover for *A. riparia*, *B. appendiculatum*, *C. meyenii*, *P. aquilinum*, *S. terebinthifolius,* and *S. chinensis*.

Canopy replacement

Most canopy tree species were found recruiting in the understory (Table 7). *Dodonaea viscosa*, *M. lessertiana*, *M. polymorpha* and *M. tremuloides* were the most commonly recruiting native tree species, while non-native recruiting tree species were primarily *S. terebinthifolius*. Native trees with no recruitment in the understory were also relatively infrequent in the canopy (with frequencies < 9%), including *Bobea elatior*, *Diospyros sandwicensis*, *Elaeocarpus bifidus*, *Nestegis sandwicensis*, *Planchonella sandwicensis*, and *Santalum ellipticum*. 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 6. Percent cover change of native and non-native species in the canopy and understory at Ohikilolo Upper MU from 2010 to 2016 in priority areas 1 and 2. Only species with frequencies greater than 0.20 (present in at least 27 plots) in 2016 or 2010 were analyzed. Native taxa and statistically significant values are in boldface (Wilcoxon signed-rank test, n = 133). Arrows indicate increase (↑) or decrease (↓) in cover.

Species	Median cover change (%)	p	Z
Understory			
Ageratina adenophora	0.0	0.094	-1.674
Ageratina riparia	0.0	**< 0.001↓**	-6.324
Alyxia stellata	0.0	0.634	-0.476
Andropogon virginicus	0.0	0.109	-1.602
Bidens torta	0.0	0.348	-0.939
Blechnum appendiculatum	0.0	**0.001↓**	-3.319
Carex meyenii	-2.5	**< 0.001↓**	-5.476
Carex wahuensis	0.0	**0.039↓**	-2.059
Centaurium erythraea	0.0	0.834	-0.210
Cocculus orbiculatus	0.0	0.083	-1.732
Conyza bonariensis	0.0	**0.001↑**	-3.402
Coprosma foliosa	0.0	0.668	-0.428
Dodonaea viscosa	0.0	**0.013↓**	-2.490
Doodia kunthiana	0.0	0.090	-1.697
Dryopteris sandwicensis	0.0	0.629	-0.483
Eragrostis grandis	0.0	0.233	-1.193
Erigeron karvinskianus	0.0	**0.036↑**	-2.100
Festuca bromoides	0.0	**0.050↓**	-1.962
Gamochaeta purpurea	0.0	0.297	-1.043
Grevillea robusta	0.0	0.329	-0.976
Kalanchoe pinnata	0.0	0.600	-0.524
Lantana camara	0.0	**0.045↓**	-2.002
Lepisorus thunbergianus	0.0	**< 0.001↑**	-3.900
Lythrum maritimum	0.0	0.954	-0.058
Melinis minutiflora	0.0	0.146	-1.456
Melinis repens	0.0	0.113	-1.586
Metrosideros polymorpha	0.0	**0.037↓**	-2.080
Metrosideros tremuloides	0.0	0.328	-0.977
Microlepia strigosa	0.0	0.146	-1.453
Myrsine lessertiana	0.0	0.877	-0.550
Oxalis corniculata	0.0	0.127	-1.528
Pteridium aquilinum	0.0	**< 0.001↓**	-4.437
Rubus rosifolius	0.0	**< 0.001↑**	-4.716
Schinus terebinthifolius	0.0	**< 0.001↓**	-4.420
Selaginella arbuscula	0.0	**0.035↑**	-2.113
Setaria parviflora	0.0	**< 0.001↓**	-4.064
Sphenomeris chinensis	0.0	**0.001↓**	-3.447
Stachytarpheta australis	0.0	0.057↑	-1.906
Youngia japonica	0.0	**< 0.001↑**	-4.849
Canopy			
Dodonaea viscosa	0.0	**< 0.001↑**	-4.108
Grevillea robusta	0.0	**0.015↑**	-2.422
Metrosideros polymorpha	0.0	0.587	-0.544
Metrosideros tremuloides	0.0	**0.022↑**	-2.294
Schinus terebinthifolius	0.0	0.169	-1.374

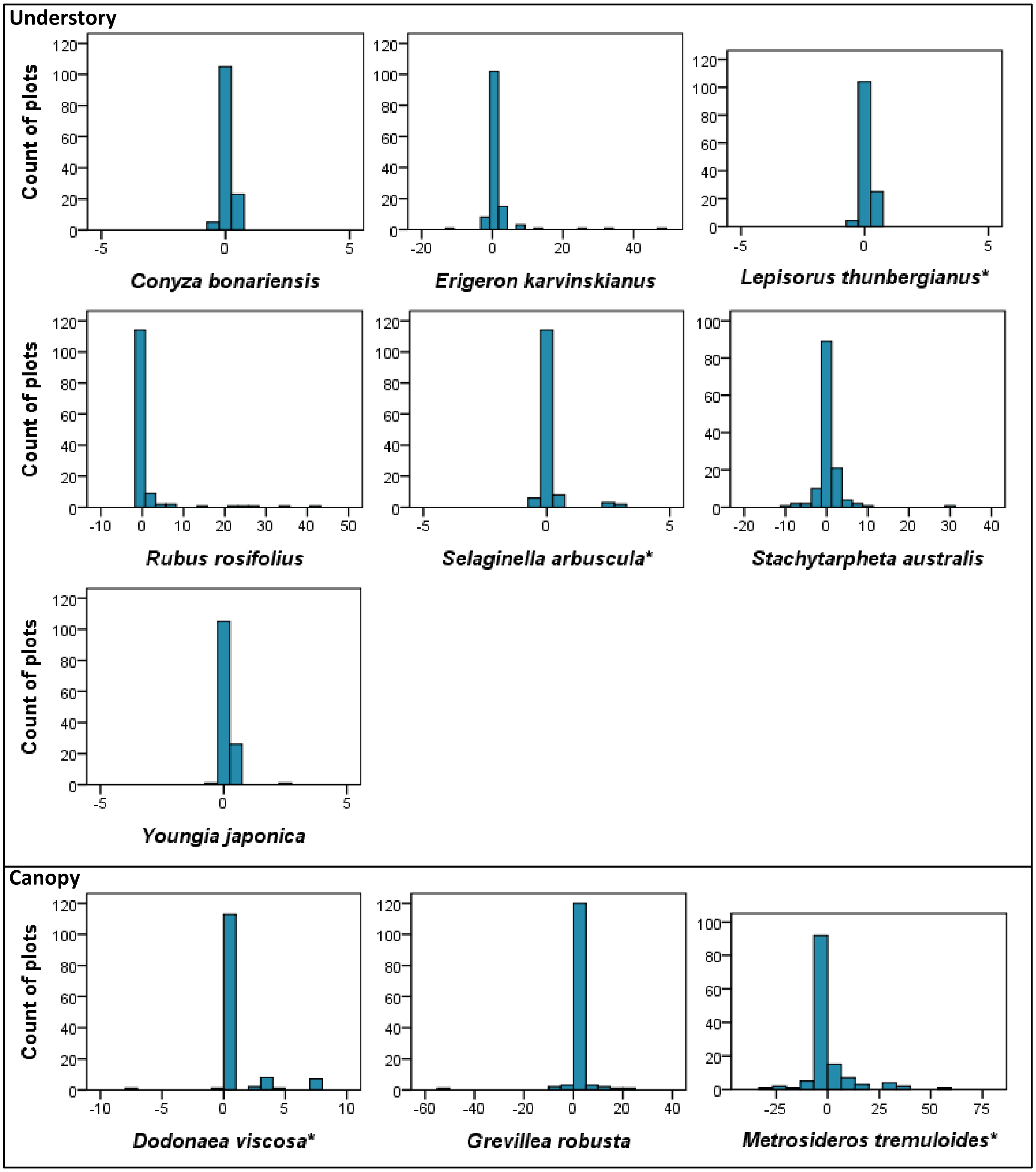


Figure 6. Histograms of percent cover change between 2010 and 2016 at Ohikilolo Upper MU in priority areas 1 and 2, for taxa with significant increases in cover in the understory and canopy. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change. *Native taxa.

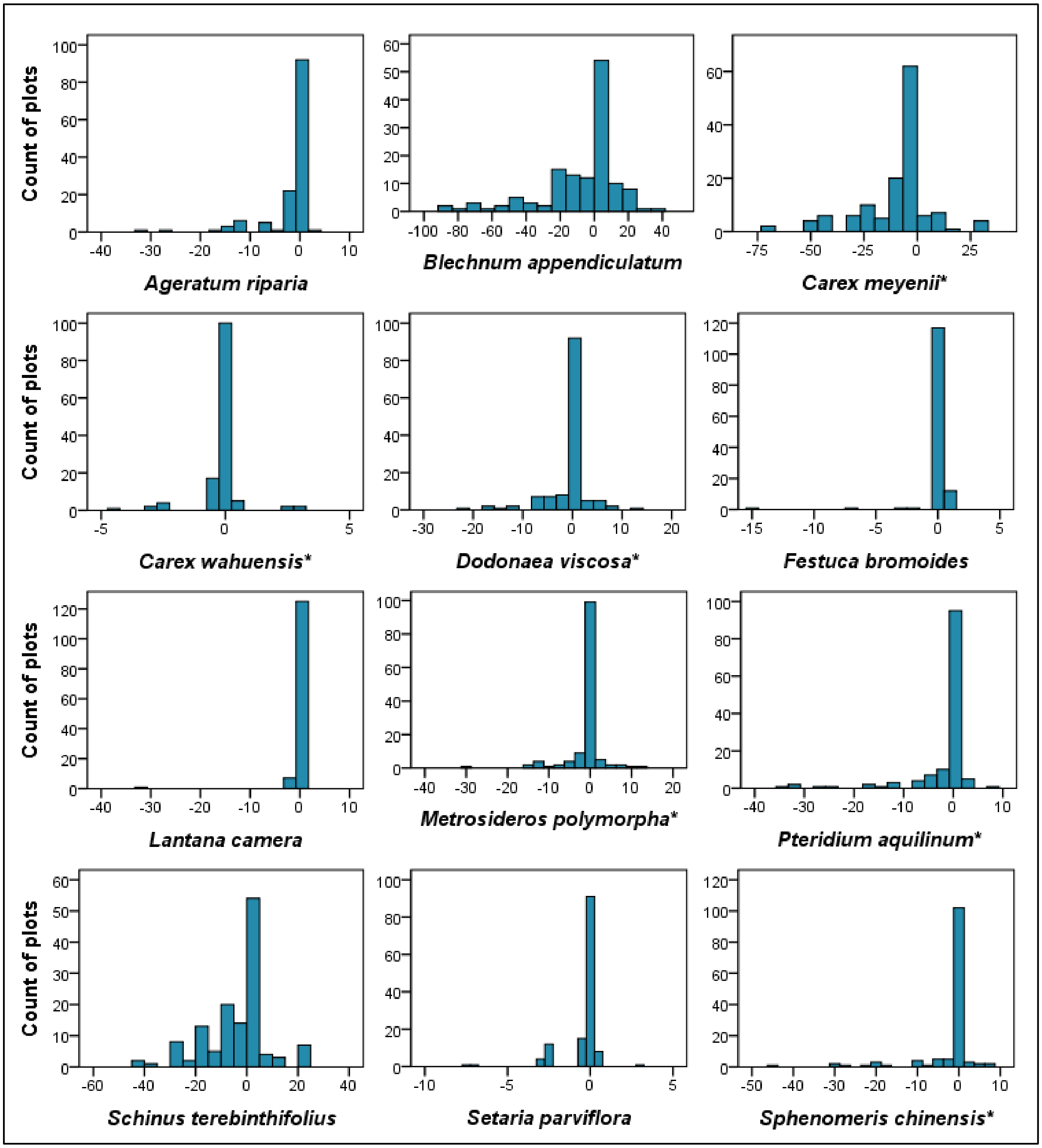


Figure 7. Histograms of percent cover change between 2010 and 2016 at Ohikilolo Upper MU in priority areas 1 and 2, for taxa with significant decreases in cover in the understory. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change. *Native taxa.

Table 7. Summary of canopy tree species recruitment in the understory during 2016 Ohikilolo Upper MU monitoring in priority areas 1 and 2, in order of most to least frequent. Frequency represents the percent occurrence of tree species with a maximum height < 2 meters (seedlings to small trees) among plots (n = 133). Native species are in boldface. *Rare taxa. **ERMUP target weed taxa.

Species	Frequency	Species	Frequency
Dodonaea viscosa	47.4	***Coprosma foliosa***	2.3
Schinus terebinthifolius	46.6	***Kadua affinis***	2.3
Myrsine lessertiana	36.1	***Pipturis albidus***	2.3
Metrosideros polymorpha	30.8	*Toona ciliata*	2.3
Metrosideros tremuloides	28.6	***Acacia koa***	1.5
*Grevillea robusta***	15.0	***Melicope oahuensis***	1.5
Wikstroemia oahuensis	10.5	*Psidium cattleianum*	1.5
Pritchardia kaalae*	7.5	***Freycinetia arborea***	0.8
Psychotria mariniana	6.0	*Leucaena leucocephala*	0.8
Antidesma platyphyllum	4.5	***Melicope makahae****	0.8
Psidium guajava	3.8	***Syzygium sandwicense***	0.8
Psychotria hathewayi	3.0		

Weed control

Weed control efforts at Ohikilolo Upper MU in priority areas 1 and 2 between the 2010 and 2016 monitoring intervals included approximately 796 person hours. The total amount of effort varied among the ten weed control areas (WCA) that encompass the MU, ranging from 0 to 373.7 hours per WCA. At least a small amount of weeding occurred at all but one WCA during that time interval. Between the 2010 and 2016 monitoring intervals, 30% of the MU WCA total area was weeded (Figure 8). Weed control efforts crossed through 37% of the plots between the 2010 and 2016 monitoring intervals, primarily in priority area 1. Only 5% of the priority 2 plots were weeded, while 88% of the plots in priority area 1 were weeded.

Six out of the 11 target weed species (taxa of special concern for weed management, including incipient species) as designated in the Ohikilolo Upper Ecosystem Restoration Management Unit Plan (ERMUP) for Ohikilolo Upper MU (OANRP 2016) were identified during monitoring, and at least one target taxa was present in 93% of the monitored plots in either the understory or canopy. These included two widespread target taxa (*Blechnum appendiculatum* and *Grevillea robusta*), and four less common target species (*Araucaria columnaris, Axonopus fissifolius, Ehrharta stipoides*, and *Passiflora suberosa*) (Figure 9). Of these, only *B. appendiculatum* had a high frequency, occurring in 90% of the plots.

In order to discern the impacts of weeding efforts, vegetation percent cover was further scrutinized to examine change in weeded (n = 49) vs. unweeded (n = 84) plots for the native and non-native understory and canopy. There was a significant decline in native understory cover both in weeded and unweeded plots (Table 8 and Figure 10). No significant change occurred in non-native understory cover in either weeded or unweeded plots. Significant canopy changes that met the 10% standard for recognized absolute cover change included an increase in native cover and decrease in non-native cover only in weeded plots.

Caution should be applied in interpreting the results of vegetation monitoring in association with weed control due to error associated with GIS data for both vegetation plots and weeded areas. Accuracy for vegetation plot locations was often poor, at times requiring hand plotting. Weeded areas were sometimes hand plotted, with estimations of size and location that may be inexact to varying degrees.

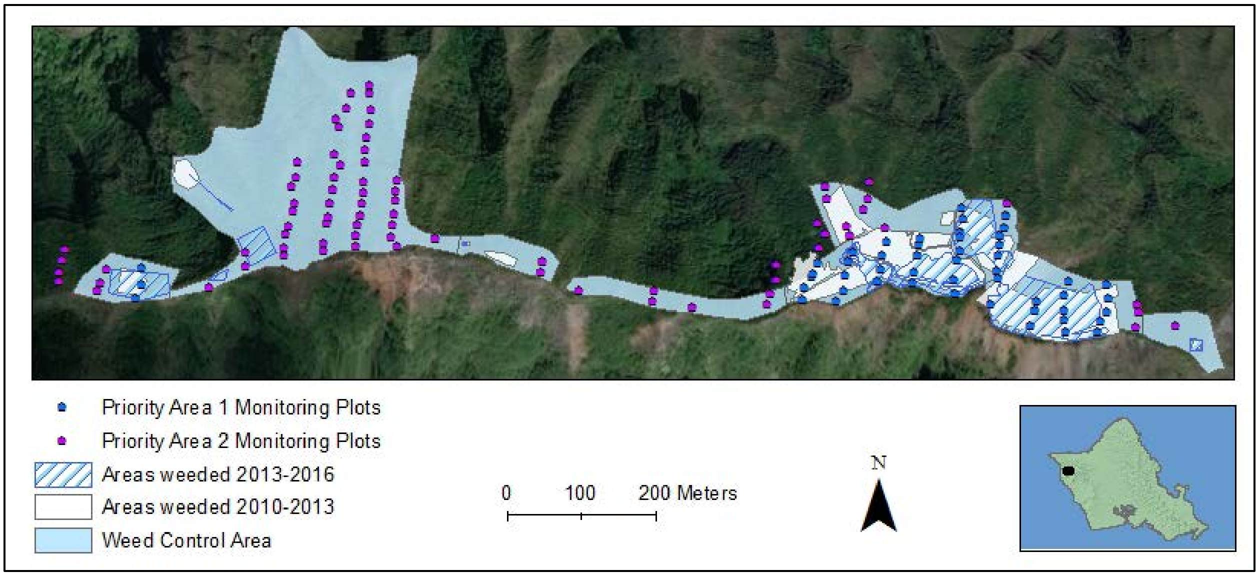


Figure 8. Locations of vegetation monitoring plots at Ohikilolo Upper MU in relation to weed control areas (WCA) and areas weeded between the 2010 to 2013 and 2013 to 2016 monitoring intervals, with plots color-coded by priority area.

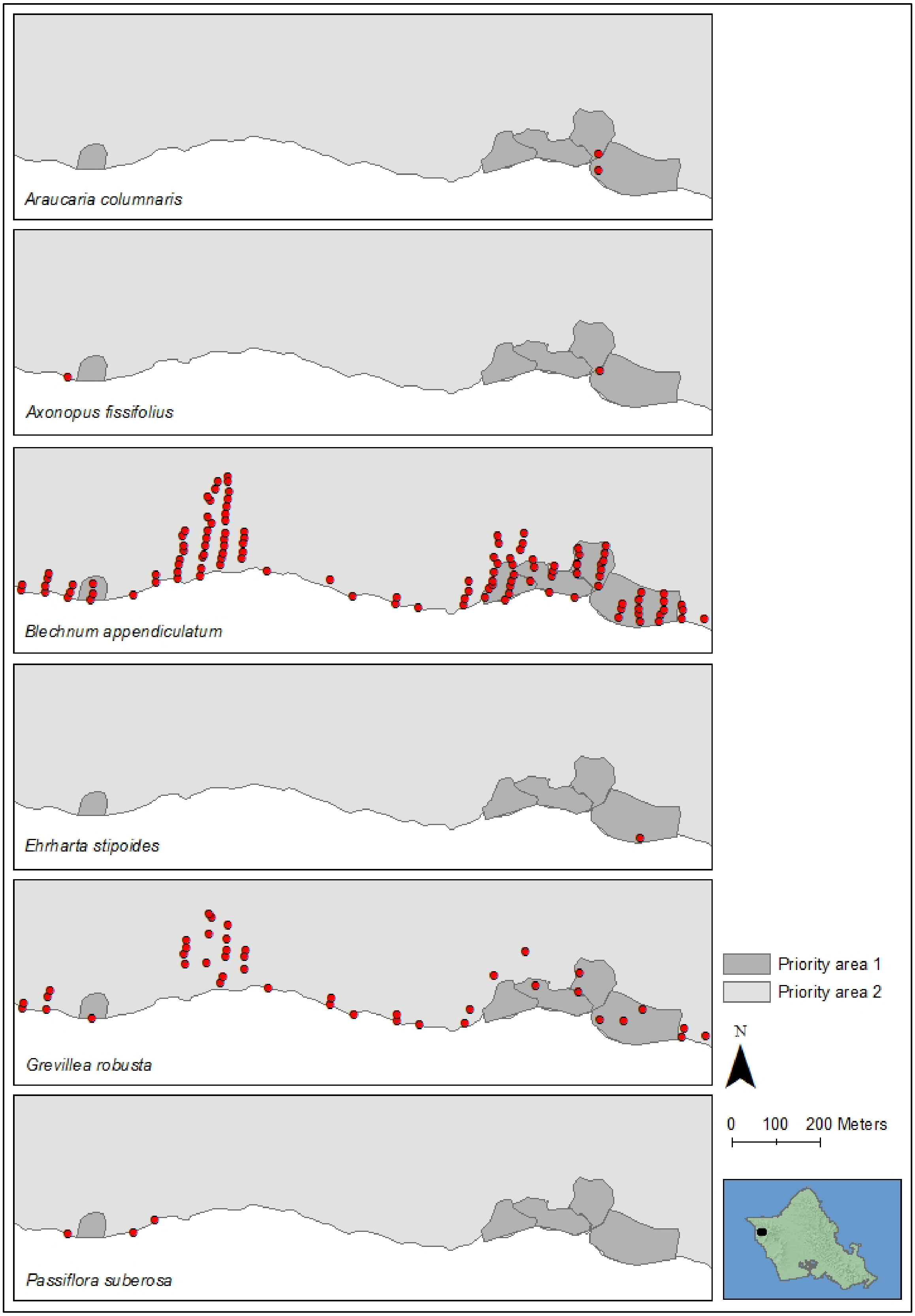


Figure 9. Locations of ERMUP target taxa in the understory and/or canopy among plots in Ohikilolo Upper MU in priority areas 1 and 2 in 2016.

Table 8. Percent cover change in weeded (n = 49) and unweeded (n = 84) plots at Ohikilolo Lower in priority areas 1 and 2 from 2010 to 2016. Median values for percent cover in 2010 and 2016 are represented. Statistically significant values that meet the 10% standard for recognized change are in boldface (Wilcoxon signed-rank test). Arrows indicate increase (↑) or decrease (↓) in cover.

	Weeded plots				Unweeded plots			
	2010	2016	p	Z	2010	2016	p	Z
Native understory	65.0	45.0	**0.009**↓	-2.611	35	15	< **0.001**↓	-4.736
Non-native understory	35.0	35.0	0.260	-1.126	85	85	0.273	-1.097
Native canopy	25.0	35.0	**0.001**↑	-3.445	0.25	3	0.029↑	-2.181
Non-native canopy	15.0	3.0	**0.027**↓	-2.205	20	25	0.003	-2.929

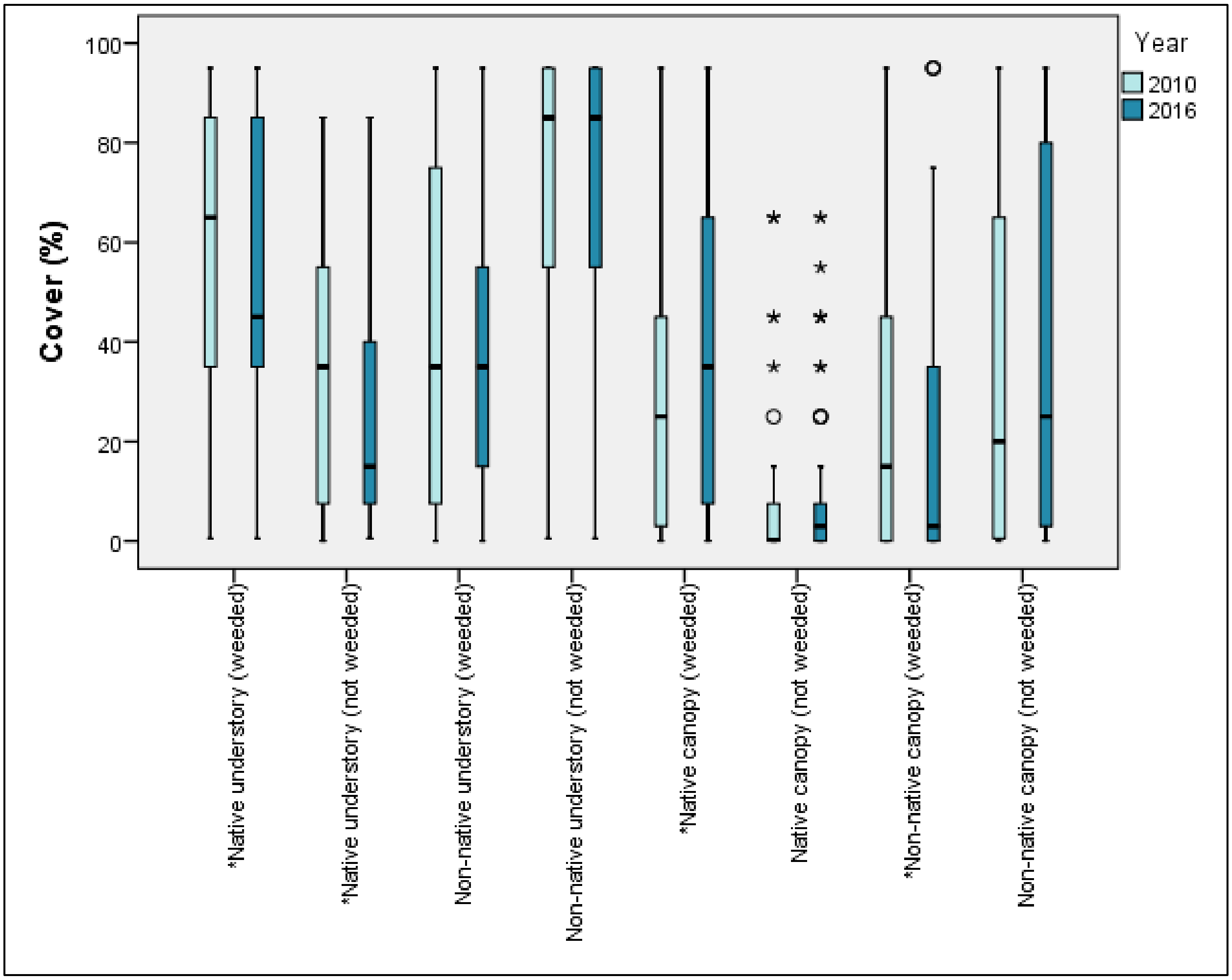


Figure 10. Boxplots of percent cover in plots within (n = 49) vs. outside (n = 84) weeded areas in 2010 and 2016 for native and non-native understory and canopy. *Significant change that meets the 10% standard for recognized change in cover between 2010 and 2016.

PRIORITY AREA 1

Understory and canopy cover categories

Management objectives of having < 50% non-native understory and canopy and > 50% native understory and canopy cover were met only for the non-native understory and canopy in 2016, as cover remained low (35% and 7.5% median values, respectively) in priority area 1 (Table 9). Native understory objectives were met in 2013, but declined to 45% cover in 2016. Native canopy cover remained low (35% median value), but progressed nearer the goal. There were several significant[1] changes in percent cover of vegetation from previous monitoring results that met the 10% standard for recognized change in cover. These included increases in cover for native canopy and total canopy, and decreases in native shrubs, native ferns, native grass/sedges, and total native understory (Figure 11).

Table 9. Percent cover of native and non-native vegetation categories in the canopy and understory at Ohikilolo MU from 2010 to 2016 in priority area 1. Median values are represented (n = 51). 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. Arrows indicate increase (↑) or decrease (↓) in cover.

	2010	2013	2016	p*	X^2	years that differed significantly	p (post-hoc)**	Management objective currently met?
Understory								
Native shrubs	25	25	15	**0.007**↓	10.043	2013-2016	0.030↓	
Native ferns	25	25	15	**0.003**↓	11.792	2010-2016	0.014↓	
Native grass/sedges	15	7.5	3	**< 0.001**↓	22.704	2013-2016 2010-2016	0.005↓ 0.001↓	
Total native understory	65	65	45	**0.013**↓	8.764	NA		No, and getting worse
Non-native shrubs	7.5	7.5	7.5	0.118	4.271			
Non-native ferns	3	7.5	3	0.001↓	13.347	2013-2016 2010-2016	0.014↓ 0.035↓	
Non-native grass/sedge	3	7.5	3	0.014↓	8.477	2013-2016	0.035↓	
Total non-native understory	45	45	35	0.228	2.955			Yes
Canopy								
Native canopy	25	25	35	**< 0.001**↑	19.069	2013-2016 2010-2016	0.012↑ 0.001↑	No, but getting better
Non-native canopy	15	15	7.5	0.394	1.863			Yes
Total canopy	55	55	65	**0.041**↑	6.411	NA		

*from Friedman's test, asymptotic significance
**from post-hoc pairwise comparisons with Bonferroni adjustment

Species richness

During monitoring of priority area 1 in 2016, 140 species were recorded in the understory (57% native taxa), and 32 were identified in the canopy (81% native). Most species present in the canopy were also represented in the understory, with the exception of one native species (*Bobea elatior*). Species richness within plots in the native canopy differed significantly between the years monitored, with small increases from 2010 to 2013, and from 2010 to 2016 (Table 10). The significant increase in richness among plots was not paired with increases in overall native canopy diversity for the MU. Eight newly recorded species (75% non-native) were found in plots in 2016, while 19 species (63% native) were recorded in 2010 and/or 2013 but not observed in 2016 (Table 11). All of the species that were not present in 2016 were uncommon in prior years, with frequencies less than 7.8%. Species newly recorded in 2016 all had frequencies less than 4%.

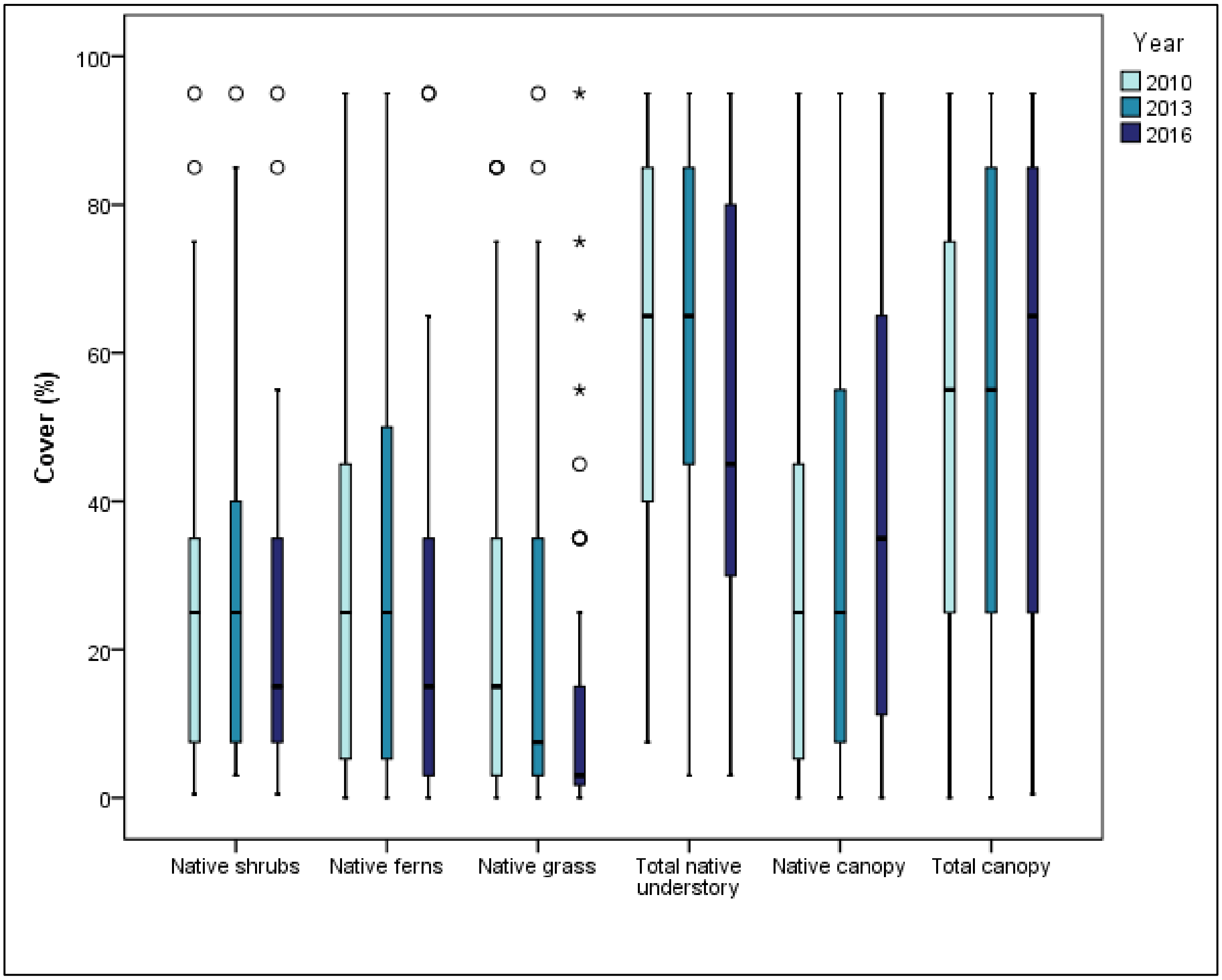


Figure 11. Boxplots for vegetation categories with significant change in percent cover that meet 10% standard for recognized change in cover between years 2010 and 2016 in Ohikilolo Upper MU, priority area 1.

Table 10. Ohikilolo Upper MU understory and canopy species richness from 2010 to 2016 in priority area 1. Mean species richness per plot during vegetation monitoring is shown by year, with the total number of species recorded among all plots in parenthesis (n = 51). Statistically significant values are in boldface. Arrows indicate increase (↑) or decrease (↓) in richness.

	2010	2013	2016	p*	F	years that differed	p (post-hoc)**
Native understory	12.24 (71)	12.43 (69)	12.53 (68)	0.714	0.338		
Non-native understory	8.94 (47)	8.00 (43)	8.75 (53)	0.056	2.974		
Native canopy	2.82 (25)	3.25 (28)	3.41 (26)	**0.004**↑	5.876	2010-2016 2010-2013	**0.011**↑ **0.031**↑
Non-native canopy	0.76 (2)	0.75 (3)	0.8 (6)	0.650	0.433		

*derived from repeated measures ANOVA

**derived from post-hoc comparisons with Bonferroni correction

Table 11. Newly recorded, and no longer present, species from 2016 Ohikilolo Upper MU monitoring in priority area 1, 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).

New species recorded in plots in 2016	2016	Species not recorded in 2016 but observed in plots previously	2010	2013
Castilleja arvensis	2.0	***Adenophorus tenellus***	3.9	-
Cyperus brevifolius	3.9	***Artemisia australis***	-	2.0
Dianella sandwicensis	3.9	*Asclepias physocarpa*	-	2.0
Ehrharta stipoides	2.0	***Asplenium caudatum***	7.8	3.9
Epidendrum x obrienianum	2.0	*Cerastium fontanum*	2.0	-
Lysimachia arvensis	2.0	***Cyrtomium caryotideum***	-	2.0
Neraudia melastomifolia	2.0	***Elaphoglossum alatum***	2.0	-
Spathodea campanulata	2.0	***Elaphoglossum sp.***	2.0	-
		Emilia fosbergii	2.0	2.0
		Erechtites valerianifolia	-	2.0
		Melicope makahae	2.0	-
		Mesosphaerum pectinatum	2.0	-
		Nephrolepis cordifolia	-	2.0
		Paspalum scrobiculatum	3.9	-
		Pteris irregularis	2.0	-
		Rhynchospora sp.	2.0	-
		Sadleria pallida	2.0	2.0
		Santalum album	2.0	-
		Zanthoxylum dipetalum var. dipetalum	2.0	-

Species frequency

Native species that occurred most frequently in plots (present in more than half the plots) in the understory included *Carex meyenii*, *Myrsine lessertiana*, *Doodia kunthiana*, *Coprosma foliosa*, *Dodonaea viscosa*, *Metrosideros polymorpha*, and *Alyxia stellata,* while *M. polymorpha* occurred most commonly in the canopy (Table 12). The most frequent non-native understory species included *Blechnum appendiculatum*, *Stachytarpheta australis*, *Melinis minutiflora*, *Schinus terebinthifolius*, *Rubus rosifolius*, and *Ageratina adenophora*. *Schinus terebinthifolius* was the most commonly occurring non-native taxa in the canopy. One out of the nine MIP/OIP rare taxa at Ohikilolo Upper MU were recorded in plots during monitoring of priority area 1 in 2016 (*Pritchardia kaalae*). One out of seven additional non-MIP/OIP rare taxa known from the MU (*Platydesma cornuta* var. *decurrens*) was also recorded. Analysis of frequency change (McNemar's test) was limited to taxa with at least ten percent change between 2010 and 2016. There were significant frequency changes in the understory, including increases for three native (*Coprosma foliosa*, *Dryopteris fusco-atra*, and *Wikstroemia oahuensis*) and two non-native (*Rubus rosifolius* and *Youngia japonica*) taxa, and decreases for three non-native taxa (*Festuca bromoides*, *Schinus terebinthifolius*, and *Setaria parviflora*) (Table 13). Most notable among these was the increased occurrence of *Rubus rosifolius* from a third to over half the plots between 2013 and 2016.

Table 12. Species frequency among plots (percent of plots in which a given species occurs) during 2016 Ohikilolo MU monitoring in priority area 1 (n= 51), in order of most to least frequent. Native species are in bold print. *Rare taxa. **ERMUP target weed taxa.

Taxon	Freq.	Taxon	Freq.
Understory			
Carex meyenii	88.2	***Kadua acuminata***	11.8
*Blechnum appendiculatum***	84.3	***Melicope oahuensis***	11.8
Stachytarpheta australis	76.5	*Triumfetta semitriloba*	11.8
Melinis minutiflora	68.6	***Acacia koa***	9.8
Myrsine lessertiana	64.7	*Centaurium erythraea*	9.8
Doodia kunthiana	62.7	*Cheilanthes viridis*	9.8
Schinus terebinthifolius	60.8	*Clidemia hirta*	9.8
Coprosma foliosa	56.9	*Cuphea carthagenesis*	9.8
Dodonaea viscosa	56.9	***Eragrostis grandis***	9.8
Metrosideros polymorpha	54.9	***Gahnia beecheyi***	9.8
Rubus rosifolius	54.9	***Bidens torta***	7.8
Ageratina adenophora	51.0	*Festuca bromoides*	7.8
Alyxia stellata	51.0	***Kadua affinis***	7.8
Kalanchoe pinnata	47.1	*Oxalis corniculata*	7.8
Metrosideros tremuloides	47.1	*Ageratum conyzoides*	5.9
Sphenomeris chinensis	47.1	***Cyrtandra waianaeensis***	5.9
Wikstroemia oahuensis* var. *oahuensis	45.1	***Dicranopteris linearis***	5.9
Cocculus orbiculatus	43.1	***Doryopteris decipiens***	5.9
Ageratina riparia	39.2	***Lachnagrostis filiformis***	5.9
Erigeron karvinskianus	39.2	***Lysimachia hillebrandii***	5.9
Freycinetia arborea	39.2	*Melinis repens*	5.9
Pteridium aquilinum	39.2	***Pipturis albidus***	5.9
Nephrolepis exaltata* subsp. *hawaiiensis	37.3	*Araucaria columnaris***	3.9
Youngia japonica	35.3	***Cyclosorus cyatheoides***	3.9
Dryopteris sandwicensis	29.4	*Cyclosorus dentatus*	3.9
Cibotium chamissoi	27.5	*Cyperus brevifolius*	3.9
Conyza bonariensis	27.5	***Dianella sandwicensis***	3.9
Elaeocarpus bifidus	25.5	***Korthalsella complanata***	3.9
Pritchardia kaalae*	25.5	***Nestegis sandwicensis***	3.9
Selaginella arbuscula	25.5	*Oplismenus hirtellus*	3.9
Antidesma platyphyllum	23.5	***Platydesma cornuta* var. *decurrens****	3.9
Cyclosorus parasiticus	23.5	*Psidium cattleianum*	3.9
Dryopteris fusco-atra	23.5	***Psilotum nudum***	3.9
Lantana camara	23.5	***Sadleria cyatheoides***	3.9
Lepisorus thunbergianus	23.5	***Scaevola gaudichaudiana***	3.9
Psychotria mariniana	23.5	*Sporobolus indicus*	3.9
Lythrum maritimum	21.6	*Adiantum hispidulum*	2.0
Microlepia strigosa	21.6	*Axonopus fissifolius***	2.0
Setaria parviflora	21.6	*Bidens pilosa*	2.0
Carex wahuensis	17.6	*Buddleja asiatica*	2.0
Dryopteris glabra	17.6	*Castilleja arvensis*	2.0
Paspalum conjugatum	17.6	*Chamaecrista nictitans*	2.0
Viola chamissoniana* subsp. *tracheliifolia	17.6	***Ctenitis latifrons***	2.0
Andropogon virginicus	15.7	*Cyperus mindorensis*	2.0
Gamochaeta purpurea	15.7	***Diospyros sandwicensis***	2.0
Psychotria hathewayi	15.7	*Ehrharta stipoides***	2.0
Athyrium microphyllum	11.8	*Emilia sonchifolia*	2.0
Deparia prolifera	11.8	*Epidendrum x obrienianum*	2.0
Elaphoglossum paleaceum	11.8	*Linum trigynum*	2.0
*Grevillea robusta***	11.8	***Luzula hawaiiensis***	2.0

Table 12, continued

Taxon	Freq.	Taxon	Freq.
Understory, cont.			
Lysimachia arvensis	2.0	***Plectranthus parviflorus***	2.0
Melicope kaalaensis	2.0	***Polypodium pellucidum* var. *pellucidum***	2.0
Neraudia melastomifolia	2.0	*Sonchus oleraceus*	2.0
Opuntia cochenillifera	2.0	*Spathodea campanulata*	2.0
Osteomeles anthyllidifolia	2.0	***Syzygium sandwicense***	2.0
Panicum nephelophilum	2.0	***Tectaria gaudichaudii***	2.0
Peperomia membranacea	2.0	*Toona ciliata*	2.0
Phaius tankervilleae	2.0	***Vaccinium reticulatum***	2.0
Phyllanthus distichus	2.0	*Verbena litoralis*	2.0
Pityrogramma austroamericana	2.0	***Xylosma hawaiiense***	2.0
Planchonella sandwicensis	2.0		
Canopy			
Schinus terebinthifolius	68.6	***Pritchardia kaalae****	5.9
Metrosideros polymorpha	54.9	*Grevillea robusta***	3.9
Metrosideros tremuloides	39.2	***Kadua affinis***	3.9
Dodonaea viscosa	35.3	***Melicope oahuensis***	3.9
Freycinetia arborea	29.4	***Syzygium sandwicense***	3.9
Elaeocarpus bifidus	21.6	***Bobea elatior***	2.0
Alyxia stellata	19.6	***Cyrtandra waianaeensis***	2.0
Cibotium chamissoi	19.6	***Korthalsella complanata***	2.0
Acacia koa	17.6	*Melinis minutiflora*	2.0
Myrsine lessertiana	17.6	***Planchonella sandwicensis***	2.0
Coprosma foliosa	13.7	*Rubus rosifolius*	2.0
Psychotria mariniana	11.8	***Sadleria cyatheoides***	2.0
Antidesma platyphyllum	7.8	***Scaevola gaudichaudiana***	2.0
Lepisorus thunbergianus	7.8	*Stachytarpheta australis*	2.0
Psychotria hathewayi	7.8	*Toona ciliata*	2.0
Nestegis sandwicensis	5.9	***Wikstroemia oahuensis* var. *oahuensis***	2.0

Table 13. Species with significant frequency change in the understory at Ohikilolo MU between 2010 and 2016 in priority area 1. Only taxa with at least 10% change in frequency were analyzed. Frequency values represent the proportion of plots in which species are present (n = 51). Native species are in boldface. P-values obtained from McNemar's test (binomial distribution). Arrows indicate increase (↑) or decrease (↓) in frequency.

Species	Freq. 2010	Freq. 2013	Freq. 2016	Freq. change (2010 to 2016)	years that differed	p
Coprosma foliosa	41.2	45.1	56.9	15.7	2010-2016	0.039↑
					2013-2016	0.031↑
Dryopteris fusco-atra	11.8	25.5	23.5	11.8	2010-2013	0.039↑
					2010-2016	0.031↑
Festuca bromoides	21.6	0.0	7.8	-13.7	2010-2013	0.001↓
					2010-2016	0.039↓
Rubus rosifolius	31.4	33.3	54.9	23.5	2010-2016	0.002↑
					2013-2016	0.001↑
Schinus terebinthifolius	76.5	66.7	60.8	-15.7	2010-2016	0.039↓
Setaria parviflora	37.3	43.1	21.6	-15.7	2010-2016	0.039↓
					2013-2016	0.003↓
Wikstroemia oahuensis	29.4	41.2	45.1	15.7	2010-2013	0.07↑
					2010-2016	0.008↑
Youngia japonica	15.7	15.7	35.3	19.6	2010-2016	0.006↑
					2013-2016	0.002↑

Species cover

Species with frequencies > 20% (present in at least 10 plots) in 2010 and/or 2016 were subjected to analysis of cover change (Friedman's test). Significant increases in percent cover occurred for three native understory taxa (*P. kaalae, Psychotria mariniana*, and *S. arbuscula*), two non-native understory species (*R. rosifolius*, and *Y. japonica*), and two native canopy species (*D. viscosa* and *Freycinetia arborea*) (Table 14 and Figures 12 and 13). Decreases in percent cover occurred for three native understory species (*C. meyenii*, *D. kunthiana*, and *Sphenomeris chinensis)*, and seven non-native understory species (*A. adenophora, A. riparia, B. appendiculatum, Festuca bromoides, Lantana camara, S. terebinthifolius,* and *Setaria parviflora*). However, in several instances the cover changes were quite small. Most notable were the decreases in *B. appendiculatum* and *C. meyenii* between 2013 and 2016, and *S. chinensis* between 2010 and 2016, and the increase in *R. rosifolius* from 2013 to 2016.

Table 14. Species with significant percent cover change in the understory and canopy at Ohikilolo Upper MU from 2010 to 2016 in priority area 1. Only species with frequencies greater than 20% (present in > 10 plots) in 2010, 2013, or 2016 were analyzed. Native taxa and statistically significant values are in boldface (n = 51). Arrows indicate increase (↑) or decrease (↓) in cover.

Species	p*	X^2	years that differed significantly	p (post-hoc)**	Median cover change
Understory					
Ageratina adenophora	0.023↓	7.507	NA		
Ageratina riparia	0.048↓	6.081	NA		
Blechnum appendiculatum	0.003↓	11.450	2013-2016↓	0.012	-3.0
Carex meyenii	<0.001↓	31.985	2010-2016↓ 2013-2016↓	<0.001 <0.001	-2.5 -2.5
Doodia kunthiana	0.022↓	7.622	NA		
Festuca bromoides	<0.001↓	16.270	NA		
Lantana camara	0.049↓	6.030	NA		
Pritchardia kaalae	0.018↑	8.000	NA		
Psychotria mariniana	0.006↑	10.383	NA		
Rubus rosifolius	<0.001↑	35.685	2010-2016↑ 2013-2016↑	0.002 0.002	0.0 0.0
Schinus terebinthifolius	0.033↓	6.819	NA		
Selaginella arbuscula	0.036↑	6.650	NA		
Setaria parviflora	<0.001↓	18.581	NA		
Sphenomeris chinensis	0.025↓	7.367	NA		
Youngia japonica	<0.001↑	16.133	NA		
Canopy					
Dodonaea viscosa	<0.001↑	17.200	NA		
Freycinetia arborea	0.034↑	6.778	NA		

*from Friedman's test

**from post-hoc pairwise comparisons with Bonferroni adjustment

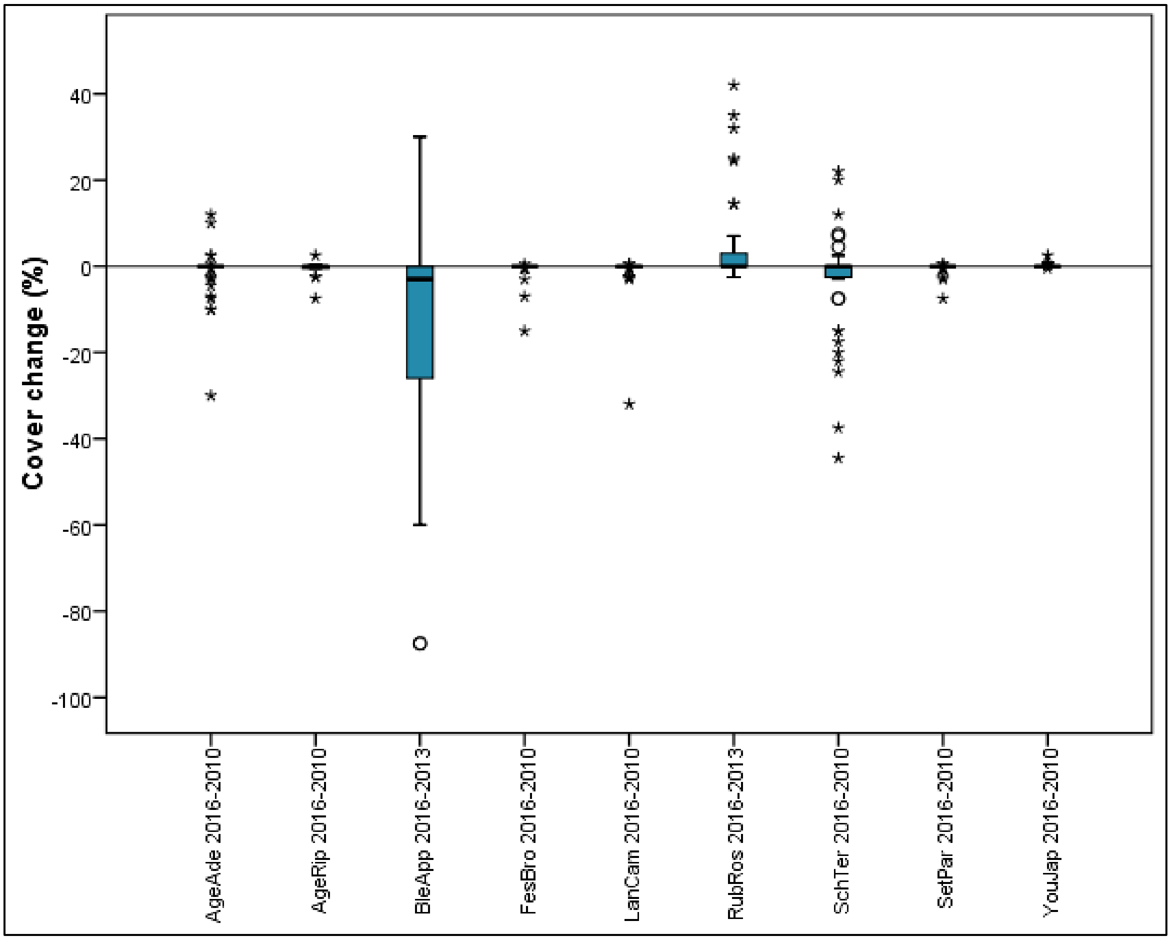


Figure 12. Boxplots of percent cover change between 2010 and 2016 in priority area 1, for understory non-native species with significant changes in cover. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover.

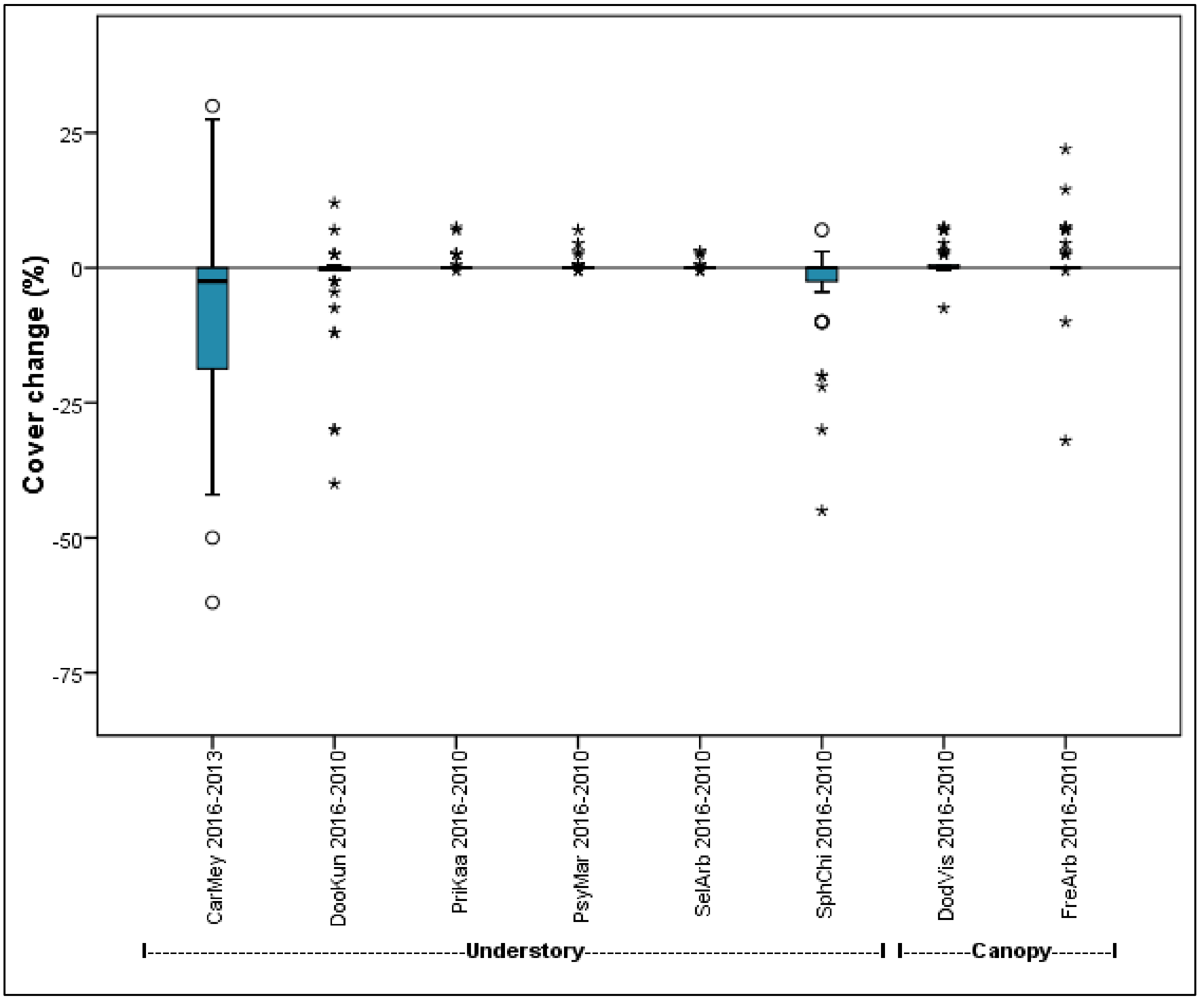


Figure 13. Boxplots of percent cover change between 2010 and 2016 in priority area 1, for native species with significant changes in cover. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover.

Canopy replacement

Most canopy tree species were found recruiting in the understory (Table 15). *Myrsine lessertiana, D. viscosa, M. polymorpha* and *M. tremuloides* were the most commonly recruiting native tree species, while non-native recruiting tree species was primarily *S. terebinthifolius*. Native trees with no recruitment in the understory were also relatively infrequent in the canopy (with frequencies < 22%), including *Bobea elatior*, *Elaeocarpus bifidus, Nestegis sandwicensis, and Planchonella sandwicensis*. 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. There were no significant differences in species recruitment frequencies (McNemar's test).

Table 15. Summary of canopy tree species recruitment in the understory at Ohikilolo Upper MU monitoring in priority area 1 in 2016, in order of most to least frequent. Frequency represents the percent occurrence of tree species with a maximum height < 2 meters (seedlings to small trees) among plots (n = 51). Native species are in boldface. *Rare taxa. **ERMUP target weed taxa.

Species	Frequency	Species	Frequency
Myrsine lessertiana	58.8	***Psychotria hathewayi***	7.8
Dodonaea viscosa	41.2	***Kadua affinis***	5.9
Metrosideros polymorpha	33.3	***Acacia koa***	3.9
Schinus terebinthifolius	31.4	***Melicope oahuensis***	3.9
Wikstroemia oahuensis	23.5	***Pipturis albidus***	3.9
Metrosideros tremuloides	19.6	***Freycinetia arborea***	2.0
Pritchardia kaalae*	19.6	*Psidium cattleianum*	2.0
Psychotria mariniana	15.7	***Scaevola gaudichaudiana***	2.0
Antidesma platyphyllum	11.8	***Syzygium sandwicense***	2.0
*Grevillea robusta***	7.8	*Toona ciliata*	2.0

SUMMARY AND DISCUSSION

Priority areas 1 and 2: Management objectives were met for percent cover of non-native canopy, but not met for native and non-native understory and native canopy vegetation for Ohikilolo MU. However, the extent to which management objectives for native canopy are applicable to this MU are debatable, wherein the habit of prevalent tree taxa such as *M. polymorpha* takes on lower stature on the steep open ridges. There were a number of significant differences in the 2016 data as compared with six years prior, many of which were relatively small. The most noteworthy changes included:

- **Categorical cover**
  - Decrease in native grass/sedges, native understory and non-native shrub cover
  - Increase in total canopy cover
- **Richness**
  - Increase in native and non-native understory and canopy richness
- **Frequency**
  - Increased:
    - *D. viscosa* (native canopy)
    - *R. rosifolius* (non-native understory)
  - Decreased:
    - *A. riparia* (non-native understory)
- **Species cover**
  - Increased:
    - *E. karvinskianus* (non-native understory)
    - *M. tremuloides* (native canopy)
    - *R. rosifolius* (non-native understory)
  - Decreased (understory):
    - *A. riparia* (non-native)
    - *B. appendiculatum* (non-native)
    - *C. meyenii* (native)
    - *P. aquilinum* (native)
    - *S. chinensis* (native)
    - *S. terebinthifolius* (non-native)
- **Cover change in weeded vs. unweeded plots:**
  - Decrease in native understory in both weeded and unweeded plots
  - Increase in native canopy in weeded plots

    - Decrease in non-native canopy in weeded plots

Priority area 1: Management objectives were met for percent cover of non-native understory and canopy, but not met for native understory and canopy vegetation. Again, there were a number of significant differences in the 2016 data as compared with three to six years prior, many of which were relatively small. The most notable changes included:

- **Categorical cover**
    - Decrease in native shrubs, ferns, grass/sedge, and total native understory
    - Increase in native and total canopy
- **Richness**
    - Increase in native canopy richness
- **Frequency**
    - Increased for non-native understory species:
        - *R. rosifolius* (2013 to 2016)
- **Species cover**
    - Increased for non-native species:
        - *R. rosifolius* (2013 to 2016)
    - Decreased for understory species:
        - *B. appendiculatum* (non-native, 2013 to 2016)
        - *C. meyenii* (native, 2013 to 2016)
        - *S. chinensis* (native, 2010 to 2016)

It should be noted that this type of analysis involves numerous statistical tests, and there are likely some erroneous results (significance is either false or missed). Human error always a factor in this type of monitoring, as it is visually based and contingent upon identification skills. *Carex* cover is challenging to estimate, as it would often be present buried below other taxa, and difficult to see. Erroneous cover changes could result from observer bias.

Overall, for the most part some things are getting a little better, some things a little worse. Species with biggest frequency changes across the MU (increases in *L. thunbergianus* and *Y. japonica*) are among the least consequential, though the taxon with the biggest frequency change in priority area 1 (*R. rosifolius* increase of 25% since 2013) is concerning. *Clidemia hirta* appears to be in the early stages of spreading in the vicinity of a single ridge at the lower end of the lower forest patch (Figure 14), with the sudden appearance in 6% of plots, when it was completely absent from plots previously. The MU was not accessible for ten months in 2015, during which weeding efforts fell behind. It was anticipated that understory weed cover would increase substantially in priority area 1, where most of the weeding occurs, but aside from *R. rosifolius* and *C. hirta*, it did not get worse overall. The decline in native understory (in both weeded and unweeded areas, and especially in priority area 1) is of concern, as the MU was just below the goal in 2010 but is now moving away from the goal. Furthermore, the priority 1 area was meeting the goal in 2010 and 2013, but is not any more. The most notable positive changes included increased native canopy paired with decreased non-native canopy in weeded plots, and increased native richness.

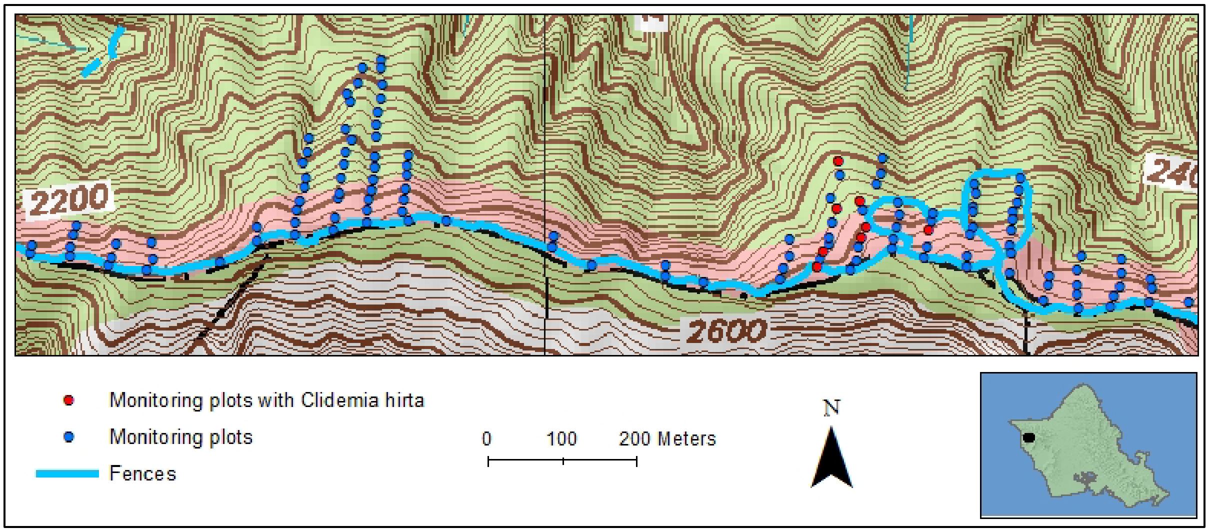


Figure 14. Locations of *Clidemia hirta* found during monitoring of Ohikilolo Upper MU in 2016.

RECOMMENDATIONS

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

- Greater efforts for general ecosystem and ERMUP target taxa weeding for targets with limited as well as widespread distributions
- Add *C. hirta* to ERMUP target list
- Focused effort on controlling and preventing spread of *C. hirta*
- Consider further expanding ERMUP target list to include additional problematic taxa, e.g., *T. ciliata* and *P. cattleianum*, and designate differing types of targets (widespread vs. limited distributions) and approaches for control
- Increased weeding efforts may be accomplished via:
    - Time freed up from rodent control once all traps are switched to A24 automatic re-setting ones with long-lasting bait
    - Additional help from other teams and foundational staff on camp trips, as possible, with the added bonus of staff bonding and education
    - Outreach Program camp trips to reward exceptional volunteers
    - One additional camp trip each year, specifically for weeding efforts
- Common outplanting/restoration of native species

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OAHU ARMY NATURAL RESOURCES PROGRAM
MONITORING PROGRAM

MONITORING OF UNDERSTORY VEGETATION CHANGE IN ASSOCIATION WITH IPA CONTROL OF *MORELLA FAYA* ONE YEAR POST-TREATMENT AT PALIKEA

INTRODUCTION

Incision Point Application (IPA) herbicide treatment of problematic non-native trees allows staff to effectively treat numerous individuals over a large area in a relatively short amount of time, with very small doses of pesticides. *Morella faya* is common throughout Palikea, and due to its ecosystem altering characteristics, is on the Hawaii Noxious Weed List, and considered a high risk weed species (Division of Plant Industry 2003; Hawaii-Pacific Weed Risk Assessment 2009). Vegetation monitoring of Palikea MU in 2014 determined *M. faya* to be the second most frequently encountered non-native tree within the MU (45% frequency), after *Schinus terebinthifolius* (63% frequency) (OANRP 2014). Recommendations were made for partial canopy thinning/removal of this species, as it is one of the more easily managed canopy weeds, and has infrequent recruitment. Large *M. faya* trees were selectively treated using IPA on November 3-4, 2015 at Palikea, including approximately 116 trees within the MU fence, and 81 outside the fence (Figure 1). This was the first round of multiple selective treatments that may be conducted, pending further discussion of management strategies for this taxon at Palikea. Understory vegetation change in association with IPA treatment of *M. faya* was documented using point intercept monitoring of a subset of treated trees within Palikea MU. Initial baseline monitoring was conducted within the first few months (December 9 and 14, 2015, and January 6, 2016) following treatment, before substantial canopy reduction and any resulting understory response occurred. Subsequent monitoring of the same trees occurred after one year, on November 9, 2016, and January 25-26, 2017.

METHODS

Point intercept monitoring was used to assess percent cover of native and non-native taxa in the understory directly below treated *M. faya* trees within Palikea MU. All species “hit” below 2 m above ground level (AGL) at points along transects were recorded. A 5 millimeter diameter pole was used to determine “hits” (live vegetation that touches the pole) along an outstretched measuring tape. Point intercepts were recorded at 25 randomly sampled treated trees every meter (m) along 5 m long transects in each cardinal direction from the tree, or alternatively, every 0.5 m along two 5 m long transects oriented North and South, or East and/or West or if slopes were too steep to the North or South (n = 500 points). Using two transects with more closely spaced point intercepts per tree was an effective attempt to expedite the data collection process, as monitoring took longer than expected using four transects with fewer point intercepts per tree. The same methods were used for baseline and 1-year post-treatment monitoring. Substrate in locations where no vegetation was intercepted in the understory was recorded as soil/leaf litter, rock, moss, etc. Trees were marked (with a combination of yellow and orange-black striped flagging) and tagged with unique identification numbers. Approximations of percent cover were obtained from the proportion of “hits” among all intercepts. The overall health (noted as healthy, moderate, poor, or dead) of trees and defoliation ranking of 1 to 4 (1: 100%, 2: > 50%, 3: < 50%, and 4: 0% defoliation) as per Leary et al. (2013) were also documented to assess treatment efficacy. Hemispheric photographs were taken of the canopy on the south-facing side of each sampled tree to document canopy openness. Photographs were taken at 2 m AGL, aimed 180° from the forest floor. Gap Light Analyzer (GLA), Version 2.0 software (Frazer et al. 1999) was used to determine percent canopy openness, using the

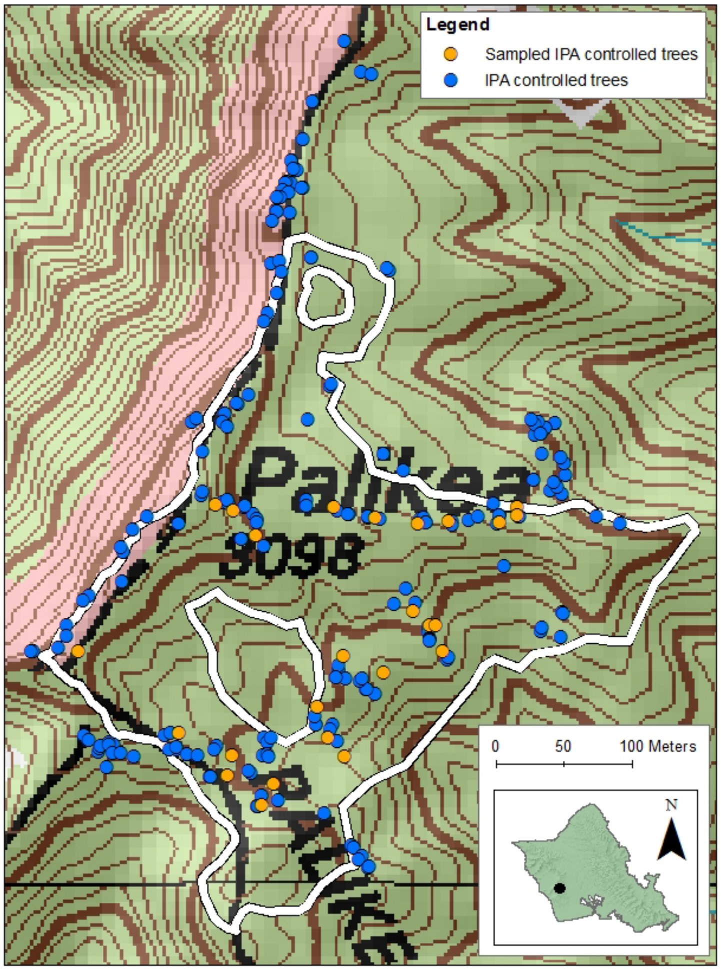

Figure 1. Location of IPA controlled *Morella faya* at Palikea, including locations of trees sampled for monitoring associated understory vegetation response.

hemispheric canopy photographs. Statistical analyses included chi-square tests for understory percent cover, and a paired t-test for canopy openness. Only significant results with statistical power > 0.90 were recognized (G*Power 3.1.9.2).

RESULTS

Understory vegetation cover beneath the sampled *M. faya* trees one year post-treatment at Palikea included 53.4% non-native taxa (primarily shrubs and grasses), 51.0% native taxa (primarily ferns and shrubs), and 11.8% non-vegetated area (Table 1). The most prevalent non-native taxa one year post-treatment were *Rubus rosifolius* (22.6%), *Clidemia hirta* (17.4%), and *Blechnum appendiculatum* (5.8%) (Table 2). Predominant native taxa included *Nephrolepis exaltata* subsp. *hawaiiensis* (11.8%), *Dicranopteris linearis* (10.2%), and *Cibotium chamissoi* (6.2%). Significant changes from baseline observations in the understory included increased cover for non-native herbs, non-native shrubs, and *R. rosifolius*, as well as decreased cover for non-native tree taxa, *M. faya*, and non-vegetated area (Table 3). While the increase in understory vegetation filled in much of the non-vegetated areas, the understory also became more multilayered, with a significant increase in the proportion of point intercepts with 2 non-native taxa per locus (from 7 % to 14%; chi-square test: $p = 0.0001$, $X = 14.99$). Overall species diversity increased for native, and particularly non-native, taxa, from 38 to 41 native and 13 to 20 non-native taxa from baseline monitoring to one year post-treatment. Subsequently, the ratio of native to non-native taxa decreased from 3:1 to 2:1.

During monitoring 1 year post-treatment, expansion of *R. rosifolius* cover was anecdotally observed primarily in weedy lower elevation sub-ridge, slope, and gulch regions, but to a lesser extent in exposed upper elevation ridge areas with more native habitat. *Rubus rosifolius* cover increased significantly in both region types in the understory below IPA treated *M. faya* trees (chi-square tests: exposed upper ridge native areas $p < 0.001$, $X = 11.46$, $n = 260$; lower sub-ridge, slope and gulch weedy areas $p < 0.001$, $X = 43.39$, $n = 240$). However the increase in cover below sampled trees in the lower weedier regions (from 10.8% to 37.1%) was much greater than for those in the upper native regions, which remained below 10% (Figure 2).

During baseline monitoring, most sampled *M. faya* trees were beginning to show signs of declining health (5 healthy, 15 moderate, 5 poor), wherein leaves were browning and/or beginning to defoliate. All trees had some degree of defoliation, with a median ranking of 3 (< 50% defoliation). One year post-treatment, all trees had substantial signs of declining health or mortality (11 poor, 14 dead), with all tree canopies completely defoliated (Figure 3). Most live trees had basal sprouts or budding leaves, while two only had live cambium. Baseline mean canopy openness increased significantly from 17.7% to 32.1% one year post-treatment (paired t-test: $t = -7.159$, $df = 24$, $p < 0.001$).

Table 1. Percent cover of native and non-native taxon groupings and non-vegetated area in the understory below IPA treated *Morella faya* during baseline monitoring and one year post-treatment at Palikea

	Baseline	1 year post-treatment
Non-native	44.0	53.4
Conifer	0.0	0.4
Fern	7.0	7.4
Grass	8.0	11.0
Herb	0.4	3.4
Shrub	20.8	36.2
Tree	9.4	3.6
Vine	3.8	5.2
Native	47.6	51.0
Fern	39.4	39.8
Herb	3.6	5.8
Sedge	0.2	0.0
Shrub	5.6	9.8
Tree	2.4	2.8
Bryophyte spp.	3.2	7.4
Non-vegetated	23.4	11.8
Dead wood	1.0	1.0
Rock	0.6	0.0
Root	0.6	0.2
Soil/leaf litter	21.2	10.6

Table 2. Percent cover of native and non-native taxa in the understory below IPA treated trees during baseline monitoring and one year post-treatment at Palikea MU. Native taxa in boldface.

Taxon	Baseline	1 year post-treatment
Rubus rosifolius	6.4	22.6
Clidemia hirta	15.6	17.4
Nephrolepis exaltata* subsp. *hawaiiensis	10.8	11.8
Dicranopteris linearis	8.6	10.2
Cibotium chamissoi	5.2	6.2
Blechnum appendiculatum	6.2	5.8
Passiflora suberosa	3.8	5.2
Ehrharta stipoides	4.8	5.0
Paspalum conjugatum	3.2	4.8
Dianella sandwicensis	3.0	4.6
Microlepia strigosa	4.2	3.6
Asplenium contiguum	2.0	3.0
Kadua affinis	0.6	2.6
Psidium cattleianum	2.8	2.4
Diplazium sandwichianum	1.8	2.4
Metrosideros polymorpha	1.8	2.4
Asplenium macraei	2.2	1.8
Melinis minutiflora	0.6	1.8
Alyxia stellata	1.6	1.6
Youngia japonica	0.4	1.6
Coprosma foliosa	0.2	1.4
Dryopteris glabra	2.2	1.2
Cyclosorus parasiticus	0.4	1.2
Doodia kunthiana	0.4	1.2
Freycinetia arborea	1.0	1.0
Pittosporum confertiflorum	0.8	1.0
Wikstroemia oahuensis* var. *oahuensis	0.2	0.8
Erechtites valerianifolia	0.0	0.8
Morella faya	6.8	0.6
Deparia petersenii	0.6	0.6
Ageratina riparia	0.0	0.6
Carex meyenii	0.0	0.6
Clermontia persicifolia	0.0	0.6
Schinus terebinthifolius	0.0	0.6
Elaphoglossum paleaceum	1.0	0.4
Elaphoglossum crassifolium	0.8	0.4
Peperomia membranacea	0.6	0.4
Asplenium caudatum	0.4	0.4
Antidesma platyphyllum	0.2	0.4
Ageratina adenophora	0.0	0.4
Ageratum conyzoides	0.0	0.4
Coprosma longifolia	0.0	0.4
Crocosmia x crocosmiifolia	0.0	0.4
Cryptomeria japonica	0.0	0.4
Leptecophylla tameiameiae	0.0	0.4
Sadleria pallida	0.0	0.4
Nephrolepis cordifolia	0.4	0.2
Sphenomeris chinensis	0.4	0.2

Table 2, continued.

Taxon	Baseline	1 year post-treatment
Athyrium microphyllum	0.2	0.2
Broussaisia arguta	0.2	0.2
Cyrtandra waiolani	0.2	0.2
Asplenium acuminatum	0.0	0.2
Asplenium lobulatum	0.0	0.2
Asplenium nidus	0.0	0.2
Bidens torta	0.0	0.2
Crassocephalum crepidoides	0.0	0.2
Dodonaea viscosa	0.0	0.2
Euphorbia multiformis	0.0	0.2
Melicope clusiifolia	0.0	0.2
Sadleria cyatheoides	0.0	0.2
Scaevola gaudichaudiana	0.0	0.2
Kadua acuminata	1.2	0.0
Cheirodendron trigynum	0.4	0.0
Diplopterygium pinnatum	0.4	0.0
Dryopteris sandwicensis	0.4	0.0
Elaphoglossum aemulum	0.4	0.0
Carex wahuensis	0.2	0.0
Cyclosorus dentatus	0.2	0.0
Elaphoglossum alatum	0.2	0.0
Melicope oahuensis	0.2	0.0
Pipturis albidus	0.2	0.0
Vaccinium reticulatum	0.2	0.0
Viola chamissoniana* subsp. *tracheliifolia	0.2	0.0

Table 3. Taxa/taxon groupings with recognized significant vegetation cover changes (statistical power > 0.90). P-values derived from chi-square tests.

Taxa/taxon grouping	Baseline cover	1 year post-treatment cover	p	*X*	Direction of change
Non-native herb	0.4	3.4	0.001	12.071	↑
Non-native shrub	20.8	36.2	0.000	29.096	↑
Non-native tree	9.4	3.6	0.000	13.838	↓
Rubus rosifolius	6.4	22.6	0.000	52.922	↑
Morella faya	6.8	0.6	0.000	26.971	↓
Non-vegetated	23.4	11.8	0.000	49.1235	↓

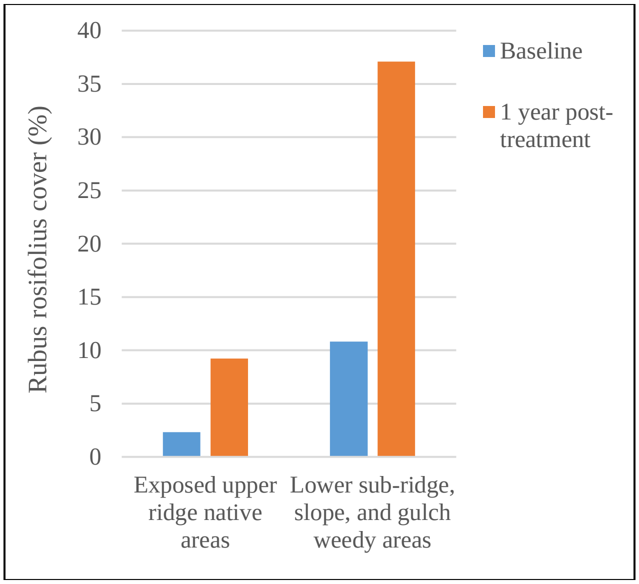

Figure 2. *Rubus rosifolius* cover in the understory below IPA treated *Morella faya* trees during baseline monitoring and one year post-treatment in lower elevation ridge, slope, and gulch weedy areas (n = 240) vs. more native exposed upper elevation ridge areas (n = 260).

Figure 3. Photographs showing defoliation in association with IPA treated *Morella faya* amongst the surrounding vegetation (left), and within the canopy of a treated tree.

DISCUSSION

The decrease in non-native tree cover that occurred in the understory was expected, as each sampled area contained a large *M. faya* tree that received IPA treatment, and live low hanging branches of that species were expected to become absent. Similarly, the significant increase in canopy openness was expected resulting from defoliation in association with IPA treatment of large *M. faya* trees within all sampled areas.

There was concern that understory weedy ingress would occur in response to increased light levels following *M. faya* defoliation. Increased *R. rosifolius* cover was apparent while monitoring some treated trees, and indeed had a significant increase in cover overall among the sampled areas, but was also anecdotally observed to be more prevalent in surrounding areas, and therefore not necessarily due to IPA treatment. Preliminary investigations of MU-scale vegetation monitoring of Palikea MU in June 2017 similarly indicate a significant increase in *R. rosifolius* understory cover (Wilcoxon signed-rank test: $p < 0.001$) as well as a significant decrease in *M. faya* canopy cover (Wilcoxon signed-rank test: $p < 0.001$) within the MU since 2014 (Figure 4). Decreased *M. faya* canopy cover in the MU-scale vegetation monitoring is presumed to be due to IPA control. However, *M. faya* canopy cover change from 2014 to 2017 did not influence *R. rosifolius* understory cover change within plots (Generalized linear model: $p = 0.860$), and *R. rosifolius* cover increased both in plots with decreased *M. faya* canopy cover (Wilcoxon signed-rank test: $p = 0.0024$. $n = 23$) as well as in plots with no change in *M. faya* canopy cover (Wilcoxon signed-rank test: $p = 0.007$, $n = 28$) (Figure 5). This suggests that increased *R. rosifolius* cover among sampled IPA treated trees is a reflection of MU-wide change in *R. rosifolius* cover unrelated to IPA control. *Rubus rosifolius* presence/absence and the extent that it got worse at each sampled tree was variable, but in general the sampled tree understories with the biggest increases in *R. rosifolius* cover were at or below the 2800 ft contour, and/or off of ridge crests. The summer months of 2016 were unusually rainy, and may have contributed to the expansion of *R. rosifolius* in those areas. Further analysis of MU-scale monitoring results may give more clarification any geographic associations with increased *R. rosifolius* cover or frequency.

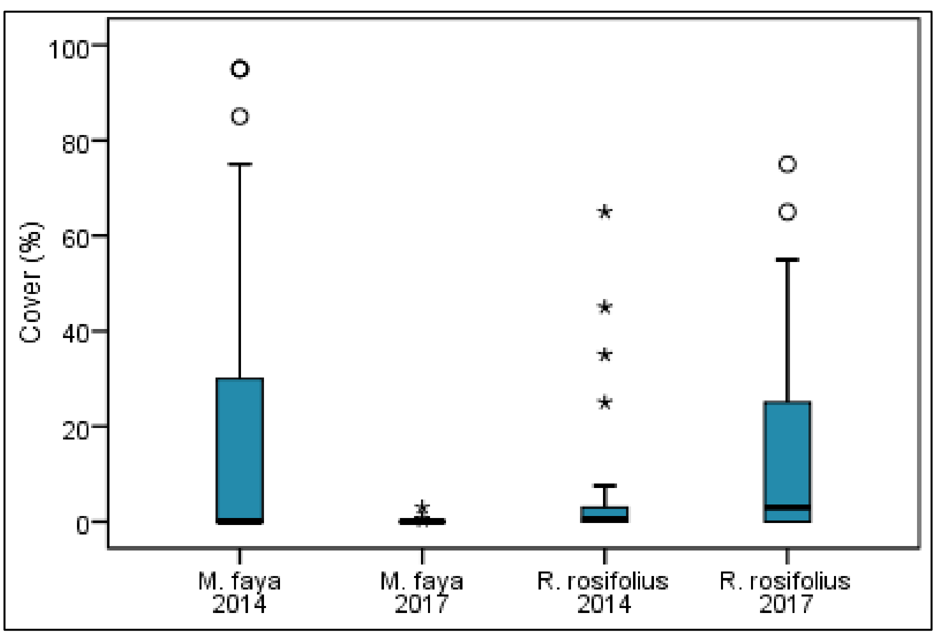

Figure 4. Percent cover of canopy *M. faya* and understory *R. rosifolius* among plots in 2014 and 2017 from Palikea MU vegetation monitoring.

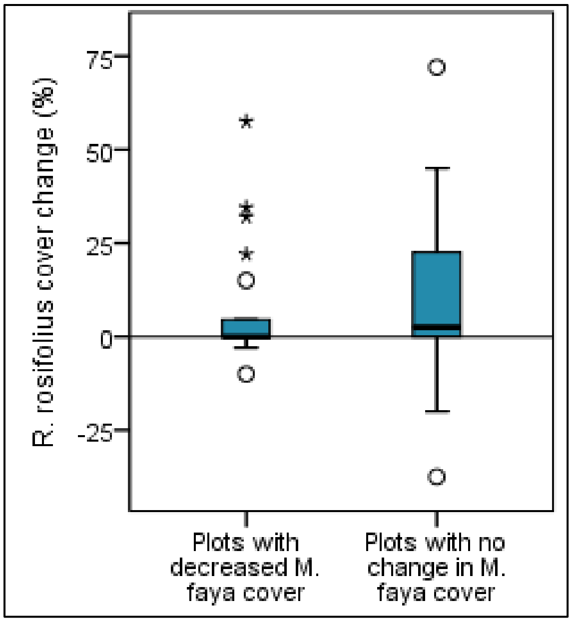

Figure 5. Cover change of understory *R. rosifolius* among plots with decreased vs. no change in *M. faya* canopy cover between 2014 and 2017 from Palikea MU vegetation monitoring. Positive numbers indicate increased cover, while negative numbers indicate decreased cover.

As with weeding efforts in association with MU-scale monitoring, WCA and ICA weeding actions occurred and will proceed irrespective of monitored trees (i.e., crews neither target nor intentionally avoiding weeding around trees used in this trial). Point intercept monitoring of understory change in association with *M. faya* IPA treatment will continue on a three year interval, to coincide with the MU-scale vegetation monitoring for comparison purposes.

While the MU-scale monitoring at Palikea was useful for distinguishing vegetation change that occurred as a direct result of IPA control vs. change occurring across the MU unrelated to treatment, future efforts to monitor understory vegetation change associated with IPA treatment at other MUs or for other taxa may more accurately reflect direct impacts of treatment by also monitoring untreated trees as a measure of control. The increased field time required to monitor untreated trees could be compensated for by monitoring fewer treated trees. While this would lessen representation of treated trees, statistical power could be maintained by increasing the number of point intercepts per tree. E.g., 10 treated and 10 untreated trees could be sampled with point intercepts every 50 cm along five transects per tree, for a total of 500 intercepts for treated trees and 500 intercepts for untreated trees. The greater capacity to assess direct impacts from treatment would likely outweigh the limitations of diminished representation of treated trees.

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OAHU ARMY NATURAL RESOURCES PROGRAM
MONITORING PROGRAM

MAKAHA ECOSYSTEM RESTORATION PRE- AND POST-CLEARING VEGETATION MONITORING

INTRODUCTION

Vegetation monitoring occurred at the “Giant Ohia” ecosystem restoration site at Makaha prior to and six months following completion of initial clearing efforts. The site encompasses approximately 0.4 acres (Figure 1) in an area generally comprised of mixed native and non-native vegetation in the understory and canopy. Restoration efforts included weeding non-native canopy and understory vegetation between August 10 and September 22, 2016, followed by seed sowing of native taxa (*Pipturis albidus*) and quarterly maintenance understory weeding. Weeding efforts were accomplished using the “clip and drip” method with chainsaws and hand saws. All weeded material was placed into large piles to leave open room for plantings, with the exception of many of the larger trees (> 7 inch diameter), which were girdled and left standing to prevent damage to surrounding native vegetation by felling and removal. Point intercept and photopoint vegetation monitoring was conducted to document change in vegetation cover, with a long term goal of obtaining < 10% non-native and > 80% native canopy cover, and < 25% non-native and > 50% native understory cover. Goals were set based on what was deemed achievable for native cover and maintainable for non-native cover at this restoration site.

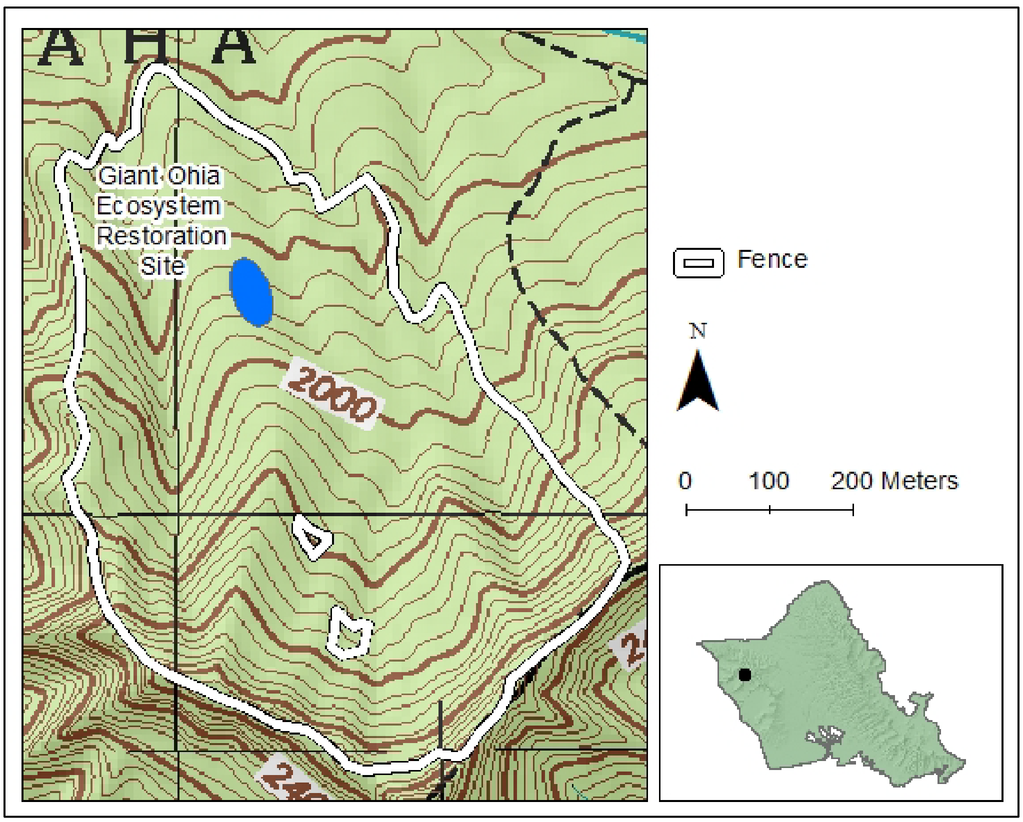


Figure 1. Location of Giant Ohia ecosystem restoration site at Makaha I MU.

METHODS

Point intercept monitoring was conducted on August 3, 2016 and March 16, 2017 to assess changes in percent cover of native and non-native taxa in the understory and canopy. All species "hit" at points along transects were recorded for understory and canopy vegetation. A 5 millimeter diameter, 6 foot tall pole was used to determine "hits" in the understory, to include live vegetation less than 2m above ground level (AGL) that touched the pole (including leaves, branches and trunks) along an outstretched measuring tape at regular intervals. A laser pointer held against the pole was used to determine laser "hits" in the canopy (above 2 mAGL) at these same intercept points, where the point fell within the perimeter of a tree's canopy. Locations where no vegetation was intercepted was recorded as non-vegetated. Locations of transects and sampled points were not permanent. Approximately 500 (or more) points were planned based on a priori analysis of a sample size necessary to detect a 10% change with a power of 0.90 using G* Power Version 3.1.9.2. Point intercepts were located every 0.5 m along 11 transects spaced 5 m apart with 630 total point intercepts in August 2016, and along 9 transects spaced 6 m apart with 547 total point intercepts in March 2017. Approximations of percent cover were obtained from the proportion of "hits" among all intercepts. Because infrequent and/or low cover taxa are less likely to be accounted for using point intercept monitoring, a list was made of all taxa anecdotally observed during the course of monitoring. Analysis included Pearson's chi-square tests of change in cover over time using IBM SPSS Version 24. Only absolute cover changes > 10% were analyzed to mitigate the probability of detecting a change when none exists (Type I error), and $\alpha = 0.05$ was used for significance determinations. Prediction maps[1] of taxa occurrence were created using Geostatistical Analyst, ArcGIS 10.3.

Photopoint monitoring was conducted on August 2, 2016, October 3, 2016, and March 20, 2017, to provide representative visual documentation of vegetation change. Four permanent photopoints were established throughout the site, marked with flagged and tagged PVC poles. Photographs were taken in each cardinal direction at each photopoint.

RESULTS

Canopy: Prior to weed clearing, the Giant Ohia site consisted of 88% non-native canopy cover, dominated by *Psidium cattleianum*, largely intermixed with 67% native canopy cover, primarily *Psydrax odorata*, *Acacia koa*, and *Metrosideros polymorpha* (Tables 1 and 2, and Figures 2 through 7). Less than 1% of the area lacked canopy cover. Weed clearing significantly reduced non-native canopy cover to 7%, and *P. cattleianum* from 86% to 3%, and increased non-canopied area to 23%.

Understory: Before clearing, the understory included 30% non-native cover, also dominated by *P. cattleianum*, partially intermixed with 21% native cover, primarily *Alyxia stellata* and *P. odorata*. More than half (53%) of the understory was non-vegetated. Similarly, clearing resulted in a significant decrease in non-native cover to < 1%, as well as *P. cattleianum* from 29% to < 1%, and an increase in non- vegetated area to 79%.

Species composition: During point intercept monitoring, sixteen native and eight non-native taxa were recorded in either the canopy or understory pre-clearing, while fourteen native and five non-native taxa were identified in either the canopy or understory six months post-clearing. An additional six taxa were observed but not intercepted during monitoring pre-clearing, (three native and one non-native), while nineteen were observed but not intercepted six months post-clearing (six native and thirteen non-native) (Table 3). Species composition changes included thirteen (77% non-native) taxa newly observed post-clearing during either point intercept monitoring or anecdotal observations, and six (83% native) taxa observed pre-clearing during either point intercept monitoring or anecdotal observations but not identified post-clearing, in either the canopy or understory (Table 4). One additional non-native taxon not observed on either of the monitoring dates (*Ageratina riparia*) was controlled during maintenance weeding.

Table 1. Native, non-native, and non-vegetated percent cover before and six months following weed removal at the Giant Ohia restoration site, Makaha. P-values derived from Pearson's chi-square test (asymptotic significance). Only taxon groupings with an absolute cover change of > 10% were analyzed. Positive values for cover change denote increased cover, while negative values indicate decreased cover.

	Pre-clearing	Post-clearing	p	X^2	Absolute cover change	Management goals currently met?
Understory						
Non-native	29.84	0.73	0.000	181.74	-29.11	Yes
Native	20.79	20.29				No
Non-vegetated	52.86	78.98	0.000	87.79	26.12	
Canopy						
Non-native	88.25	7.13	0.000	770.84	-81.12	Yes
Native	67.14	74.41				No
Non-vegetated	0.48	22.85	0.000	151.24	22.37	

Table 2. Species cover before and six months following weed removal at the Giant Ohia restoration site, Makaha. Native taxa in boldface. Positive values for cover change denote increased cover, while negative values indicate decreased cover. P-values derived from Pearson Chi-square (asymptotic significance) test. Only taxa with > 10% absolute cover change were analyzed.

Taxon	Pre-clearing	Post-clearing	Cover change	p	X^2
Understory					
Acacia koa	0.16	3.29	3.13		
Alyxia stellata	11.27	7.86	-3.41		
Bobea elatior	0.16	0.00	-0.16		
Carex wahuensis	0.48	0.55	0.07		
Clidemia hirta	0.16	0.00	-0.16		
Coffea arabica	0.16	0.00	-0.16		
Coprosma foliosa	0.79	0.00	-0.79		
Cordyline fruticosa	0.32	0.37	0.05		
Crassocephalum crepidoides	0.00	0.18	0.18		
Diospyros sandwicensis	0.32	0.37	0.05		
Dodonaea viscosa	0.00	0.18	0.18		
Doodia kunthiana	0.32	0.37	0.05		
Euphorbia multiformis	0.00	0.18	0.18		
Kadua affinis	0.32	0.00	-0.32		
Lepisorus thunbergianus	0.00	0.18	0.18		
***Melicope* sp.**	0.16	0.00	-0.16		
Metrosideros polymorpha	0.00	0.91	0.91		
Microlepia strigosa	0.79	0.91	0.12		
Psidium cattleianum	28.73	0.18	-28.55	0.000	182.53
Psychotria mariniana	0.16	0.00	-0.16		
Psydrax odorata	7.62	6.58	-1.04		
Schinus terebinthifolius	0.16	0.00	-0.16		
Syzygium cumini	0.32	0.00	-0.32		
Canopy					
Acacia koa	30.32	31.81	1.49		
Aleurites moluccana	0.48	0.00	-0.48		
Alyxia stellata	9.05	5.30	-3.75		
Bobea elatior	2.06	1.46	-0.60		
Cocculus orbiculatus	0.16	0.00	-0.16		
Cordyline fruticosa	0.16	0.00	-0.16		
Diospyros sandwicensis	6.35	4.75	-1.60		
Dodonaea viscosa	0.63	1.46	0.83		
Grevillea robusta	1.27	0.00	-1.27		
Kadua affinis	0.48	0.00	-0.48		
Metrosideros polymorpha	13.33	21.21	7.88		
Nestegis sandwicensis	2.86	1.10	-1.76		
Psidium cattleianum	86.03	3.11	-82.92	0.000	807.35
Psychotria mariniana	1.90	1.65	-0.26		
Psydrax odorata	34.60	44.42	9.82		
Schinus terebinthifolius	1.27	2.01	0.74		
Syzygium cumini	2.70	2.01	-0.69		

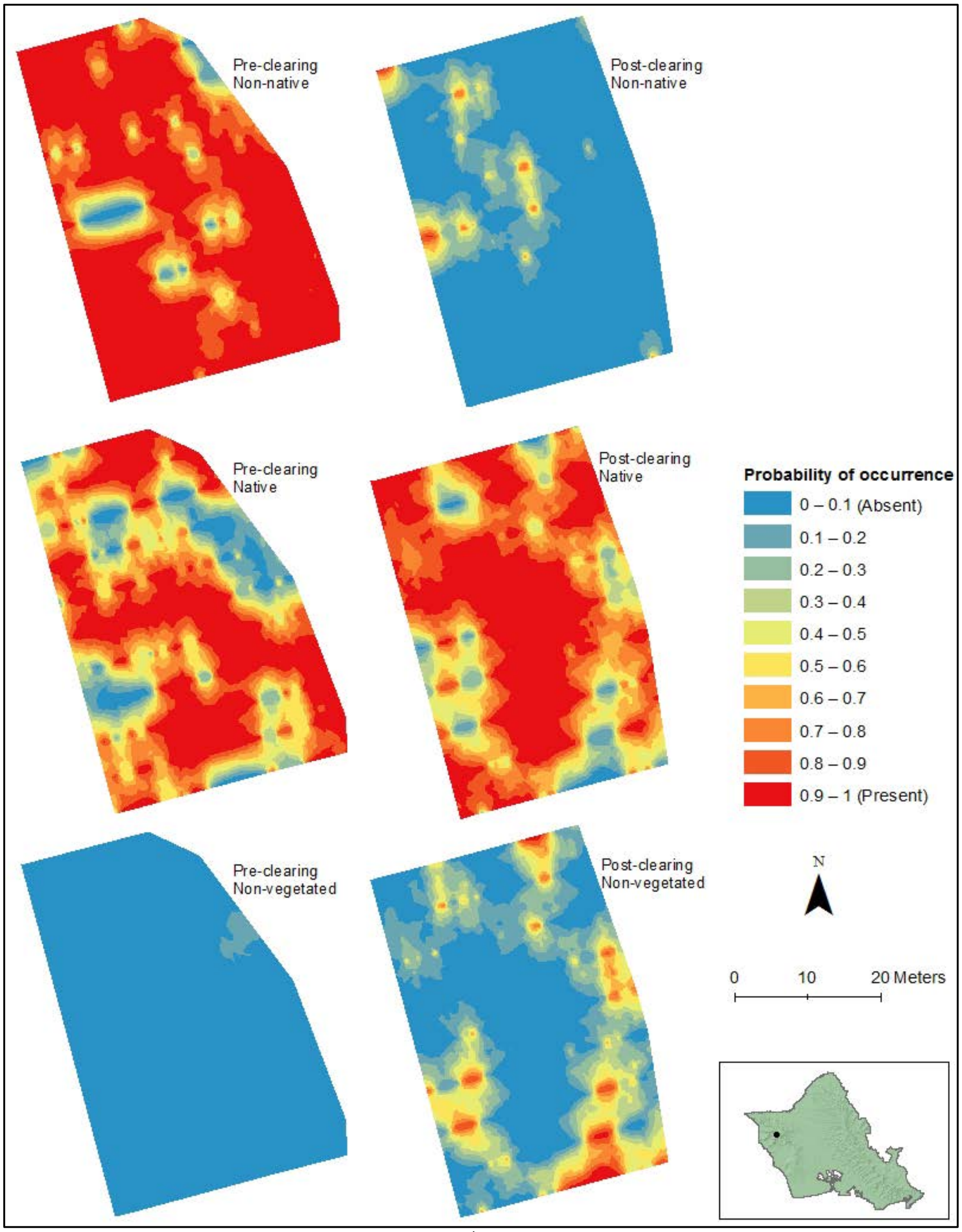


Figure 2. Ordinary kriging predicted locations[1] of canopy taxa prior and six months following weed clearing, showing overall non-native and native cover as well as non-vegetated areas. Probability of occurrence is scaled from zero (contours shown in blue, indicating absence) to one (contours shown in red, indicating presence). Predictions extend to the outer extent of transect locations, thus map shapes differ as a result of small differences in transect locations and lengths pre- and post-clearing.

[1]*Maps created using statistical methods in association with geographic information to show predicted locations of one or more variables, with the probability of occurrence indicated by color coded values. This technique maps probable, not actual, distributions. Known locations are used to predict presence/absence in unsampled locations. When used in association with point intercept data, locations of taxa and taxon groupings with higher cover, particularly those that tend to occur in clusters, may be more accurately predicted. Those with low cover and spotty distributions will have considerably less certainty when mapped.*

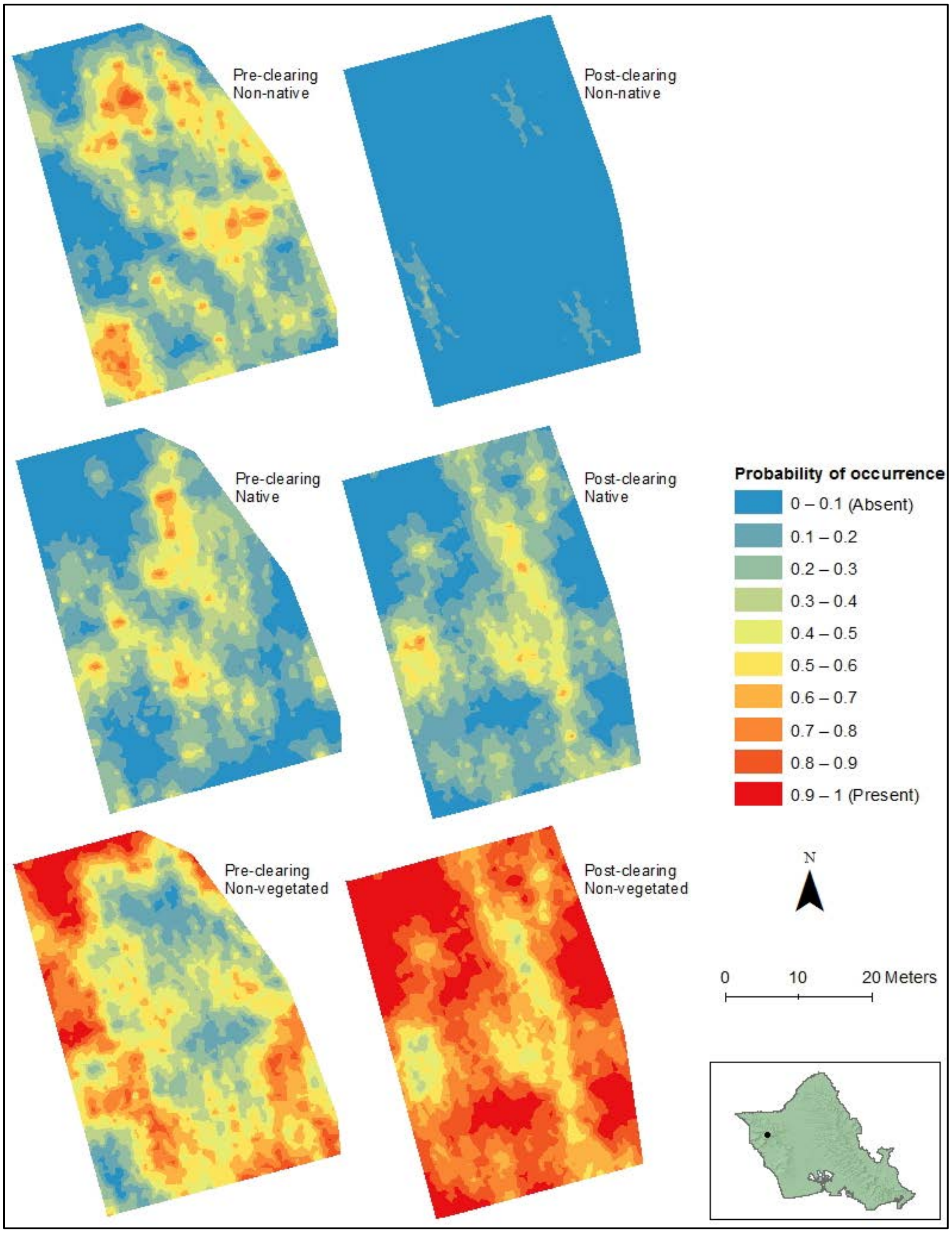


Figure 3. Ordinary kriging predicted locations of understory taxa prior to and six months following weed clearing, showing overall non-native and native cover as well as non-vegetated areas. Probability of occurrence is scaled from zero (contours shown in blue, indicating absence) to one (contours shown in red, indicating presence). Predictions extend to the outer extent of transect locations, thus map shapes differ as a result of small differences in transect locations and lengths pre- and post-clearing.

Pre-clearing *< 1 month post-clearing* *6 months post-clearing*

Figure 4. Photopoint 1 pre-clearing (left column), within one month post-clearing (middle column), and six months post-clearing (right column), with views to the north, east, south, and west, from top to bottom.

Pre-clearing | *< 1 month post-clearing* | *6 months post-clearing*

Figure 5. Photopoint 2 pre-clearing (left column), within one month post-clearing (middle column), and six months post-clearing (right column), with views to the north, east, south, and west, from top to bottom.

Pre-clearing | *< 1 month post-clearing* | *6 months post-clearing*

Figure 6. Photopoint 3 pre-clearing (left column), within one month post-clearing (middle column), and six months post-clearing (right column), with views to the north, east, south, and west, from top to bottom.

Pre-clearing *< 1 month post-clearing* *6 months post-clearing*

Figure 7. Photopoint 4 pre-clearing (left column), within one month post-clearing (middle column), and six months post-clearing (right column), with views to the north, east, south, and west, from top to bottom.

Table 3. Taxa observed, but not intercepted, during monitoring prior to and six months after initial weed clearing in the understory and/or canopy. Native taxa in boldface. *Intercepted during post-clearing monitoring. **Intercepted during pre-clearing monitoring.

Pre-clearing	Post-clearing
Asplenium nidus	***Asplenium caudatum***
Euphorbia multiformis	*Aleurites moluccana***
Lepisorus thunbergianus*	*Blechnum appendiculatum*
Nephrolepis exaltata* subsp. *hawaiiensis	*Clidemia hirta***
Phlebodium aureum	*Coffea arabica***
Planchonella sandwicensis	*Conyza bonariensis*
	Emilia sonchifolia
	Kadua affinis**
	Korthalsella complanata
	***Melicope* sp.** **
	Paspalum conjugatum
	Passiflora edulis
	Phlebodium aureum
	Pipturis albidus
	Psilotum nudum
	Rubus rosifolius
	Spathodea campanulata
	Toona ciliata
	Trema orientalis

Table 4. Species composition changes, showing newly recorded, and no longer identified, taxa from point intercept monitoring and anecdotal observations in the canopy and/or understory six months post-clearing, with percent cover values indicated for intercepted taxa. Native taxa are in boldface.

Taxa recorded pre-clearing but not post-clearing	Cover	New taxa recorded post-clearing	Cover
Asplenium nidus		***Asplenium caudatum***	
Cocculus orbiculatus	0.16	*Blechnum appendiculatum*	
Coprosma foliosa	0.79	*Conyza bonariensis*	
Grevillea robusta	1.27	*Crassocephalum crepidoides*	0.18
Nephrolepis exaltata* subsp. *hawaiiensis		*Emilia sonchifolia*	
Planchonella sandwicensis		***Korthalsella complanata***	
		Paspalum conjugatum	
		Passiflora edulis	
		Pipturis albidus	
		Rubus rosifolius	
		Spathodea campanulata	
		Toona ciliata	
		Trema orientalis	

DISCUSSION

Weed removal and maintenance successfully altered vegetation at the Giant Ohia restoration site at Makaha such that management goals for non-native cover were met for the canopy, and far surpassed for the understory. Though goals were not met for native canopy or understory, it is anticipated that those changes will occur gradually over time, particularly in the canopy, and that progress toward those objectives will be made by one year following clearing, at least in the understory.

While the significant reduction in non-native cover in the canopy and understory was anticipated (namely resulting from significant reductions in *P. cattleianum* dominated canopy and understory), there was also concern that weeding actions would result in an initial reduction in native cover due to the destructive nature of clearing such a large volume of non-native trees, particularly for native vines in the canopy, and native understory taxa in general. Such was the case during restoration efforts at the Kahanahaiki "chipper site," where *A. stellata* frequency dropped from 86% to 0% in the canopy and from 86% to 40% in the understory within one month following clearing (but rebounded to 45% in the canopy and 80% in the understory after five years), as so much of it was growing on and around non-native trees removed using chainsaws (OANRP 2016). Many *P. cattleianum* trees were girdled and left standing at the Giant Ohia site, and trunks and branches of dead trees remained standing six months post-weeding. This likely mitigated damage to native vegetation, as not all trees were felled and dragged off site. The low initial cover values for *A. stellata* in the canopy and understory at this site also likely minimized the impact to that species. Likewise, no change occurred in overall native understory cover.

Though the native canopy cover estimate was slightly higher six months post-clearing as compared with pre-clearing, it did not meet the 10% absolute cover change prerequisite for analysis that mitigates the potential for Type 1 errors. The increased cover estimate is primarily attributed to slight increases in estimated cover for *M. polymorpha* and *P. odorata* canopy. Increased cover over such a short amount of time, especially for slow-growing species like *M. polymorpha* and *P. odorata*, was unexpected. The canopy was so dense with *P. cattleianum* during pre-clearing monitoring, such that it was very difficult at times to see all layers of canopy vegetation, and *P. odorata* in particular could have been easily missed. Also, as the transects were not permanent, the post-clearing ones may by chance have encountered more natives as compared with pre-clearing. Slightly different results are expected with non-permanent sampling. As such, the apparent increase could be a result of human error from obstructed canopy, and/or random sampling differences. Alternatively, a small amount of increased cover could have genuinely resulted via native trees flushing out in association with seasonality (post-clearing monitoring occurred in the winter, whereas pre-clearing data was collected in the summer), and/or growth following release from competition with non-native trees for resources. Future monitoring, which will occur only around the month of September, may give a better indication of the validity of this change, if cover continues to increase over time.

Weed ingress was expected to occur rapidly in response to increased light levels following alien canopy removal, however the ingress was slower than expected. The relatively high native canopy cover may facilitate maintenance of weeds in the understory to low levels, precluding weedy incursions in expansive light gaps which could otherwise occur following the removal of dense *P. cattleianum* canopy. As some non-native trees were girdled rather than felled, this also likely promoted a gradual change in light levels, preventing flushes of weeds in response to sudden light availability.

Change in native understory cover is expected to occur gradually over the next several years. Seed sowing efforts may result in measurable changes in the understory by one to two years, as *P. albidus* was observed anecdotally post-clearing, though it had only been sown in the preceding quarter.

The canopy now has a patchy distribution of small open areas. A number of new *A. koa* seedlings were anecdotally observed in sunnier areas (but less so in canopied areas), however these newly open areas may also be more prone to weed incursion, and may be targeted for outplanting or seed sowing of native taxa that respond well to higher light levels (e.g., *P. albidus*, *Bidens torta*). The understory also has considerably more open area below native canopy, which may become colonized by shade tolerant native and non-native species, and additional restoration of shade tolerant native taxa may be targeted for those non-vegetated understory areas (e.g., *A. stellata*, ferns).

Though a number of new weedy taxa were anecdotally observed while monitoring post-clearing, their presence remained small enough to escape interception during monitoring. The larger number of non-intercepted taxa during the post-clearing monitoring also may be influenced in part by having fewer point intercepts, which slightly reduced the likelihood of interception for taxa with very low cover.

The presence of individual taxa may vary over time, particularly for short-lived species and those present in low numbers at early life stages (when they are most vulnerable to mortality). Small or infrequent taxa not intercepted during monitoring may also be overlooked during anecdotal observations. This may partially explain differences in species composition pre- and post-clearing. However, those changes were more heavily weighted towards increased diversity of non-native taxa, and to a lesser extent towards slightly reduced native diversity, suggesting an influx of diverse new weedy taxa, and the possible loss of a few native taxa, following clearing efforts. All taxa potentially no longer present, as well as those new to the site, had low cover values less than 2%, or were only anecdotally observed.

The small proportion of non-native cover remaining in the canopy indicates that a small number of non-native trees still need to be weeded. Observational notes indicated that there were a few trees that were inadvertently missed, and a few larger girdled trees were not completely defoliated. Mortality following girdling may take several months, and larger trees in particular may require a second round of treatment. These remaining trees will be cleared or retreated as needed during quarterly weed maintenance.

Future monitoring is planned for one, two and five years post-clearing during the month of September to track short term change in association with vegetation restoration. Subsequent long term monitoring plans will be evaluated after five years. Quarterly maintenance weeding is planned, as well as outplanting and seed sowing of native taxa, to enhance restoration efforts. While the bounds of the restoration area may expand over time, monitoring will recur only in previously monitored areas to track change over time from the initial phase of restoration.

REFERENCES

OANRP. 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.

Appendix 3-12

The importance of cleaning cars

Thanks for all your diligence in washing vehicles!

it IS worth it . . .

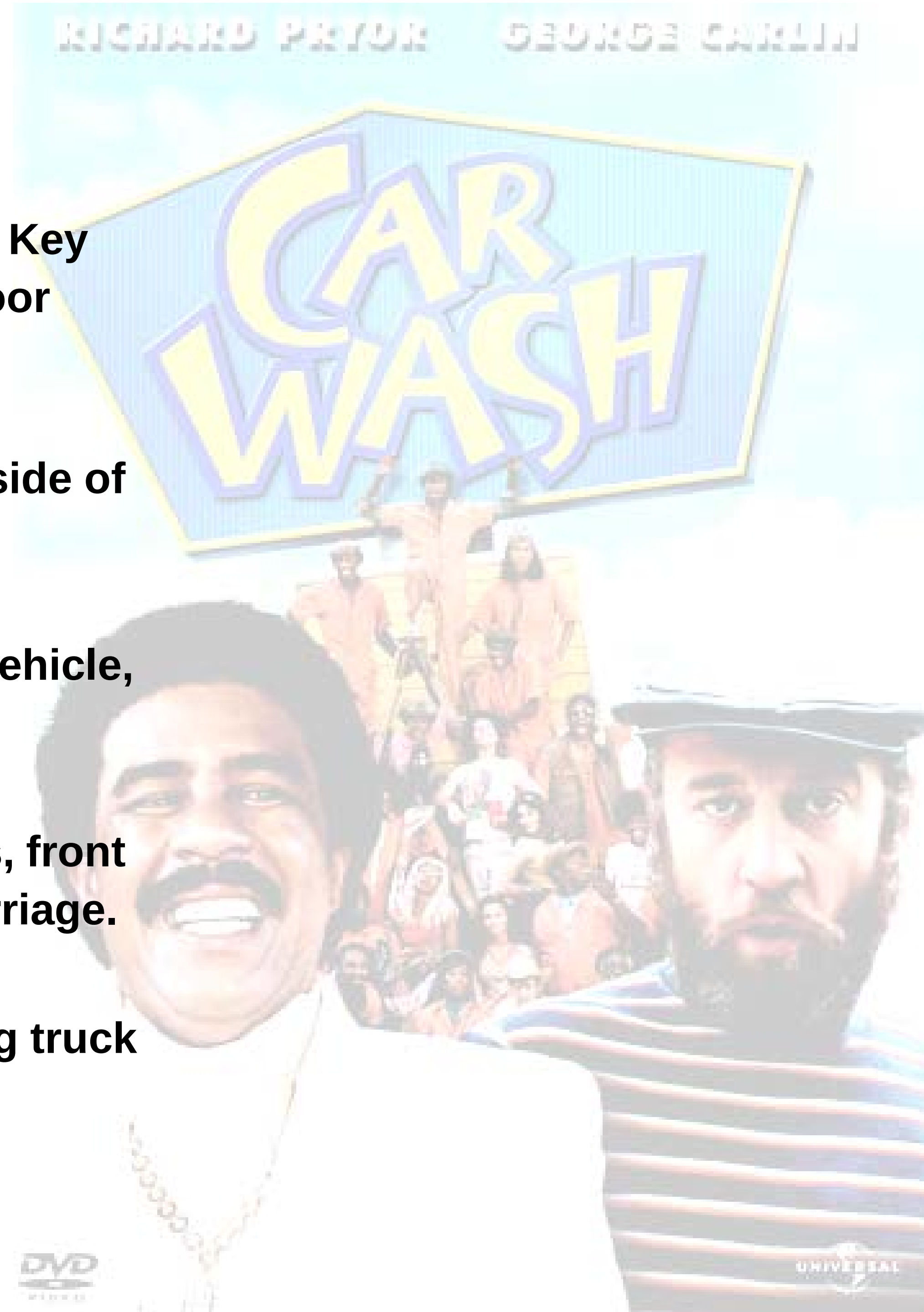

Appendix 3-12

WHEN TO WASH:

- Exterior and interior of all vehicles will be cleaned PRIOR to the FIRST day of use of the work week.
- Particularly muddy or dirty vehicles, will be cleaned immediately before returning to the field.
- Cleaning is mandatory when vehicles are driven through incipient weed infestations, particularly *Chromolaena odorata*, *Schizachyrium condensatum* and *Cenchrus setaceus* sites.
- See SOP-9 Fleet Management for more info.

Range Specific Considerations:

- We are required to ensure vehicles are CLEAN when ENTERING a range.
- All vehicles are REQUIRED to wash upon EXITING a range, particularly KTA, SBE, SBW.
- All vehicles are required to wash when moving between geographically separate locations.
    - Includes off-installation off-road areas.
    - Includes between SBS & SBW.
- If you do NOT leave the hardball road (paved or gravel only, no grassy road edges); no need to wash that day.
- If you are working in the same installation multiple days in a row; can wash at the end of last day, before heading to new work site.



- **Vacuum** **inside of car. Key areas are floor, seats, and door pockets/edges.**

- **Alternatively, sweep inside of car with brush.**

- **Clean any trash out of vehicle, interiors and truck beds**

- **Spray tires, wheel wells, front and back bumpers, undercarriage.**

- **Wash exterior, including truck beds.**

Appendix 3-12

Washing Locales

SBE Washrack

- Higgins/Santos Dumont Rd.
- Schedule on RFMSS
- Call contractor (DP&R) in morning to confirm.

All Army Washracks: No soap

Central Vehicle Washrack, Schofield

- 2175 Lyman Road
- No need to schedule!
- 8am to 4pm (last entry 2:30)
- First come, first served, but scheduled Units have priority

KTA Washrack

- 250m mauka Charlie 2 Gate
- Schedule on RFMSS
- Walk-ins fine
- In morning advise Range when expect to use WR
- Check out key from Range and use Sign In/Out sheet
- Refer to "KTA TVWF Operation Instruction.pdf" for directions (V/Forms/Wash Rack Related/)

For operational assistance or equipment failure issues, call DP&R at (808)655-5947

Or

West Base!

- Always open
- Pressure washer available
- Hose dirt off pavement into sump after washing
- No soap
- No excuse

= **only place with a vacuum**

Army Wash Rack Info:

Central Wash:

- 2175 Lyman Road, Schofield Barracks.
- Operation Hours: M-F, 0800-1600. Must enter by 1530.
- Budget half an hour.
- If washing less than 5 vehicles: first-come-first serve basis, however scheduled Unit vehicles take priority.
- Weekend, holiday or special hours must be scheduled in RFMSS 14 days in advance.
- Operational deficiencies: Call 655-1275 &/or report to tower.
- If facility completely unavailable, notify Kapua Kawelo.

East Range Wash:

- Higgins Road , ~1/4mi East of Kamehameha Highway
- Budget half an hour.
- Schedule in advance on RFMSS.
- Contractor will meet at facility at requested time. Recommend confirming with contractor in morning at 655-5947

Kahuku Wash:

- Charlie Road at KTA, ~300m inside Charlie 2 Gate.
- Operation Hours: M-F 0800-1530. NO after Hours Support.
- Budget half an hour.
- Operational Assistance & Equipment Failure Reporting: DP&R (808) 655-5947. If no one answers, call Range Control 497-6660. Notify Kapua Kawelo/Jane Beachy of major issues.
- When check in at KTA Range Desk, advise them when you expect to use the WR to confirm someone will be around to check-out/in the key from.
- Use the Sign In/Out sheet (ask for it if they don’t remember!)

Primary, secondary and invasive species proposed for management at Pohakuloa Training Area

Ambrosia artemisiifolia

- A.k.a: Common Ragweed
- Non-native: naturalized
- Family: Asteraceae
- This plant is a summer annual up to 3' tall that branches frequently. The hairy stems are green to light pinkish red. The leaves are up to 6" long and 4" across, and are opposite or alternate along the stems. They are deeply pinnatifid, broadly lanceolate (in outline), and usually much wider at the base than the tip. Mature leaves are relatively hairless, but small emergent leaves often have hairs on their undersides. Many of the upper stems terminate in one or more cylindrical spikes of flowers about 1-4" long. Near the base of the central flowering spike, one or two small spikes may develop that are only half as long. The small flowers are initially green, but later turn yellowish green or brown as they mature and develop into achenes. Each flower is about 1/8" long, the males producing a fine yellow pollen that is easily carried by the wind. Numerous seeds are produced, which can remain viable for 5 years or more. The extensive root system is fibrous

Help. I don't know what that means.

Achene: a small, dry, one-seeded fruit that does not open to release the seed

WRA Score and designation: N/A

* More information about this system on final slide of this presentation

Centaurea melitensis

- A.k.a: Napa thistle, yellow star thistle, Malta Star thistle
- Non-native: naturalized
- Family: Asteraceae
- This is a winter annual with a yellow-flowered, spiny head that can reach a height of 3.3 ft (1m). Leaves are alternate, linear or narrowly oblong with smooth, toothed margins. Leaf bases are decurrent and give the stems a winged appearance. Flowers are yellow, 0.5in (1.3cm) across and surrounded by sharp, tan, spiny cobwebbed bracts. The fruit are 0.08-0.12 in (2-3 mm) in length, grayish to tan in color with deeply notched bases and tan bristles that are 0.04-0.12in (1-3mm) long. This plant is native to Europe and North America and prefers disturbed areas such as grasslands, open woodlands, roadsides, fields and pastures.

WRA Score and designation: 18, High Risk, H(HPWRA)

Cirsium vulgare

- A.k.a: pua kala, bull thistle, spear thistle
- Non-native: naturalized
- Family: Asteraceae
- Herbaceous plant that invades disturbed areas. The spiny, spreading, winged stems are up to 7ft (2.1m) tall. Leaves are 3-12 in (7.6-30.5 cm) long, lance-shaped and very hairy. Flowers develop, at the apex of the plant. The purple/pink to rose colored flower heads are 1.5-2 (3.8-5.1cm) in diameter with narrow, spine-tipped bracts. Fruits have several bristles on the tip and are up to 0.2in (5mm) long. Native to Europe, western Asia and northern Africa. Can invade almost any type of disturbed area, such as forest clear cuts, riparian areas and pastures. Plants can form dense thickets, displacing other vegetation.

WRA Score and designation: 18.5, High Risk, H(HPWRA)

Datura stramonium

Appendix 3-14

- A.k.a: jimson weed, Devil's snare, thorn apple
- Non-native: naturalized
- Family: Solanaceae
- Annual herb which grows up to 5 feet tall. It has a pale green stem with spreading branches. Leaves are ovate with green or purplish coloration, coarsely serrated along edges and 3-8 inches long. Flowers are white or purple with a 5-pointed corolla up to four inches long and set on short stalks in the axils of branches. Seeds are contained in a hard, spiny capsule,, about 2 inches in diameter, which splits lengthwise into four parts when ripe.
- All parts of this plant are poisonous to humans and animals. Do not eat.

WRA Score and designation: N/A

Delairea odorata also called Senecio mikanioides

- A.k.a: Cape ivy, german ivy
- Non-native: naturalized
- Family: Asteraceae
- Non-woody vine with thin but slightly fleshy, glossy leaves with angular lobes. The flowers are yellow and daisy-like, but lacking conspicuous petals, sweet-scented and are produced in winter or early spring. Seed is small, with a ‘parachute’ of fine hairs to assist its dispersal. The plant climbs into the lower branches of trees, smothers smaller plants such as shrubs and can carpet the ground so thoroughly as to exclude all other plants. Typically on forest edges, around towns/old farms, often along rivers and roadsides.
- Can reproduce vegetatively from stem segments dumped or transported by floods. Hand-pull young plants or cut through stems and leave upper parts to die off in place. Spray regrowth, adding a surfactant to improve penetration of the waxy leaves.

WRA Score and designation: 14, High Risk, H(Hawai’i)

Emex spinosa

- A.k.a: Spiny emex, devil's thorn, prickly doc
- Non-native: naturalized
- Family: Polygonaceae (Buckwheat family)
- Glabrous, monoecious annual, plants decumbent to ascending, the stems 3-8 diameter long; leaves alternate, oblong-ovate to somewhat triangular, with scarious sheathing stipules, 5-12 cm long; flowers small, in axillary, staminate flowers sessile and with 5-6 parted calyx and narrow segments. Fruiting calyx hard, 3 or 6 angled, bur-like, the outer segments spine tipped 5-6 mm long.

Help. I don't know what that means.

Scarious: thin, dry and membranous in texture

WRA Score and designation: N/A

Eschscholzia californica

- A.k.a: California poppy
- Non-native: naturalized
- Family: Papaveraceae
- Feathery, highly-dissected, blue-green leaves clasp the 1-2ft stems of this popular, perennial wildflower. Showy, 1-3 in. wide, four-petaled flowers are open only on sunny days. The flowers are solitary and long-stalked and vary in color from orange to yellow. Each of the satiny petals ahs a deep-orange spot at its base. Easy to grow, drought tolerant and reseeds readily.

WRA Score and designation: 14, high risk, H (HWPWRA)

Foeniculum vulgare

- A.k.a: Fennel
- Non-native: naturalized
- Family: Apiaceae
- Upright, branching perennial that is typically grown in vegetable and herb gardens for its anise-flavored foliage and seeds. Grows 3-5 feet tall and has feathery, compound, aromatic yellow-green leaves with needle-like segments and tiny yellow flowers in large, flattened, compound umbels

WRA Score and designation: 19, High Risk, H(HPWRA)

Heteromeles arbutifolia

- A.k.a: Toyon
- Non-native: naturalized
- Family: Rosaceae
- A California native evergreen shrub that typically grows into a dense plant to 10 feet tall and 8 feet wide. Grey bark, either smooth or fissured. Leaves are leathery, 2-4 inches long, oblong and are serrated along the margins. Small white mildly fragrant flowers in terminal clusters produce bright red pea sized berries. Hollywood was named for this plant.

WRA Score and designation: 9, High Risk, H (HWPRA)

Kalanchoe tubiflora

- A.k.a: Bryophyllum tubilora, Kalanchoe delagoensis, Chandelier plant
- Non-native: naturalized
- Family: Rosaceae
- Erect, pinkish stems thickly hung with pendant cylindric dark leaves spotted reddish brown and emerald and tipped with notches nurturing bungles of plantlets; showy clusters of pale red bellflowers. Native of Madagascar.

WRA Score and designation: N/A

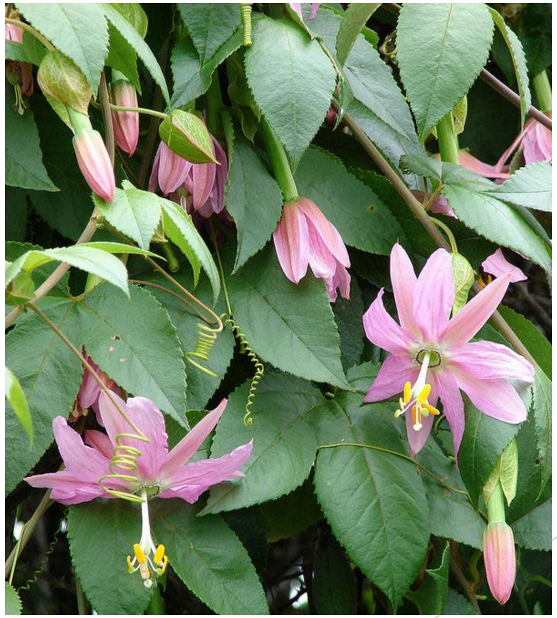
Parthenium hysterophorus

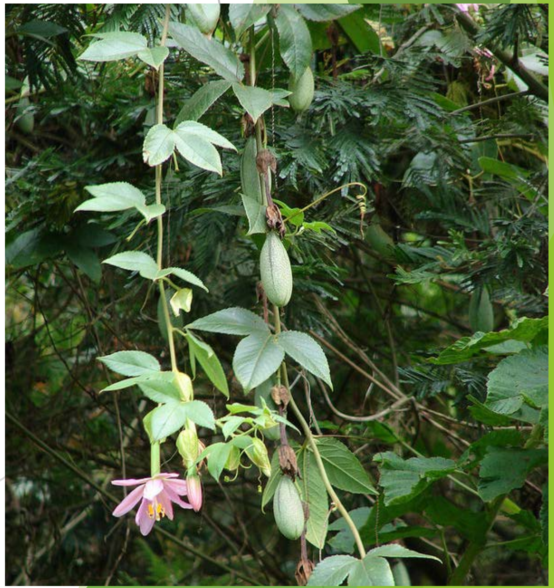
- A.k.a: False ragweed, Santa Maria
- Non-native: naturalized
- Family: Asteraceae
- Much branched, short-lived (annual), upright herbaceous plant that forms a basal rosette of leaves during the early stage of growth. Grows 0.5-1m tall. Mature stems are greenish and longitudinally grooved, covered in small stiff hairs (hirsute) and become much branched at maturity. The alternately arranged leaves are simple with petioles up to 2cm long and form a basal rosette during the early stages of growth. Lower leaves are relatively large (3-30cm) while leaves on upper branches decrease in size and are less divided than the lower leaves. Numerous small white or cream colored flower-heads are arranged in clusters at the tips of branches. They are surrounded by two rows of small green bracts whose colour changes to light brown when seeds are mature and about to shed.

WRA Score and designation: N/A

Passiflora tarminiana

- A.k.a: Banana poka, banana passionfruit, bananadilla, banana passion flower
- Non-native: naturalized
- Family: Passifloraceae
- A climbing vine possessing trilobed, serrated leaves with soft, downy undersides, always hairless on top. Flower pendent, sepals and petals light pink to bright pink, floral tube light green, bracts ovate, fruit fusiform, growing larger at high elevations to 150g. Pericarp soft and yellow to yellow-orange; pulp orange; numerous black seeds. Newly described species, formerly included with the species P. mollissima





WRA Score and designation: 24, High Risk, H(Hawai'i)

Piptatherum miliaceum

- A.k.a: Smilo grass, rice millet, Oryzopsis
- Non-native: naturalized
- Family: Poaceae
- A clumping perennial grass producing sturdy, erect stems that can reach 1.5m tall. The inflorescence is a panicle of several whorls of branches that divide into secondary branches bearing clusters of spikelets.

WRA Score and designation: 7, High risk, H (HPWRA)

Portulaca pilosa

- A.k.a: Pink purslane, kiss-me-quick, Chisme, hairy pigweed
- Non-native: naturalized
- Family: Portulacaceae
- Succulent, sprawling, wooly stems reach 20cm in length and branch to form low irregular mounds or mats. The small purplish to reddish flowers are surrounded by long hairs and are followed by shiny capsule with many black shining seeds. Plants that grow in a moister environment tend to have less hairs than plants that grow in an arid environment. Leaves terete (cylindrical) and alternate, although uppermost leaves are whorled. Flowers are deep rose-red to purple, 4 or 5-petalled.

WRA Score and designation: N/A

Rhamnus californica

- A.k.a: Coffeeberry, California buckthorn
- Non-native: naturalized
- Family: Rhamnaceae
- 2-6 feet tall, compact evergreen shrub with red-purple stems. Likes sun to part shade and has low water requirements. Leaves simple, generally alternate. Often clustered on short-shoots. Clusters of berries, beginning green ripening to orange/red and finally black. Bark is bright gray or brown, twigs glabrous to finely hairy. Leaves are light green when young, maturing to dark green often with red tips, smooth, leathery, 2-4 inches long. Edges curl under during dry periods. Flowers are white, star-shaped sepals only.

WRA Score and designation: N/A

Rubus niveus

- A.k.a: Mysore raspberry, hill raspberry, Ceylon raspberry
- Non-native: naturalized *Known to have two forms. F. a with mostly white stems and f. b with mostly red stems
- Family: Rosaceae
- A large perennial shrub growing up to 4.5 m in height that may form dense thickets of intertwining stems. The flexible, arching stems may be downy when young but become glabrous and glaucous at maturity. They are covered with sharp, hooked thorns 3-7mm long. Leaves are pinnately compound into 5-9 serrated, elliptic-ovate leaflets. The leaves are dark green and glaucous above and white tomentose below. The inflorescences are short, axillary or terminal panicles of 24 or more flowers which are pink to rose purple. The fruit is 1-2cm in diameter with a purple-black colour. It is juicy and sweet with small seeds and may be produced throughout the year.

Help. I don’t know what that means.

Glaucous: of a dull grayish-green or blue color

Tomentose: covered with densely matted wooly hairs

WRA Score and designation: 19, High Risk, H(HPWRA)

Salsola tragus

- A.k.a: Tumbleweed, Russian thistle, Windwitch
- Non-native: naturalized
- Family: Chenopodiaceae
- A noxious bushy summer annual that grows to approximately 1m in height and width and after flowering and drying out, the plant breaks at the soil line and becomes a ‘tumbleweed’ and is blown about, thereby dispersing the upward of 250k seeds in the mature plant. The mature plant has stiff, needle-like upper stem leaves that alternate.

Salsola kali

WRA Score and designation: N/A

Sambucus mexicana

- A.k.a: Mexican elderberry, blue elderberry
- Non-native: naturalized
- Family: Adoxaceae (formerly Caprifoliaceae)
- A deciduous shrub that grows 15 to 30 ft. The leaves are opposite, pinnately compound, 6 to 10 inches long, 5 to 9 leaflets, narrowly ovate or lanceolate, unequal at base, coarsely serrate, bright green. Umbellated clusters of small white flowers in late spring followed by clusters of dark blue to purple fruit which are edible.

Help. I don't know what that means.

Umbellate: an inflorescence in which a number of flower stalks or pedicels, nearly equal in length, spread from a common center.

WRA Score and designation: 9, High Risk, H(HPWRA)

Schinus molle

- A.k.a: California pepper tree, peruvian pepper tree
- Non-native: naturalized
- Family: Anacardiaceae
- Evergreen tree, open spreading canopy with yough branches strongly pendulous. Foliage is aromatic, odd pinnately compound. Yellow green flowers in terminal panicles, fruit rose colored, small and rounded in clustered, elongated panicles, strongly aromatic. Dried fruit is called ‘pink peppercorn’ because of the peppery flavor.

WRA Score and designation: 10, High risk, H(HPWRA)

Senecio madagascariensis

- A.k.a: Fireweed
- Non-native: naturalized
- Family: Anacardiaceae
- Daisy-like herb that grows up to 2’ high. The stem is upright and slender with bright green leaves. The leaves are smooth, very narrow (only ¼” wide), have serrated edges and they reach about 5” long. The small yellow flowers have 13 petals and are about the size of a nickel. The mature flowers turn into white thistle-like downy seed balls.

WRA Score and designation: 23, High risk, H (Hawai’i)

Tribulus terrestris

- A.k.a: Puncture vine, goathead
- Non-native: naturalized
- Family: Zygophyllaceae
- Plants grow prostrate over open ground, but when shaded or competing with other plants can grow nearly erect. Stems occasionally grow over 3 feet (1m long), have many branches, are green to reddish brown and spread radially from the crown. Stems and leaves are covered with hairs. Flowers are bright yellow and are produced singly where the stem and leaf stalk meet. The fruit, a woody five-lobed bur, is gray to yellowish tan, hairy. Fruits separate at maturity into five (sometimes four) wedge-shaped nutlets, each with two stout spines and several short prickles. Each nutlet usually encloses three to five seeds.

WRA Score and designation: 11, High Risk, H(HPWRA)

Other plants

- Acacia mearmsii
- Asclepias physocarpa
- Cenchrus setaceus
- Cupressus species
- Festuca arundinaceae
- Grevillea robusta
- Lantana camara
- Leucaena leucocephala
- Lophospermum erubescens
- Melinis munutiflora
- Nicotiana glauca
- Nicotiana tabacum
- Olea europea
- Pluchea carolinensis
- Prosopis pallida
- Psidium guajava
- Ricinus communis
- Rubus rosifolius

Weed Risk Assessments for Hawaii and Pacific Islands

- Hawaii-Pacific Weed Risk Assessment (HP-WRA) helps identify plants that pose a high weed risk. The score does notmeasure actual invasiveness or economic or ecological harm in the field. It is a prediction of whether a species will become invasive. This only considers published information on invasiveness in Hawaii or elsewhere and does not include an actual ‘in-the-field’ evaluation.

Hawaii-Pacific Weed Risk Assessment (HP-WRA) helps identify plants that pose a high weed risk. The score does not measure actual invasiveness or economic or ecological harm in the field. It is a prediction of whether a species will become invasive. This only considers published information on invasiveness in Hawaii or elsewhere and does not include an actual ‘in-the-field’ evaluation.

WRA designation and meaning

- L - Not currently recognized as invasive in Hawaii and not likely to have major ecological or economic impacts on other Pacific Islands
- L(Hawai’i) – Not currently recognized as invasive in Hawaii based on a track record of not becoming naturalized despite being widely planted in Hawaii for at least 40 years
- H (HPWRA) – Likely to be invasive in Hawaii and on other Pacific Islands as determined by the HP-WRA screening process which is based on published sources describing species biology and behavior in Hawaii and/or other parts of the world
- H (Hawai’i) – Documented to cause significant ecological or economic harm in Hawaii, as determined from published information on the species’ current impacts in Hawaii
- Evaluate – The species has been assessed using the HP-WRA system; however, no assessment of risk can be provided at this time because 1) important information is missing from the assessment or 2) the species possesses a combination of traits and characteristics that make its likely behavior difficult to assess using the WRA system.

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October 26, 2016

Notice: Likely Melastomaceae Seed Contamination of cinder

In September 2016, OANRP staff discovered Melastomaceae seedlings growing out of potting media at both our nursery at Schofield Barracks and at the Nike Nursery Facility in the northern Waianae Mountains. In all, about 20 seedlings have been found. In order to positively identify the species, several keiki are being grown out to flowering stage to allow for definitive identification. Thus far, it appears to be some type of *Tibouchina* or possibly a *Melastoma.* Both genera are on the Hawaii Noxious Weed list.

We strongly suspect the cinder in our media is the source of the *Tibouchina* contamination. We are currently in the process of bare-root cleaning and transplanting all 2,400 of the plants we still hope to outplant this year, as we don’t want to introduce *Tibouchina* anywhere, much less remote native forest.

Why do we think the cinder is the source of the contamination?

- Pots were all brand new
- Potting media kept indoors
- Potting media mix made up of cinder (Big Island), Sunshine Mix #4 (Canada), Perlite (Oregon, extreme heat used in manufacturing), and Vermiculite (purchased in 2014, unlikely source). Both *Tibouchina* and *Melastoma* are not known from North America, according to www.cabi.org.
- Shade houses fully enclosed (therefore birds unlikely disperser)
- No known, extant populations of *Tibouchina* or *Melastoma* within 10 miles of our greenhouses
- *Tibouchina* and other Melastomaceae are established on the Big Island.

This is the first time we’ve found such Melastomaceae contamination in our nursery in more than 10 years of operation. We suspect that the contaminated cinder was part of a purchase made in May or September of this year. In future, we will not use cinder as part of our media. We have discussed the issue with the vendor, and also have notified HDOA.

We strongly encourage other programs examine their greenhouses, potting media, and any plants destined for outplanting for similar contamination. Also, it may be prudent to monitor the sites of previous reintroductions for *Melastomaceae* keiki and other pests. If *Tibouchina* seeds can make their way to Oahu, a pathway may exist for other noxious pests too.

Please contact Dan Sailer (dksailer@gmail.com), Joby Rohrer (jobriath.l.rohrer.ctr@mail.mil) or Jane Beachy (beachy@hawaii.edu) for more information

Left: Melastomaceae seedling sprouting out of pilo pot

Right: 3-4 month old Melastomaceae, being grown for identification

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February 22, 2016

Updated Notice: *Tibouchina longifolia* Seed Contamination of Cinder

In September 2016, OANRP staff discovered Melastomaceae seedlings growing out of potting media at both our nursery at Schofield Barracks and at the Nike Nursery Facility in the northern Waianae Mountains. In all, about 30 seedlings were found. This species has been identified as *Tibouchina longifolia* both by Bishop Museum herbarium staff and via genetic analysis by Dr. Cliff Morden’s lab. The entire *Tibouchina* genus is on the Hawaii Noxious Weed list.

Tibouchina longifolia is currently only known from the Hilo and Puna regions of the Big Island. This is the first documented instance of it growing on O‘ahu. The Hawaii-Pacific Weed Risk Assessment score for *T. longifolia* is 8, giving it a ‘High Risk’ rating. The very fact that it spread to O‘ahu suggests this taxa has invasive potential.

We strongly suspect the Big Island-produced cinder in our media was the source of the *T. longifolia* contamination. Since this discovery, we bare-root cleaned and transplanted all potentially contaminated plants to prevent accidental introduction of *T. longifolia* into any of our work sites. This is the first time we’ve found such Melastomaceae contamination in our nursery in more than 10 years of operation. We suspect that the contaminated cinder was part of a purchase made in May or September of this year. We no longer use cinder as part of our media. We have discussed the issue with the vendor, and also have notified HDOA.

We strongly encourage other programs examine their greenhouses, potting media, and any plants destined for outplanting for similar contamination. Also, it may be prudent to monitor the sites of previous reintroductions for *Tibouchina longifolia* keiki and other pests. If *Tibouchina* seeds can make their way to Oahu, a pathway may exist for other noxious pests too.

Please contact Dan Sailer (dksailer@gmail.com), Joby Rohrer (jobriath.l.rohrer.ctr@mail.mil) or Jane Beachy (beachy@hawaii.edu) for more information

Appendix 3-16

Seedling

3-4 months

4-5 months

4-5 months

Buds, 4-5 months

Flower, 6 months

Flower, 6 months

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 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
Kahanahaiki to Keawapilau	Manage for stability	2	6	0	1	1	0	**1**	**1**	**0**	1	0	0	0	1	0	2016-05-18	No monitoring in the last year
Makua	Manage for stability	15	0	0	6	0	0	**4**	**0**	**0**	4	0	0	0	0	0	2017-02-14	Several trees have died 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	**13**	**0**	**0**	13	0	0	0	0	0	2015-05-11	No monitoring in the last year
	In Total:	73	11	0	22	1	0	**20**	**1**	**0**	20	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 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
Central Kaluaa to Central Waieli	Manage for stability	50	3	0	3	5	0	**3**	**1**	**0**	3	0	0	0	1	0	2017-02-16	Monitoring in the last year showed a decline Monitoring in the last year showed a decline
Makaha	Manage for stability	75	0	2	29	0	0	**29**	**0**	**0**	29	0	0	0	0	0	2015-12-03	No changes observed in the last year
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	5	0	**32**	**1**	**0**	32	0	0	0	1	0		
	Total for Taxon:	214	14	2	54	6	0	**52**	**2**	**0**	52	0	0	0	2	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 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
Kahanahaiki and Pahole	Manage for stability	210	66	0	210	82	22	**200**	**76**	**20**	65	26	15	135	50	5	2016-10-24	Small changes were 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	211	85	22	**201**	**79**	**20**	66	29	15	135	50	5		

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 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
Central Ekahanui	Manage for stability	20	0	0	183	136	54	**184**	**118**	**54**	61	52	42	123	66	12	2016-09-14	A new census was initiated but not yet completed
Makaha and Waianae Kai	Manage for stability	9	3	0	161	128	5	**161**	**128**	**5**	5	7	5	156	121	0	2015-10-14	A new census was initiated but not yet completed
South Huliwai	Genetic Storage	27	0	0	17	13	23	**17**	**17**	**2**	17	17	2	0	0	0	2016-10-13	A thorough census has shown a substantial decline in the seedling age class
	Out Total:	56	3	0	361	277	82	**362**	**263**	**61**	83	76	49	279	187	12		
	Total for Taxon:	266	69	0	572	362	104	**563**	**342**	**81**	149	105	64	414	237	17		

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		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Cyanea longiflora

Target # of Matures: 75 # 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 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
Kapuna to West Makaleha	Manage for stability	66	0	0	63	196	2	**61**	**196**	**2**	12	18	2	49	178	0	2017-04-17	Small changes were noted during monitoring in the last year
Pahole	Manage for stability	114	0	0	60	18	2	**59**	**15**	**2**	59	15	2	0	0	0	2017-04-10	Small changes were noted during monitoring in the last year
	In Total:	180	0	0	123	214	4	**120**	**211**	**4**	71	33	4	49	178	0		

Action Area: Out

TaxonName: Cyanea longiflora

Target # of Matures: 75 # 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 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
Makaha and Waianae Kai	Manage for stability	4	0	0	119	187	0	**116**	**130**	**0**	7	2	0	109	128	0	2017-05-23	Thorough monitoring in the last year showed a decline
	Out Total:	4	0	0	119	187	0	**116**	**130**	**0**	7	2	0	109	128	0		
	Total for Taxon:	184	0	0	242	401	4	**236**	**341**	**4**	78	35	4	158	306	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 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
Kahanahaiki	Manage reintroduction for stability	3	149	0	48	178	1	**48**	**178**	**1**	0	0	0	48	178	1	2016-04-18	A new census was initiated but not yet completed
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	**143**	**249**	**5**	0	0	0	143	249	5		

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 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
Makaha	Manage reintroduction for stability				27	172	246	**27**	**172**	**246**	0	0	0	27	172	246	2015-04-14	A new census was initiated but not yet completed
Manuwai	Manage reintroduction for stability	0	0	0	0	108	0	**0**	**79**	**0**	0	0	0	0	79	0	2017-04-25	Thorough monitoring in the last year showed a decline
	Out Total:	0	0	0	27	280	246	**27**	**251**	**246**	0	0	0	27	251	246		
	Total for Taxon:	34	288	0	170	529	251	**170**	**500**	**251**	0	0	0	170	500	251		

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 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
Kahanahaiki	Manage for stability	52	45	0	33	142	9	**33**	**142**	**9**	33	142	9	0	0	0	2016-05-13	A new census was initiated but not yet completed
Kawaiiki (Koolaus)	Manage for stability	50	0	0	13	79	2	**2**	**19**	**1**	2	19	1	0	0	0	2016-06-23	Thorough monitoring in the last year showed a decline
Opaeula (Koolaus)	Manage for stability	21	5	0	35	161	2	**35**	**161**	**2**	35	161	2	0	0	0	2016-04-27	A new census was initiated but not yet completed
Pahole to West Makaleha	Manage for stability	300	0	0	610	892	261	**330**	**484**	**97**	330	484	97	0	0	0	2016-09-22	Thorough monitoring in the last year showed a decline
	In Total:	423	50	0	691	1274	274	**400**	**806**	**109**	400	806	109	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 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
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	694	1274	274	**403**	**806**	**109**	403	806	109	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 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
Kahanahaiki to Keawapilau	Manage for stability	33	1	0	240	17	0	**185**	**9**	**0**	5	1	0	180	8	0	2017-07-06	Thorough monitoring in the last year showed a decline
Kaluakauila	Manage reintroduction for storage				15	3	0	**15**	**3**	**0**	0	0	0	15	3	0	2014-04-30	No monitoring in the last year
Kapuna	Manage reintroduction for storage				113	46	0	**113**	**46**	**0**	0	0	0	113	46	0	2014-04-29	No monitoring in the last year
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	**10**	**15**	**3**	10	15	3	0	0	0	2016-05-25	No monitoring in the last year
	In Total:	37	1	0	379	81	3	**324**	**73**	**3**	16	16	3	308	57	0		

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 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
Ekahanui	Manage for stability	14	44	0	196	23	0	**196**	**23**	**0**	2	1	0	194	22	0	2015-05-28	No monitoring in the last year
Kaluaa	Manage for stability	44	0	0	598	63	0	**499**	**39**	**0**	5	2	0	494	37	0	2017-04-12	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				88	44	0	**132**	**36**	**0**	0	0	0	132	36	0	2017-06-06	A thorough census has shown immature plants transition into mature plants
Palawai	Genetic Storage	1	0	0	24	30	0	**24**	**30**	**0**	24	30	0	0	0	0	2016-06-22	No monitoring in the last year
	Out Total:	59	51	0	910	173	0	**855**	**141**	**0**	35	46	0	820	95	0		
	Total for Taxon:	96	52	0	1289	254	3	**1179**	**214**	**3**	51	62	3	1128	152	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Dubautia herbstobatae

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 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
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	89	2	0	**133**	**4**	**0**	133	4	0	0	0	0	2016-09-27	A thorough census led to more plants being discovered
Ohikilolo Mauka	Manage for stability	1300	0	0	415	9	0	**373**	**27**	**0**	373	27	0	0	0	0	2016-09-29	Small changes were noted during monitoring in the last year
	In Total:	2070	0	0	803	11	0	**805**	**31**	**0**	805	31	0	0	0	0		

Action Area: Out

TaxonName: Dubautia herbstobatae

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 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
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	79	2	0	**52**	**2**	**0**	23	2	0	29	0	0	2017-06-13	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	2005-06-22	No monitoring in the last year
	Out Total:	6	0	0	89	6	0	**62**	**6**	**0**	33	6	0	29	0	0		
	Total for Taxon:	2076	0	0	892	17	0	**867**	**37**	**0**	838	37	0	29	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 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
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	No monitoring in the last year
North Kahanahaiki	Genetic Storage	218	0	0	115	36	0	**115**	**36**	**0**	115	36	0	0	0	0	2013-03-21	No monitoring in the last year
Puaakanoa	Manage for stability	147	10	0	120	11	0	**135**	**15**	**0**	135	15	0	0	0	0	2016-02-24	A thorough census led to more plants being discovered
	In Total:	420	15	0	333	50	0	**348**	**54**	**0**	348	54	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 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
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	No monitoring in the last year
Keawaula	Genetic Storage	69	6	0	43	1	2	**43**	**1**	**2**	43	1	2	0	0	0	2014-08-25	No 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	**977**	**277**	**68**	977	277	68	0	0	0		
	Total for Taxon:	858	26	0	1310	327	68	**1325**	**331**	**68**	1325	331	68	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 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
Kapuna to Pahole	Manage for stability	170	0	0	54	44	1	**54**	**43**	**1**	13	8	1	41	35	0	2017-05-23	Monitoring showed a slight decline
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	44	1	**54**	**43**	**1**	13	8	1	41	35	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 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 reintroduction for stability				0	0	0	**0**	**20**	**0**	0	0	0	0	20	0	2017-03-30	Plants were added to the outplanting site
Makaha	Manage reintroduction for storage				3	12	0	**2**	**7**	**0**	0	0	0	2	7	0	2017-03-22	Monitoring showed a slight decline
	Out Total:				3	12	0	**2**	**27**	**0**	0	0	0	2	27	0		
	Total for Taxon:	170	0	0	57	56	1	**56**	**70**	**1**	13	8	1	43	62	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 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
Kahanahaiki to Kapuna	Manage for stability	6	26	0	6	130	0	**5**	**138**	**0**	5	0	0	0	138	0	2017-07-06	More plants were added to the outplanting site
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	**6**	**0**	**0**	6	0	0	0	0	0	2014-01-29	No monitoring in the last year
	In Total:	12	26	0	13	130	0	**12**	**138**	**0**	12	0	0	0	138	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 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
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 monitoring 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	**9**	**55**	**0**	9	0	0	0	55	0	2017-06-14	A new census was initiated but not yet completed
Manuwai	Manage reintroduction for stability	0	0	0	0	45	0	**0**	**16**	**0**	0	0	0	0	16	0	2017-04-12	Thorough monitoring in the last year showed a decline
Mt. Kaala NAR	Genetic Storage	4	0	0	3	0	0	**2**	**0**	**0**	2	0	0	0	0	0	2017-04-25	Thorough monitoring in the last year showed a decline
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	2017-05-23	No changes observed in the last year
	Out Total:	19	0	0	20	100	0	**19**	**71**	**0**	19	0	0	0	71	0		
	Total for Taxon:	31	26	0	33	230	0	**31**	**209**	**0**	31	0	0	0	209	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Gouania vitifolia

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 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
Keaau	Manage for stability				51	0	0	**51**	**0**	**0**	51	0	0	0	0	0	2016-06-14	No monitoring in the last year
	In Total:				51	0	0	**51**	**0**	**0**	51	0	0	0	0	0		

Action Area: Out

TaxonName: Gouania vitifolia

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 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
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	**3**	**0**	**0**	3	0	0	0	0	0	2016-06-13	No monitoring in the last year
	Out Total:				3	0	0	**3**	**0**	**0**	3	0	0	0	0	0		
	Total for Taxon:				54	0	0	**54**	**0**	**0**	54	0	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 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
Haleauau	Manage for stability				1	0	0	**1**	**4**	**0**	1	0	0	0	4	0	2017-05-24	More plants were added to the outplanting site
Pahole NAR	Manage reintroduction for stability	8	0	0	2	32	0	**3**	**21**	**0**	0	0	0	3	21	0	2017-04-03	Thorough monitoring in the last year showed a decline
	In Total:	8	0	0	3	32	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 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
Makaha	Manage for stability	13	0	0	11	35	0	**11**	**34**	**0**	5	0	0	6	34	0	2017-03-22	Small changes were noted during monitoring in the last year
Pualii	Manage reintroduction for stability				16	52	0	**14**	**58**	**1**	0	0	0	14	58	1	2017-04-04	More plants were added to the outplanting site
Waianae Kai	Genetic Storage	9	0	1	0	1	0	**0**	**1**	**0**	0	1	0	0	0	0	2014-08-12	No monitoring in the last year
	Out Total:	22	0	1	27	88	0	**25**	**93**	**1**	5	1	0	20	92	1		
	Total for Taxon:	30	0	1	30	120	0	**29**	**118**	**1**	6	1	0	23	117	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 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
Keaau	Manage for stability				20	38	0	**82**	**4**	**0**	0	3	0	82	1	0	2017-06-01	More plants were added to the outplanting site
Makua	Manage for stability	4	3	0	124	20	0	**124**	**20**	**0**	16	5	0	108	15	0	2016-04-06	A new census was initiated but not yet completed
	In Total:	4	3	0	144	58	0	**206**	**24**	**0**	16	8	0	190	16	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 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
Haili to Kawaiu	Manage for stability	3	1	0	44	22	0	**117**	**5**	**0**	1	5	0	116	0	0	2017-01-24	More plants were added to the outplanting site
Manuwai	Manage reintroduction for stability				145	6	0	**102**	**8**	**20**	0	0	0	102	8	20	2017-03-14	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	238	113	9	**268**	**98**	**29**	50	90	9	218	8	20		
	Total for Taxon:	11	13	0	382	171	9	**474**	**122**	**29**	66	98	9	408	24	20		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Kadua degeneri subsp. degeneri

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 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
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
Outplanting site to be determined	Manage reintroduction for stability				0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		Outplanting site to be determined
	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 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
Alaiheihe and Manuwai	Manage for stability	60	0	0	81	64	28	**77**	**84**	**4**	19	18	4	58	66	0	2017-06-06	A thorough census has shown an increase in the immature age class
Central Makaleha and West Branch of East Makaleha	Manage for stability	47	0	0	22	10	22	**22**	**10**	**22**	22	10	22	0	0	0	2016-09-15	No changes observed 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	103	74	50	**99**	**94**	**26**	41	28	26	58	66	0		
	Total for Taxon:	278	0	0	205	174	200	**201**	**194**	**176**	143	128	176	58	66	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 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
Ohikilolo	Manage for stability	66	0	0	112	103	0	**129**	**101**	**0**	76	86	0	53	15	0	2017-03-23	More plants were added to the outplanting site
	In Total:	66	0	0	112	103	0	**129**	**101**	**0**	76	86	0	53	15	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 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
Ekahanui	Manage reintroduction for stability				6	39	0	**58**	**29**	**0**	0	0	0	58	29	0	2017-03-28	More plants were added to the outplanting site
Halona	Manage for stability	64	0	0	31	4	0	**31**	**4**	**0**	31	4	0	0	0	0	2016-06-29	A new census was initiated but not yet completed
	Out Total:	64	0	0	37	43	0	**89**	**33**	**0**	31	4	0	58	29	0		
	Total for Taxon:	130	0	0	149	146	0	**218**	**134**	**0**	107	90	0	111	44	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 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
Kahanahaiki	Genetic Storage	300	0	0	13	6	0	**1**	**0**	**0**	1	0	0	0	0	0	2016-09-20	Thorough monitoring in the last year showed a decline
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	1088	11	0	**571**	**11**	**0**	571	11	0	0	0	0	2016-09-27	Thorough monitoring in the last year showed a decline
	In Total:	2441	21	0	1305	147	0	**776**	**141**	**0**	776	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 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
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	2251	417	274	**1722**	**411**	**274**	1722	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 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
Kaluakauila	Manage reintroduction for stability				100	24	1	**100**	**24**	**1**	0	0	0	100	24	1	2016-03-30	No monitoring in the last year
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	68	7	13	**67**	**11**	**0**	21	4	0	46	7	0	2017-02-13	Small changes were noted during monitoring in the last year
Punapohaku	Genetic Storage				4	0	0	**2**	**0**	**0**	2	0	0	0	0	0	2016-05-23	Thorough monitoring in the last year showed a decline
	In Total:	30	0	22	172	31	14	**169**	**35**	**1**	23	4	0	146	31	1		

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 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
Halona	Genetic Storage	15	0	0	4	10	1	**4**	**10**	**1**	4	10	1	0	0	0	2016-08-15	No changes observed 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	142	8	0	**131**	**8**	**0**	3	8	0	128	0	0	2017-03-20	Thorough monitoring in the last year showed a decline
Manuwai	Manage for stability	12	0	0	110	97	14	**97**	**64**	**10**	0	4	0	97	60	10	2017-03-14	Thorough monitoring in the last year showed a decline
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	289	117	15	**265**	**84**	**11**	36	24	1	229	60	10		
	Total for Taxon:	141	39	22	461	148	29	**434**	**119**	**12**	59	28	1	375	91	11		

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 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
Kahanahaiki	Genetic Storage	140	0	0	78	4	0	**79**	**5**	**0**	79	5	0	0	0	0	2017-05-31	Small changes were noted during monitoring in the last year
Kaluakauila	Manage for stability	200	0	0	160	48	0	**140**	**48**	**0**	140	48	0	0	0	0	2016-10-10	Thorough monitoring in the last year showed a decline
Keaau	Genetic Storage	21	31	0	21	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	**70**	**70**	**10**	70	70	10	0	0	0	2016-03-30	No monitoring in the last year
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	558	233	10	**538**	**234**	**10**	531	234	10	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 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
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				112	0	0	**111**	**0**	**0**	0	0	0	111	0	0	2017-04-11	No monitoring in the last year
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	155	135	0	**204**	**101**	**0**	204	101	0	0	0	0	2017-06-29	A thorough census led to more plants being discovered
	Out Total:	446	7	0	333	141	0	**381**	**107**	**0**	270	107	0	111	0	0		
	Total for Taxon:	1280	100	0	891	374	10	**919**	**341**	**10**	801	341	10	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 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
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 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
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 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
North Mohiakea	Manage for stability	20	10	0	39	12	0	**39**	**12**	**0**	39	12	0	0	0	0	2013-05-21	No monitoring in the last year
Ohikilolo	Manage for stability	14	0	0	8	0	0	**28**	**22**	**0**	0	0	0	28	22	0	2017-03-23	More plants were added to the outplanting site
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	51	17	0	**71**	**39**	**0**	43	17	0	28	22	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 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
Ekahanui	Manage for stability	16	17	0	7	76	0	**5**	**52**	**0**	5	50	0	0	2	0	2017-05-17	Thorough monitoring in the last year showed a decline
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	2016-05-23	No monitoring in the last year
Waieli	Manage reintroduction for storage				12	30	0	**12**	**30**	**0**	0	0	0	12	30	0	2014-04-14	No monitoring in the last year
	Out Total:	98	17	0	26	115	0	**24**	**91**	**0**	12	59	0	12	32	0		
	Total for Taxon:	144	27	0	77	132	0	**95**	**130**	**0**	55	76	0	40	54	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 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
Ohikilolo	Manage for stability	65	408	0	85	1590	0	**85**	**1590**	**0**	72	1178	0	13	412	0	2014-04-23	No monitoring in the last year
Ohikilolo East and West Makaleha	Manage reintroduction for stability	0	75	0	6	328	0	**6**	**328**	**0**	0	0	0	6	328	0	2016-04-20	No monitoring in the last year
	In Total:	65	483	0	91	1918	0	**91**	**1918**	**0**	72	1178	0	19	740	0		

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 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
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	No changes observed in the last year
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	**219**	**1934**	**0**	200	1194	0	19	740	0		

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 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
Keaau	Manage for stability	16	125	0	0	13	16	**0**	**28**	**34**	0	28	34	0	0	0	2017-03-21	A thorough census led to more plants being discovered
Ohikilolo	Manage for stability	34	128	0	2	158	180	**0**	**229**	**0**	0	97	0	0	132	0	2017-03-22	A thorough census has shown seedlings transition into immature plants
	In Total:	50	253	0	2	171	196	**0**	**257**	**34**	0	125	34	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 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
Kamaileunu	Manage for stability	26	0	0	3	264	6	**31**	**182**	**1**	31	182	1	0	0	0	2017-03-21	Thorough monitoring in the last year showed a decline
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	3	264	6	**31**	**182**	**1**	31	182	1	0	0	0		
	Total for Taxon:	78	253	0	5	435	202	**31**	**439**	**35**	31	307	35	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 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	Manage for stability	3	0	0	58	67	7	**45**	**39**	**3**	2	0	0	43	39	3	2017-03-13	Thorough monitoring in the last year showed a decline
	In Total:	3	0	0	58	67	7	**45**	**39**	**3**	2	0	0	43	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 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
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	**164**	**4**	**0**	0	0	0	164	4	0	2016-05-10	A new census was initiated but not yet completed
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	149	148	0	**172**	**96**	**1**	9	2	0	163	94	1	2017-03-20	Thorough monitoring in the last year showed a decline
	Out Total:	19	128	0	416	152	2	**439**	**100**	**3**	25	2	1	414	98	2		
	Total for Taxon:	22	128	0	474	219	9	**484**	**139**	**6**	27	2	1	457	137	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 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
Kahanahaiki to Pahole	Manage for stability	48	17	0	88	35	317	**88**	**35**	**317**	6	0	0	82	35	317	2016-06-13	A new census was initiated but not yet completed
Kapuna-Keawapilau Ridge	Manage for stability	3	1	0	55	2	0	**55**	**2**	**0**	0	0	0	55	2	0	2015-12-28	Thorough monitoring in the last year showed a decline
	In Total:	51	18	0	143	37	317	**143**	**37**	**317**	6	0	0	137	37	317		

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 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
Makaha	Manage reintroduction for stability	0	0	0	91	5	0	**91**	**5**	**0**	0	0	0	91	5	0	2016-04-12	A new census was initiated but not yet completed
	Out Total:	0	0	0	91	5	0	**91**	**5**	**0**	0	0	0	91	5	0		
	Total for Taxon:	51	18	0	234	42	317	**234**	**42**	**317**	6	0	0	228	42	317		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Schiedea obovata

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 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
Kahanahaiki to Pahole	Manage for stability	65	25	0	232	216	182	**229**	**122**	**23**	0	0	0	229	122	23	2017-04-10	Thorough monitoring in the last year showed a decline
Keawapilau to West Makaleha	Manage for stability	24	12	0	36	458	36	**42**	**363**	**16**	24	363	16	18	0	0	2017-03-28	Thorough monitoring in the last year showed a decline
	In Total:	89	37	0	268	674	218	**271**	**485**	**39**	24	363	16	247	122	23		

Action Area: Out

TaxonName: Schiedea obovata

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 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
Makaha	Manage reintroduction for stability	0	0	0	76	14	0	**76**	**14**	**0**	0	0	0	76	14	0	2016-06-15	A new census was initiated but not yet completed
	Out Total:	0	0	0	76	14	0	**76**	**14**	**0**	0	0	0	76	14	0		
	Total for Taxon:	89	37	0	344	688	218	**347**	**499**	**39**	24	363	16	323	136	23		

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 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
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	**24**	**93**	**0**	24	93	0	0	0	0	2013-05-21	No monitoring in the last year
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	1902	1464	20	**1903**	**1464**	**20**	1903	1464	20	0	0	0	2016-09-27	A new census was initiated but not yet completed
Puhawai	Manage for stability	6	6	0	3	3	1	**3**	**3**	**1**	0	0	0	3	3	1	2016-04-21	No changes observed in the last year
	In Total:	2581	6	0	2349	1801	38	**2350**	**1801**	**38**	2347	1798	37	3	3	1		

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 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
Waianae Kai	Manage for stability	20	2	0	20	0	0	**20**	**0**	**0**	20	0	0	0	0	0	2016-07-11	No changes observed 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	2369	1801	38	**2370**	**1801**	**38**	2367	1798	37	3	3	1		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Viola chamissoniana subsp. chamissoniana

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 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
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				208	55	0	**191**	**52**	**0**	191	52	0	0	0	0	2016-09-27	Thorough monitoring in the last year showed a decline
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	292	65	0	**275**	**62**	**0**	275	62	0	0	0	0		

Action Area: Out

TaxonName: Viola chamissoniana subsp. chamissoniana

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 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
Halona	Manage for stability	3	0	0	15	5	0	**16**	**5**	**0**	16	5	0	0	0	0	2016-06-29	Small changes were noted during 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	**68**	**11**	**0**	68	11	0	0	0	0	2014-05-14	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	143	26	1	**144**	**26**	**1**	144	26	1	0	0	0		
	Total for Taxon:	410	14	0	435	91	1	**419**	**88**	**1**	419	88	1	0	0	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 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
Kaawa to Puulu	Manage for stability	36	88	6	30	49	1	**27**	**176**	**1**	27	176	1	0	0	0	2016-07-28	A thorough census has shown a substantial increase in the immature age class
Kahanahaiki	Manage reintroduction for stability	0	0	0	72	6	0	**69**	**5**	**0**	0	0	0	69	5	0	2017-02-07	Small changes were noted during monitoring 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	1	0	10	**0**	**0**	**0**	0	0	0	0	0	0	2016-09-07	Thorough monitoring in the last year showed plants died
	In Total:	37	92	16	103	58	11	**96**	**184**	**1**	27	176	1	69	8	0		

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 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
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	**57**	**118**	**0**	5	37	0	52	81	0	2016-07-25	No changes observed in the last year
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	No monitoring in the last year
Makaha Mauka	Genetic Storage	5	58	4	13	1	0	**13**	**1**	**0**	13	1	0	0	0	0	2015-07-09	No monitoring in the last year
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	**181**	**268**	**0**	129	187	0	52	81	0		
	Total for Taxon:	135	250	66	284	326	11	**277**	**452**	**1**	156	363	1	121	89	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 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
Helemano-Punaluu Summit Ridge to North Kaukonahua	Manage for stability	59	13	7	130	142	0	**96**	**109**	**9**	96	109	9	0	0	0	2017-06-19	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	190	89	0	**195**	**89**	**0**	195	89	0	0	0	0	2016-12-29	A thorough census led to more plants being discovered
	In Total:	147	46	7	322	231	0	**293**	**198**	**9**	293	198	9	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 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
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	529	390	50	**500**	**357**	**59**	500	357	59	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 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
Kaipapau, Koloa and Kawainui	Manage for stability	51	25	6	93	16	0	**113**	**12**	**0**	113	12	0	0	0	0	2017-05-10	A thorough census led to more plants being discovered
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	22	2	0	**21**	**7**	**0**	21	7	0	0	0	0	2016-09-28	A thorough census led to more plants being discovered
Poamoho	Manage for stability	12	0	0	20	19	0	**20**	**19**	**0**	20	19	0	0	0	0	2017-05-02	A new census was initiated but not yet completed
	In Total:	96	36	6	154	46	0	**173**	**47**	**0**	173	47	0	0	0	0		

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 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
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	172	48	0	**191**	**49**	**0**	191	49	0	0	0	0		

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 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
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	**21**	**26**	**1**	21	26	1	0	0	0	2016-03-30	No monitoring in the last year
Kaleleiki	Genetic Storage	25	30	250	14	54	80	**14**	**54**	**80**	14	54	80	0	0	0	2015-05-06	No monitoring in the last year
Kaunala	Manage for stability	48	93	6	20	39	27	**20**	**39**	**27**	20	39	27	0	0	0	2017-04-04	A new census was initiated but not yet completed
Malaekahana	Genetic Storage				5	21	0	**0**	**4**	**0**	0	4	0	0	0	0	2017-04-04	Thorough monitoring in the last year showed a decline
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	**22**	**6**	**141**	22	6	141	0	0	0	2014-07-23	No monitoring in the last year
	In Total:	169	437	282	97	159	249	**92**	**142**	**249**	92	142	249	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 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
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	99	159	249	**94**	**142**	**249**	94	142	249	0	0	0		

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 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
Haleauau	Manage for stability	2	0	0	77	0	0	**74**	**0**	**0**	3	0	0	71	0	0	2017-04-18	Small changes were noted during monitoring in the last year
Helemano and Poamoho	Manage for stability	18	0	0	21	1	0	**22**	**1**	**0**	22	1	0	0	0	0	2017-07-17	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	20	0	**10**	**12**	**0**	10	0	0	0	12	0	2017-05-24	Thorough monitoring in the last year showed a decline
South Kaukonahua	Genetic Storage	2	0	0	2	0	0	**2**	**0**	**0**	2	0	0	0	0	0	2016-03-30	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	2016-03-28	No monitoring in the last year
	In Total:	88	1	0	124	21	0	**122**	**13**	**0**	51	1	0	71	12	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 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
Ihiihi-Kawainui ridge	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
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	**2**	**0**	**0**	2	0	0	0	0	0	2017-05-11	No changes observed in the last year
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 monitoring 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 monitoring 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 monitoring in the last year
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	**10**	**0**	**0**	10	0	0	0	0	0		
	Total for Taxon:	124	1	0	134	21	0	**132**	**13**	**0**	61	1	0	71	12	0		

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 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
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	No monitoring in the last year
Lower Opaeula	Manage for stability	9	15	0	15	23	0	**11**	**15**	**6**	11	15	6	0	0	0	2017-05-03	Thorough monitoring in the last year showed a decline
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	21	12	5	**13**	**1**	**4**	13	1	4	0	0	0	2017-05-03	Thorough monitoring in the last year showed a decline
	In Total:	182	128	139	225	201	52	**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 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
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	226	205	53	**214**	**186**	**58**	214	186	58	0	0	0		

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 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
East Makaleha to North Mohiakea	Manage for stability	84	16	2	298	51	0	**294**	**49**	**0**	68	0	0	226	49	0	2017-02-06	Small changes were noted during monitoring in the last year
	In Total:	84	16	2	298	51	0	**294**	**49**	**0**	68	0	0	226	49	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 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
Koloa	Manage reintroduction for stability				9	5	0	**9**	**22**	**0**	0	0	0	9	22	0	2017-02-21	More plants were added to the outplanting site
	Out Total:				9	5	0	**9**	**22**	**0**	0	0	0	9	22	0		
	Total for Taxon:	84	16	2	307	56	0	**303**	**71**	**0**	68	0	0	235	71	0		

Action Area: In

TaxonName: Phyllostegia hirsuta

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 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
Haleauau to Mohiakea	Manage for stability	6	12	0	96	2	0	**96**	**2**	**0**	11	2	0	85	0	0	2016-05-12	No monitoring in the last year
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	114	39	1	**111**	**38**	**1**	3	2	1	108	36	0	2017-05-10	Small changes were noted during monitoring in the last year
	In Total:	32	19	6	217	45	1	**214**	**44**	**1**	21	8	1	193	36	0		

Action Area: Out

TaxonName: Phyllostegia hirsuta

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 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
Hapapa to Kaluaa	Genetic Storage	11	9	7	1	27	0	**1**	**27**	**0**	1	27	0	0	0	0	2016-07-20	No changes observed in the last year
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 changes observed 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	**87**	**55**	**0**	0	0	0	87	55	0	2016-04-12	No monitoring in the last year
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	**95**	**85**	**0**	8	30	0	87	55	0		
	Total for Taxon:	50	29	13	312	130	1	**309**	**129**	**1**	29	38	1	280	91	0		

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 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
Mohiakea	Genetic Storage	0	4	0	0	0	0	**1**	**0**	**0**	1	0	0	0	0	0	2017-05-24	A thorough census led to more a new plant being discovered
	In Total:	0	4	0	0	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 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
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	74	63	0	**72**	**25**	**0**	0	0	0	72	25	0	2017-02-07	Thorough monitoring in the last year showed a decline
Pualii	Manage reintroduction for stability	0	0	0	11	0	0	**11**	**0**	**0**	0	0	0	11	0	0	2015-05-06	No monitoring in the last year
Waieli	Genetic Storage	0	0	0	1	0	0	**1**	**0**	**0**	1	0	0	0	0	0	2012-12-04	No monitoring in the last year
	Out Total:	73	11	0	87	63	0	**85**	**25**	**0**	1	0	0	84	25	0		
	Total for Taxon:	73	15	0	87	63	0	**86**	**25**	**0**	2	0	0	84	25	0		

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 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
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	No monitoring in the last year
	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 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
Haleauau	Manage reintroduction for stability	1	0	0	281	0	0	**230**	**0**	**0**	0	0	0	230	0	0	2017-04-18	Thorough monitoring in the last year showed a decline
	In Total:	1	0	0	281	0	0	**230**	**0**	**0**	0	0	0	230	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 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 reintroduction for stability	0	79	0	26	178	0	**26**	**178**	**0**	0	0	0	26	178	0	2015-03-23	No monitoring in the last year
Makaha	Manage reintroduction for stability				0	60	0	**0**	**60**	**0**	0	0	0	0	60	0	2016-06-15	A new census was initiated but not yet completed
	Out Total:	0	79	0	26	238	0	**26**	**238**	**0**	0	0	0	26	238	0		
	Total for Taxon:	1	79	0	307	238	0	**256**	**238**	**0**	0	0	0	256	238	0		

OAHU ARMY NATURAL RESOURCES PROGRAM
MONITORING PROGRAM

RESULTS OF AN INVESTIGATION OF SEED GERMINATION FROM FRESH VERSUS SENESCING *DELISSEA WAIANAEENSIS* FRUIT

INTRODUCTION

Data indicate that seed viability declines as *Cyanea superba* subsp. *superba* fruit senesce (desiccate and/or decompose), suggesting potential dispersal limitation (OANRP 2015, OANRP 2016). It was hypothesized that similar losses in seed viability associated with fruit senescence may occur in other fleshy-fruited Lobelioids, including *Delissea waianaeensis*. Fruits of these species have characteristics suggestive of bird dispersal, though native dispersers no longer occur, and non-harvested fruits of both species begin to decompose prior to falling off the plant. A laboratory trial was conducted by the Oahu Army Natural Resources Program (OANRP) to examine seed viability in fresh versus senesced *D. waianaeensis* fruit.

METHODS

Collections of fresh and senesced *D. waianaeensis* fruits were made on June 14, 2016 at an outplanted population at Kaluaa and Waieli Management Unit (KAL-C) (Figure 1). A single fruit was collected from fifteen individual plants for each treatment (Figure 2). All fruits were collected directly from plants (not from the ground). The senesced fruits were of unknown age. Seeds were extracted from fruits and sown at the OANRP seed laboratory on June 15, 2016. Twenty-five seeds per fruit were sown on agar in petri dishes. Petri dishes were stored in a Percival Controlled Environment Chamber (with diurnal light and temperature settings matching average monthly temperatures for the Nike missile installation at Pahole, at approximately 2100 feet elevation as a best approximation for conditions at the reintroduction site), and examined weekly for germination for a total of 15 weeks. Germination rates were compared using a t-test in IBM SPSS Version 24. Excess seeds from collected fruit (an estimated 2408 seeds from fresh fruit, and 1867 from senesced fruit) were dried at 33% relative humidity (RH) at 24 C for one month and stored at 20% RH and 4 C at the OANRP seed laboratory for seed storage longevity testing, the results of which will be reported upon at a future date.

Map removed to protect rare resources

Figure 1. Location of *Delissea waianaeensis* fruit collection at Kaluaa and Waieli Management Unit.

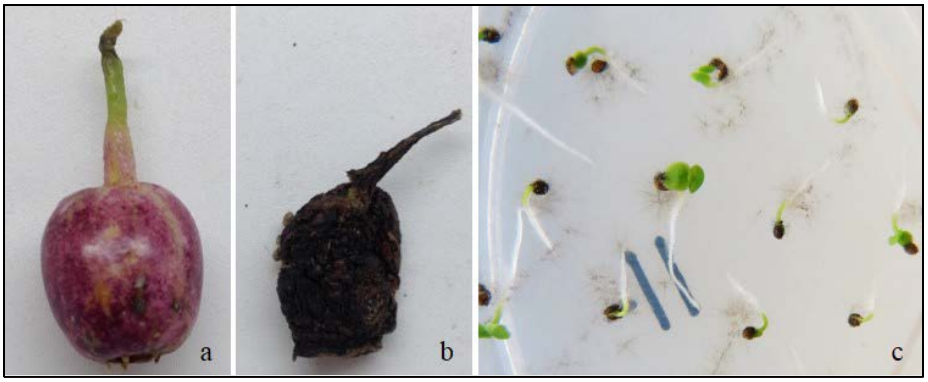

Figure 2. Fresh (a), and senesced (b), *Delissea waianaeensis* fruits and germinating seeds (c).

RESULTS

Seeds began germinating by three weeks. Peak germination (highest number of seeds germinating at any one time) occurred around four weeks. There was no germination after eight weeks. Mean germination rates were similarly and consistently high both for seeds from fresh (95.7%, SE 1.43) as well as senesced (94.1%, SE 2.43) fruit (t-test: T = 0.576, df = 28, p = 0.576) (Figure 3).

Figure 3. Mean seed germination rates for fresh and senesced *Delissea waianaeensis* fruits.

DISCUSSION

As germination rates remained high in senescing *D. waianaeensis* fruit, seeds from fruits not removed by frugivores retain the potential to germinate. However, the length of time non-harvested fruits remain on plants, seed viability upon abscission, and seed viability over time in undispersed fruit that has fallen to the ground remain unexplored.

REFERENCES

Oahu Army Natural Resources Program. 2015. Appendix ES-11. Results of a laboratory seed sow trial for *Cyanea superba* subsp. *superba in* 2015 Status Report for the Makua and Oahu Implementation Plans.

Oahu Army Natural Resources Program. 2016. Appendix 4.1. A trial to assess the rate and extent of seed germination reduction during *Cyanea superba* subsp. *superba* fruit senescence *in* 2016 Status Report for the Makua and Oahu Implementation Plans.

OAHU ARMY NATURAL RESOURCES PROGRAM
MONITORING PROGRAM

A LABORATORY TRIAL TO ASSESS THE EFFECT OF FRUIT SENESCENCE ON *CYANEA GRIMESIANA* SUBSP. *OBATAE* SEED VIABILITY

INTRODUCTION

Limited recruitment of *Cyanea grimesiana* subsp. *obatae* (Campanulaceae) occurs in populations managed by the Oahu Army Natural Resources Program (OANRP). Several factors may limit successful recruitment, including predation of seedlings by slugs, soil moisture, light availability and senescence (desiccation and/or decomposition) of undispersed fruit. For OANRP to achieve goals of long-term self-sustaining *C. grimesiana* subsp. *obatae* populations, these issues must be taken into consideration. This taxon as well as other Campanulaceae managed by OANRP have fleshy fruits that likely evolved for bird dispersal, though native dispersers are no longer present, and non-native birds do not appear to be filling the niche. Prior investigations of the effect of fruit senescence on seed viability on other Campanulaceae taxa had mixed results. *Cyanea superba* subsp. *superba* seeds were 50% less viable in senesced vs. fresh mature fruit (OANRP 2015). Seed viability declined significantly within five days among fruit that senesced in the laboratory (OANRP 2016). No germination occurred in seeds from fruit that senesced for 15 to 19 days. Reduced seed germination from senescing *C. superba* subsp. *superba* fruit suggests this species is dispersal limited. Without effective dispersers, long-term self-sustaining populations may not occur, and populations may require on-going replacement via outplanting or seed sowing. Viability remained high among senesced *Delissea waianaeensis* fruit, suggesting fruits not removed by frugivores retain the potential to germinate upon senescence (Appendix 4-2). This trial explored *C. grimesiana* subsp. *obatae* recruitment limitations in association with fruit senescence, by examining the ability of seeds from progressively senescing fruit to germinate over time in the laboratory.

METHODS

Fresh mature *C. grimesiana* subsp. *obatae* fruits were collected from a reintroduction site (CyaGriOba.EKA-C) in Ekahanui Management Unit (MU) in January 2017 (Figure 1). A total of 30 fruits were collected from 15 individuals. While all collected fruit were considered mature and fresh, there was a range in coloration, varying from greenish-yellow to orange (Figure 2). Fruits were cleaned and stored individually on labeled vial caps in a clear plastic container with ventilation holes (containing a moist sponge to maintain humid conditions) at ambient room temperature at the OANRP seed lab. Five fruits were randomly sampled twice a week for three weeks, beginning on the collection date, for a total of six viability assay dates with 0, 6, 9, 13, 16, and 20 days in which fruit were allowed to senescence. Seeds were sown on agar in petri dishes, including 50 seeds per fruit/sample (1500 total sown seeds). Seed set was plentiful for all fruits, with a mean of 359 seeds per fruit. Petri dishes were stored in a Percival Controlled Environment Chamber (with diurnal light and temperature settings matching average monthly temperatures for the Nike missile installation at Pahole, at approximately 2100 feet elevation, as a best approximation for natural conditions at the reintroduction site), and examined weekly for germination for a total of 16 weeks. The majority of germination (94%) occurred within 6 weeks of sowing. It was observed that two fungal morphotypes formed on the fruits, one that produced long stolons with black sporangiophores, and one that did not produce long branching hyphae. Fruits were spatially separated from one another to limit the direct spread of mold onto neighboring fruits, particularly the long stolon morphotype, which rapidly expanded beyond the edges of the vial caps. Germination rates were compared using ANOVA with Games-Howell post-hoc pairwise comparisons. Additionally, because it was unknown how the initial color or fungal morphotype might affect the outcome, two-way ANOVA were used to examine interactions between senescence time and initial color (five categories ranging from greenish-yellow to orange), fungal morphotype (none, "short," and "long"), and degree of moldiness (none, small, medium, and large). All analyses were performed in IBM SPSS Statistics Version 24. Excess seeds (approximately 9300) were used for long-term seed storage testing of seeds from fruit of varying stages of senescence, the results of which will be assessed later.

Map removed to protect rare resources

Figure 1. Location of *C. grimesiana* subsp. *obatae* fruit collection at Ekahanui MU.

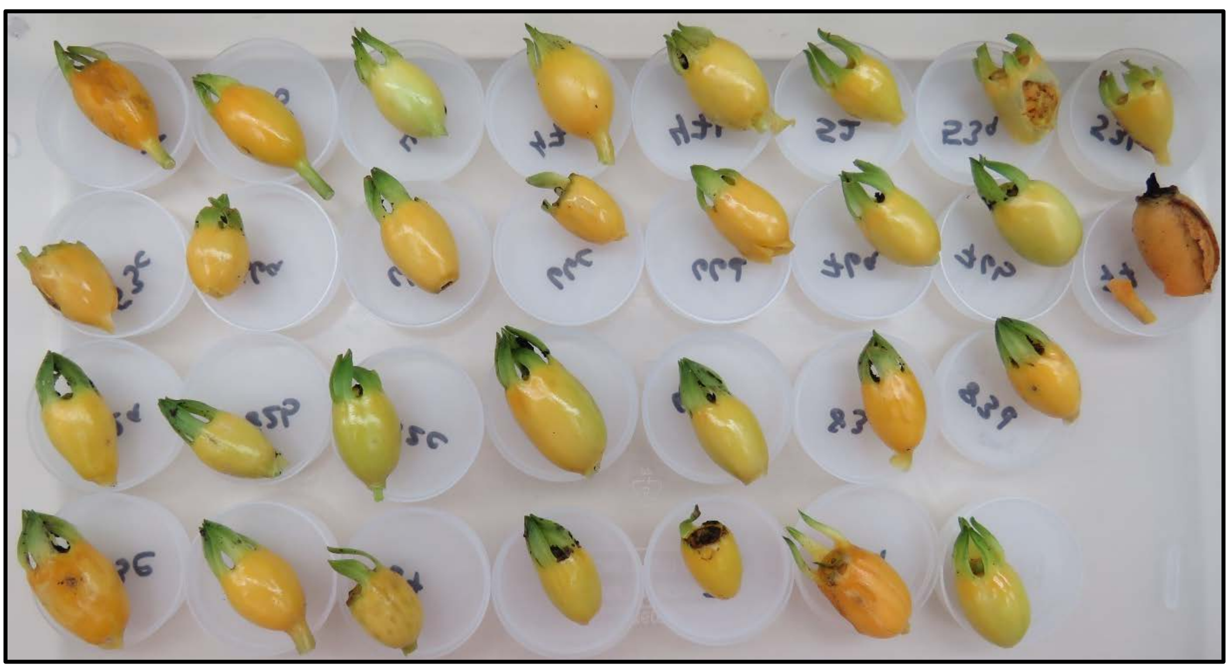

Figure 2. Mature *C. grimesiana* subsp. *obatae* fruit at the start of the trial.

RESULTS

Fruits began to desiccate within one week, and more extensively by two weeks (Figure 3). Mold (both morphotypes) was visible by the second week, and all fruits were covered in mold by the end of the trial. Germination rates differed in accordance with the amount of time fruits senesced prior to sowing (ANOVA: $p < 0.000$, $F = 7.736$) (Figure 4). Mean viability remained high among fruits that senesced up to nine days, but declined progressively thereafter, with less than 40% mean germination after 20 days of fruit senescence. Germination among fruits that senesced up to 9 days differed significantly from those that senesced for 20 days. There were no pairwise differences among fruits that senesced up to 16 days, as at least one fruit retained high viability among each of those groups. Similarly, there were no pairwise differences among fruits that senesced between 13 and 20 days, as at least two fruits exhibited reduced viability among each of those groups. There was no interaction between senescence time and initial color (two-way ANOVA: $p = 0.154$, $F = 2.068$), fungal morphotype (two-way ANOVA: $p = 0.288$, $F = 1.351$), or degree or moldiness (two-way ANOVA: $p = 0.094$, $F = 2.680$) on germination rates.

DISCUSSION

Though sample sizes were small, with only five fruits sampled per assay date, a clear pattern emerged of progressive seed viability loss over time after nine days of fruit senescence. The pattern of viability loss was similar to that of *C. superba* subsp. *superba* (OANRP 2016), though the rate of decline was not as rapid for *C. grimesiana* subsp. *obatae.* Recruitment from undispersed fruits that fall to the ground may be limited by seed viability loss as fruits senesce.

The method used for this trial lays the foundation for possible future field trials. Testing seed viability over time from intact fruits on the forest floor would provide a more accurate representation of viability loss in undispersed fruits under natural conditions. Conditions contributing to viability decline in intact fruit may differ among fruit that have fallen to the ground versus those in the lab. The mechanism responsible for the observed decline in viability remains unknown. Prior testing of seeds removed from fresh mature fruit and kept moist and in the dark in the OANRP growth chamber (as a proxy for soil seed bank longevity) retained high germination rates after 2 years (OANRP 2017), suggesting that seeds should otherwise remain viable in the soil if removed from the fruits.

Rats are presumed to remove *C. grimesiana* subsp. *obatae* fruit, though the extent to which they, or any other vertebrate, consumes fruit remains unknown. Seeds of *C. grimesiana* subsp. *obatae* are very small (< 1mm), and are well within the observed size threshold for passing intact through rats (Shiels and Drake 2011), though they do not necessarily disperse seeds into favorable locations. Installation of game cameras to observe frugivores and removal rates would provide insight into the extent of potentially effective vs. ineffective dispersal. If effective *C. grimesiana* subsp. *obatae* dispersers are identified, considerations should be made to incorporate and/or enhance this interaction at managed populations. Should effective dispersers not occur at managed *C. grimesiana* subsp. *obatae* populations, supplemental greenhouse propagation and/or human-mediated seed dispersal may be necessary for continued population stability.

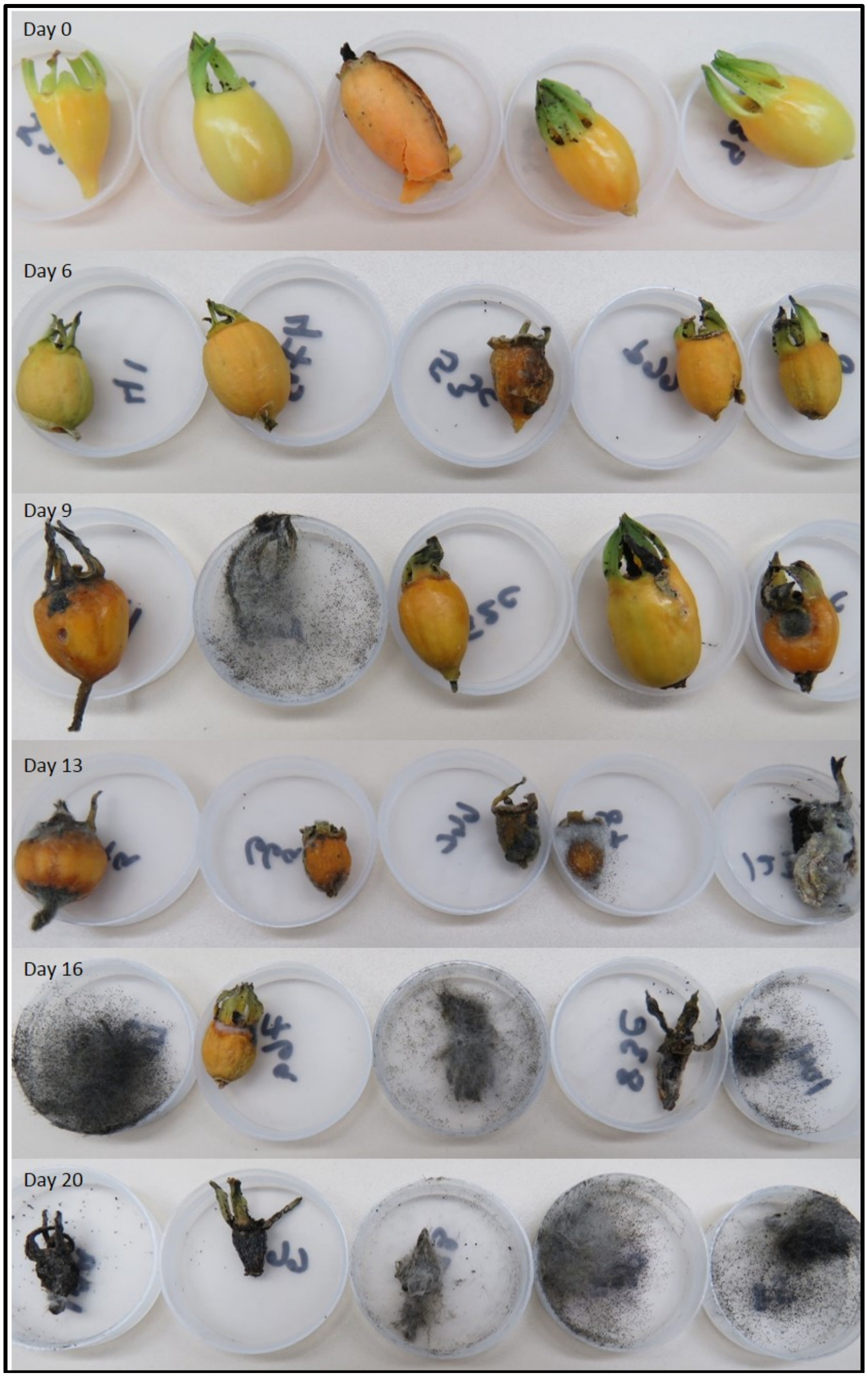

Figure 3. Photographs of sampled *C. grimesiana* subsp. *obatae* fruit allowed to senesce for 0 to 20 days, with visible signs of desiccation and molding over time. Fruits shown are the actual ones sampled for germination testing, and do not represent the same five fruits over time.

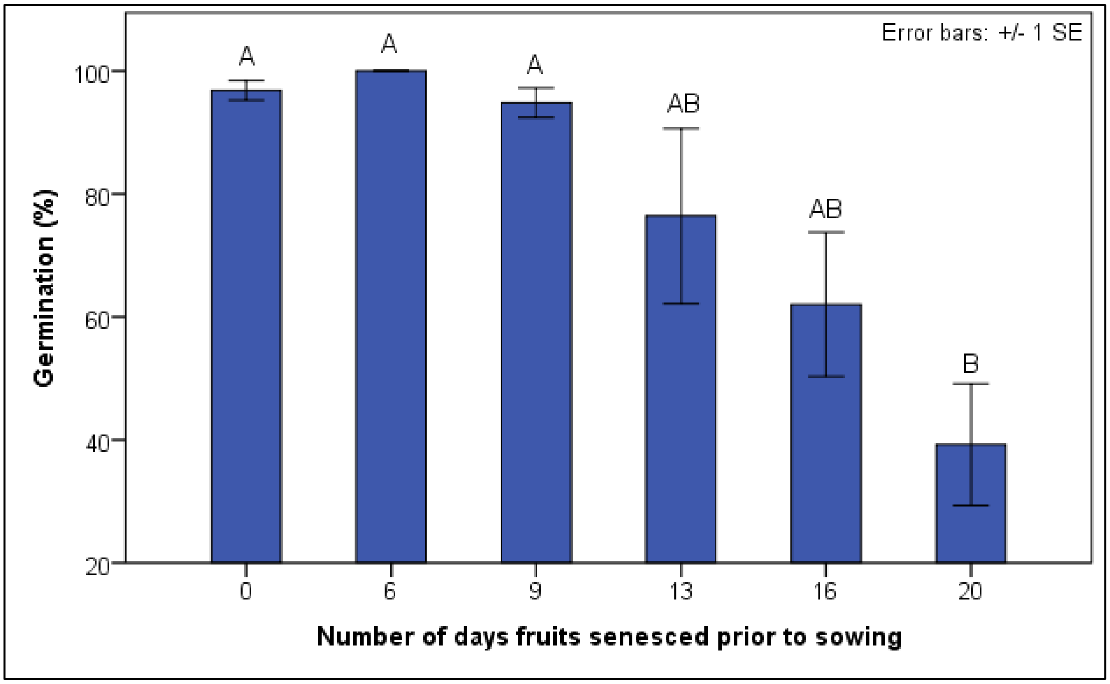

Figure 4. Mean germination rates among *C. grimesiana* subsp. *obatae* seed sown from fruits allowed to senesce between 0 and 20 days (n = 5 per assay date). Differing letters denote significant differences between groups (Games-Howell post-hoc tests).

REFERENCES

Oahu Army Natural Resources Program. 2015. Appendix ES-11. Results of a laboratory seed sow trial for *Cyanea superba* subsp. *superba in* 2015 Status Report for the Makua and Oahu Implementation Plans.

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OAHU ARMY NATURAL RESOURCES PROGRAM
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PRELIMINARY RESULTS FOR A FIELD SEED SOW TRIAL OF *CYANEA SUPERBA* SUBSP. *SUPERBA:* GERMINATION MONITORING

INTRODUCTION

Several factors are known to limit successful recruitment of *Cyanea superba* subsp. *superba*, including seedling predation by slugs, seed predation by rats, and senescence of undispersed fruit (Joe and Daehler 2008, Shiels and Drake 2011, Pender et al. 2013, OANRP 2015, OANRP 2016). Other factors that may limit successful recruitment include soil moisture, light availability, temperature, relative humidity, and competition with other plant taxa. Despite having typically high seed germination rates in fresh mature fruit, rat and weed control at all Manage for Stability (MFS) sites, and slug control at some MFS sites, limited recruitment of *C. superba* subsp. *superba* occurs at Oahu Army Natural Resources Program (OANRP) MFS sites (OANRP 2017a, OANRP 2017b). Mature fruits are fleshy and presumed to have evolved for bird dispersal. Recruitment occurs at the Kahanahaiki MFS primarily beneath parent plants, but survivorship is poor. The Pahole to Kapuna MFS has had very limited recruitment and survivorship, also beneath parent plants. There has been some successful recruitment and survivorship at the Makaha and Palikea MFSs in recent years both in proximal and distant locations from parental sources, some of which has occurred in unexpected locations, such as dense *Blechnum appendiculatum* ground cover at Palikea. Outplants have not matured at the Manuwai MFS, and its capacity for successful regeneration remains unknown. Thus far, no seedlings have survived to maturity at any site. Controlled comparisons of germination and survivorship have not been examined across the MFS sites. In order for OANRP to achieve goals of long term self-sustaining *C. superba* subsp. *superba* populations, these issues must be taken into consideration. A field trial was implemented to assess the relative success rates for *C. superba* subsp. *superba* recruitment from sown seeds both in the short term (plants surviving to outplant readiness size, > 25 cm) and the long term (plants becoming reproductive) in relation to environmental conditions that may influence germination and survival at four OANRP MFS sites (Kahanahaiki, Makaha, Manuwai, and Palikea) as well as a potential future MFS site (Opaeula Lower) under consideration (Figure 1). Preliminary results pertaining to germination monitoring are reported.

METHODS

Trial Design

Cyanea superba subsp. *superba* seeds stored at 20% relative humidity (RH) and 4° C in the OANRP seed laboratory for one to two years were used in the trial. Viability of the stored seed (n = 50) was assessed in the OANRP seedbank laboratory to estimate number of viable seeds sown per plot. Soil seed bank persistence for *C. superba* subsp. *superba* is unknown. To estimate how many years would be necessary for monitoring plots with no seedlings, testing was initiated to determine the potential for seeds (n = 100) from fresh fruit to germinate after being kept in the dark on petri dishes in a growth chamber for 6 months, and 1, 2, 5, and 10 years as a proxy for the potential of persistence in the field. An estimated 179 viable seeds (equivalent to the number of seeds within 1-2 fruits) were sown in each of 100 plots measuring 30 cm by 30 cm at each site. Control plots (4-5 per site) with no added seeds were also established in order to gauge natural *C. superba* subsp. *superba* recruitment levels at the site. Plots were established in areas deemed appropriate habitat for *C. superba* subsp. *superba* (not necessarily within existing reintroduction sites), and where no potentially disruptive future management is planned (Figure 2). Plots were spaced one to two meters apart, with the aim of haphazardly positioning plots in diverse

Map removed to protect rare resources

Figure 1. Locations of *Cyanea superba* subsp. *superba* field seed sow trials at OANRP management units.

Figure 2. Photographs showing the diversity of *C. superba* subsp. *superba* seed sowing sites used in the study, with varied vegetation and levels of understory cover. Clockwise from top left: Kahanahaiki, Mahaka, Opaeula Lower, Palikea, and Manuwai. Pin flags visible within photographs are seed sow plot markers.

microhabitats. Plots were not positioned directly on rocks, stream bottoms, vertical slopes, or within 2 m of outplanted *C. superba* subsp. *superba* individuals. Plots in areas frequented by natural resource managers were delineated by string and pin flags in all four corners with a numbered write-on metal tag affixed to one of the pin flags. Plots in areas less heavily frequented were simply marked with a single pin flag and a numbered write-on tag in the center of the plot. Field crews were informed of the trial locations, and instructed to avoid disturbing them. The trial was initiated during the winter season (Table 1), to generally correspond with the natural timing of *C. superba* subsp. *superba* fruit maturation and seed dispersal. All plots were mapped to facilitate monitoring.

Table 1. Dates *C. superba* subsp. *superba* seeds were sown and germination monitored at trial sites. Sow dates and days elapsed between sowing and monitoring differed across sites due to logistical constraints.

Site	Date sown	Date monitored	Days elapsed between sowing and monitoring
Kahanahaiki	2017-02-15	2017-04-12	56
Makaha	2017-01-24	2017-03-30	65
Manuwai	2017-02-23	2017-05-08	74
Opaeula Lower	2017-03-07	2017-05-24	78
Palikea	2017-02-07	2017-04-20	72

Environmental data was recorded at each plot, including soil moisture (using a General Digital Moisture Meter DSMM500, at time of sowing and during germination monitoring, with mean moisture per plot used in analyses), canopy openness (using hemispheric photography with a Canon PowerShot SX60 HS camera 2 m above ground level aimed 180° from the forest floor during initial sowing), understory cover (visual estimates at 10% intervals), and dominant understory taxa. Temperature and relative humidity were measured using a single data logger at each site (Onset HOBO U23-001, logging every 30 minutes, with data offloaded annually). Relative slug abundance was also documented at each site, corresponding with the timing of germination monitoring. This was accomplished using baited pitfall traps (McCoy 1999) consisting of 10 Styrofoam™ cups per site, placed in holes so that their openings were level with the soil surface and baited with six oz. of beer (Pabst Blue Ribbon). Pitfall traps were set and checked 2-3 times per site, with the number of days elapsed prior to checking ranging from 8 to 28 days, and a total combined number of trapping days among sites ranging from 33 to 54.

Molluscicide was not used at any of the sites, as it was determined that for the purposes of the trial, logistical limitations imposed by Sluggo® use outweighed the problem of slug pressure. Based on prior research, slugs account for roughly 50% mortality of seedlings (Joe and Daehler 2008). It was anticipated that the large sample size would offset the problem of higher mortality rates resulting from slugs (as well as other stochastic events). Using Sluggo would greatly limit the locations in which plots may be placed due to label restrictions associated with native snails in proximity to application sites. Further, it would require extensive repeated snail surveys to ensure that label restrictions are met. Existing slug controlled areas were not large enough to support the scale of the trial. In order to have equivalent slug pressure among plots, they would have to be spaced much further apart, necessitating expansion into inappropriate habitat, and would take considerably longer to monitor. It would entail two years of applying Sluggo over an extensive area every two weeks, or an even larger area every four weeks, which surpasses OANRP resource capacity. Ultimately, it would necessitate a greatly reduced sample size, limiting our ability to collect sufficient data. If it was determined that Sluggo simply could not be applied due to label restrictions at one or more sites, it would limit the ability to make comparisons among sites. In short, foregoing slug control allowed for a more robust and meaningful data set, with substantially less effort.

Germination Monitoring Protocol

Monitoring for germination occurred between 56 and 78 days after seeds were sown. Under laboratory conditions, most germination occurs within 60 days. Germination monitoring was intended to provide an approximation of germination success. In the field, germination likely occurred gradually over several weeks, and at the time of monitoring, some seeds might have already germinated and died, and others might not have germinated yet. During monitoring, all seedlings were counted in each plot. Soil moisture was also documented, as described above. Germination monitoring occurred only once per site, as information regarding longer term survival is of greater interest for the trial than more precise data for total germination.

Data Analysis

Gap Light Analyzer (GLA), Version 2.0 software (Frazer et al. 1999) was used to calculate percent canopy openness in hemispheric canopy photographs. Differences among sites for environmental variables (canopy openness, understory cover, and relative slug abundance (slugs/trap/trapping day)) were assessed using Kruskal-Wallis tests. Generalized linear models were used to examine the influence of environmental variables (as well as interactions among variables) on seedling counts among plots. Poisson models were used when data fit a Poisson distribution and were not overdispersed (Manuwai seedling counts), while negative-binomial models were used when assumptions for a Poisson model failed (seedling counts for all other sites, and all sites combined). Suitability for a Poisson model was determined using one-sample Kolmogorov-Smirrnov tests for Poisson distribution, and Pearson dispersion statistics for equidispersion using a standard of chi-square/df < 2. Models were chosen based on Pearson dispersion statistics, Akaike information criterion scores, and omnibus tests of whether the independent variables improved the model. Within site analyses examined seedling count influences by covariates (soil moisture, canopy openness, and understory cover) and factors (geographic plot groupings, when applicable). Relative slug abundance was not included as slug data were not directly associated with individual plots. Across site analyses examined seedling count influences by covariates (canopy openness, understory cover, and relative slug abundance) and factors (site). Soil moisture was not included as measurements (as per the methods used herein) among differing soil types are not comparable. Slug abundance data consisted of mean slugs per trap per trapping day for each site. Statistical analyses were performed using IBM SPSS Statistics Version 24.

RESULTS

Seedling counts as well as environmental variables (understory cover, canopy openness, soil moisture, and relative slug abundance (slug/trap/trapping day)) differed significantly by site (Kruskal-Wallis $p < 0.001$ for each), as did the proportion of plots with seedlings (chi-square: $p < 0.001$) (Figure 3). Four slug taxa were documented in traps, with differing combinations of species and relative abundances among sites (Figure 4). Seedlings germinated within understory cover ranging from 0% to 100%, beneath canopy openness ranging from 5% to 48%, and (mostly) across the full ranges of soil moisture occurring at each site. At all sites, control plots contained no *C. superba* subsp. *superba* seedlings.

Kahanahaiki: This site had relatively moderate numbers of seedlings observed in comparison with the other sites. Seedlings occurred in 36% of plots, with a mean of 0.68 seedlings per plot, and a total of 71 seedlings. No more than 6 seedlings were present per plot. Plots were in two clusters, one large and one small, with seedlings present only within the large cluster. The seedlings contained only cotyledons. Some seeds apparently washed slightly out of plots, and resulting seedlings were included in seed counts. Among plots, soil moisture was variable. Mean understory cover (31%) was relatively moderate, while mean canopy openness (13.3%) and mean slug abundance (0.052 slugs/trap/day) were relatively low, compared with the other sites.

Makaha: Numbers of seedlings observed at this site was by far greater than any other site. Seedlings were present in 61% of the plots, with a mean of 15 seedling per plot, and a total of 1534 seedlings. Most plots with observed germination had 10 or fewer seedlings, though 2 had > 100 seedlings (Figure 5). One plot had as many as 113 seedlings. Most seedlings contained only cotyledons, though many had emerging true leaves. Plots were in eight clusters, and some clusters of plots had markedly better results than others (Figure 6). Some seeds apparently washed slightly out of plots, and resulting seedlings were included in seed counts. Soil moisture was variable among plots. Mean slug abundance (0.038 slugs/trap/day) was relatively low, and mean canopy openness (11.2%) and mean understory cover (6%) were lower than the other sites.

Manuwai: This site had relatively moderate numbers of seedlings. Seedlings occurred in 38% of plots, with a mean of 0.61 seedlings per plot, and a total of 61 seedlings. No more than 4 seedlings were present per plot. Most seedlings contained only cotyledons, though a few had emerging true leaves. One seedling (included in count) was slightly outside of a plot, apparently resulting from seed(s) washed out. Soil moisture was variable among plots. Mean understory cover (45%) was higher than any other site, while mean canopy openness (15.7%) was moderately low compared with the other sites. No slugs were present in any traps.

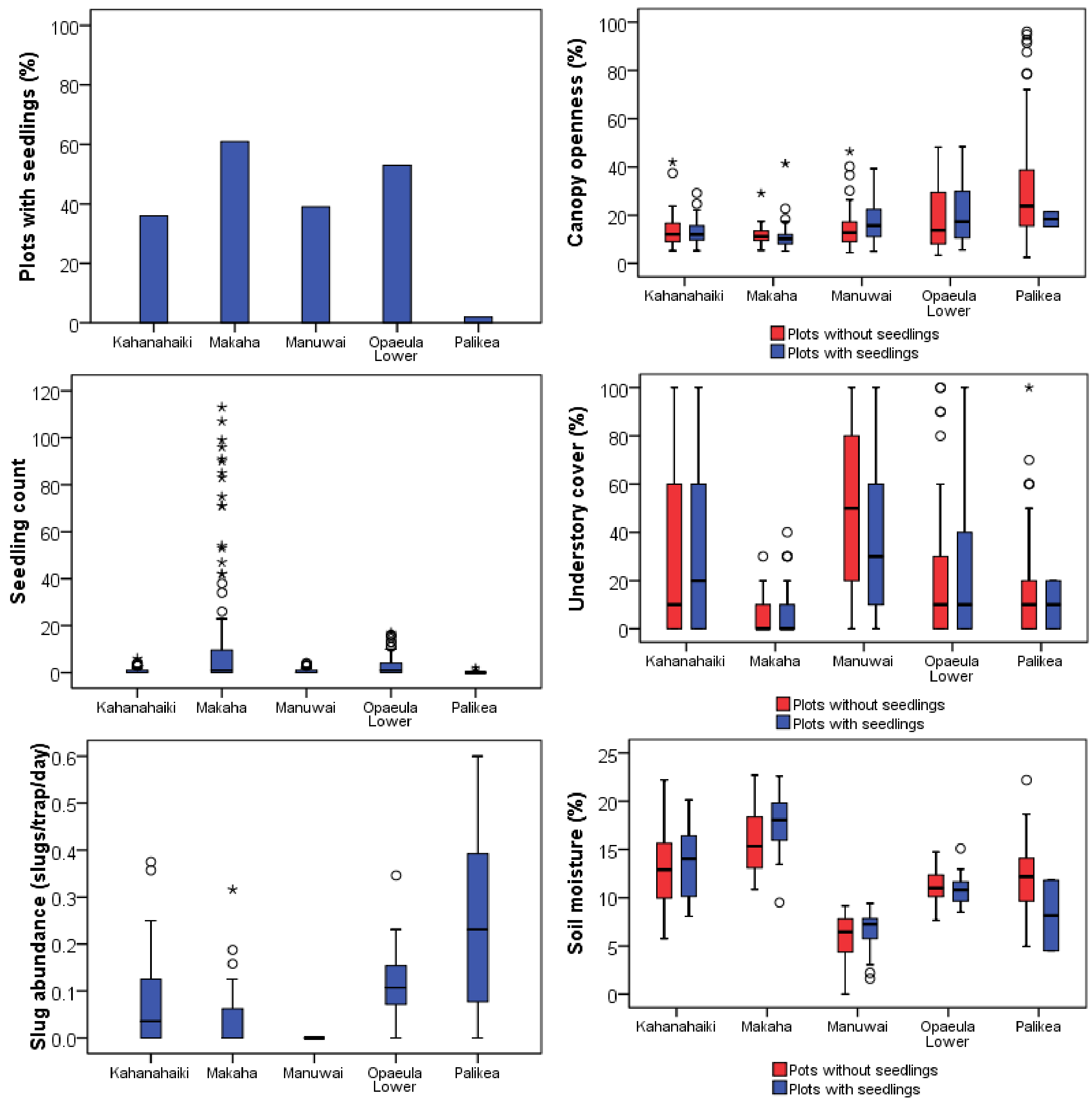

Figure 3. Germination results and environmental characteristics by site, with a bar graph of the percent of plots with seedlings present, and boxplots of seedling counts and relative slug abundance among plots, and box plots of percent understory cover, canopy openness, and soil moisture among plots with and without seedlings.

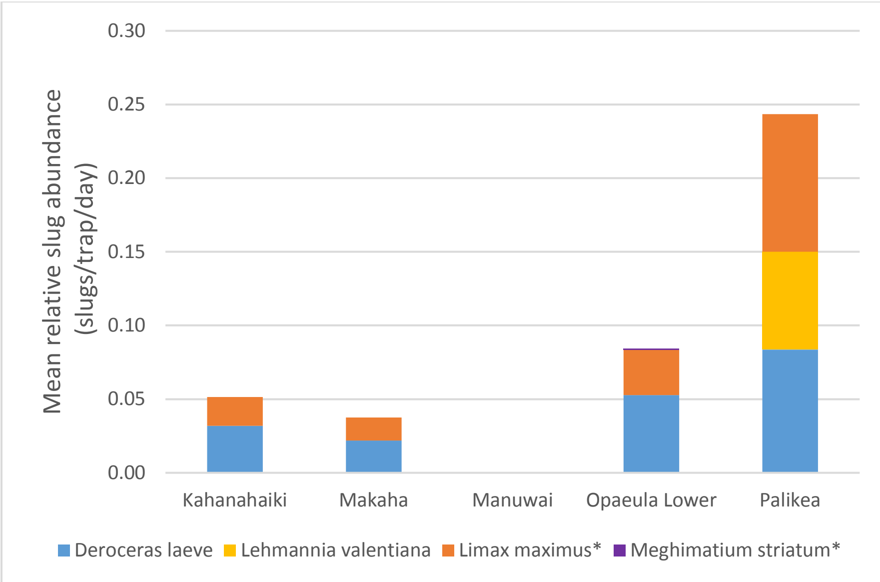

Figure 4. Mean relative slug abundance by species among sites. *Relatively large-sized slug species.

Figure 5. Photograph of a seed sow plot at Makaha showing large numbers of *C. superba* subsp. *superba* seedlings during germination monitoring.

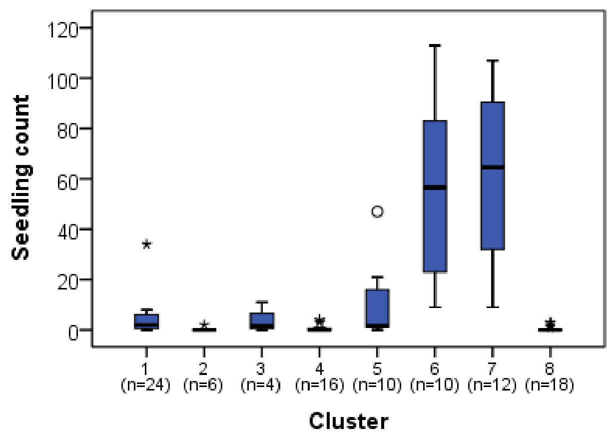

Figure 6. Seedling counts among plots in geographic clusters at Makaha.

Opaeula Lower: Numbers of seedlings observed at this site was moderately high in comparison with the other sites. Seedlings were present in 53% of plots, with a mean of 2.8 seedlings per plot, and a total of 293 seedlings. Most plots with germination had 10 or fewer seedlings. No more than 17 seedlings were present per plot. The seedlings contained only cotyledons. Soil moisture was less variable among plots in comparison with other sites. Mean canopy openness (19.5%) and mean understory cover (25%) were moderate in comparison with other sites. Mean slug abundance (0.084 slugs/trap/day) was also comparably moderate, more than twice as much as the abundance at Makaha.

Palikea: Numbers of observed seedlings at this site was markedly lower than any other site. Only 2% of plots had seedlings, with a total of 3 seedlings (mean = 0.03 seedlings per plot). The seedlings contained only cotyledons. One seedling (included in count) was slightly outside of a plot, apparently resulting from seed(s) washed out. Soil moisture was variable among plots. Mean canopy openness (31.6%) and mean slug abundance (0.243 slugs/trap/day, > 6 times that of Makaha) were higher than the other sites, while mean understory cover (15%) was relatively low.

Environmental influences on seedling counts

Within site: Effects of environmental predictors on seedling counts were variable among the sites (Figure 7). Soil moisture influenced seedling counts positively at Kahahahaiki ($p = 0.019$) (plots with higher soil moisture were more likely to have higher seed counts), and negatively at Opaeula Lower ($p = 0.001$) (plots with higher soil moisture were more likely to have lower seed counts). Geographic plot groupings, rather than measured environmental variables, influenced seedling counts at Makaha ($p < 0.001$). At Manuwai, canopy openness influenced seedling counts ($p < 0.001$) (plots with greater light availability were more likely to have higher seed counts), and there was a significant interaction between canopy openness, soil moisture, and understory cover ($p = 0.009$), with higher seedling counts more likely in plots with greater light availability, higher soil moisture, and lower understory cover. Though the few seedlings counted at Palikea occurred in plots with lower canopy openness and understory cover as compared with other plots, there were not enough plots with seedlings for meaningful statistical analyses.

Across sites: Site is a significant factor influencing seedling counts ($p < 0.001$), as is canopy openness ($p = 0.006$) (more seedlings with greater openness, up to 50%), slug abundance ($p = 0.015$) (more seedlings with less slugs), and the interaction between canopy openness and slug abundance ($p = 0.018$) (lower seedling counts expected with greater numbers of slugs despite greater canopy openness).

DISCUSSION

The divergent seed counts resulting from sown seeds and varying environmental influences reveal a somewhat complex picture for the initial stages of efforts to examine the relationship between environmental variables and survivorship to outplanting and reproductive stages at diverse sites. Some of the results were not particularly surprising, while others were not anticipated, or otherwise enigmatic.

Within site results of analyses of environmental influences were particularly variable. The positive influence of higher soil moisture on seedling counts at Kahanahaiki, which has relatively low annual rainfall, and the negative influence of higher soil moisture on seedling counts at Opaeula Lower, which has by far the highest annual rainfall, suggests a possible upper and lower limit on soil moisture for successful recruitment, as might be expected for a species associated with mesic habitat. The essential failure of sown seeds at Palikea was not anticipated, given the successful recruitment observed in the vicinity of outplants in other locations at Palikea. However, the low numbers of seedlings is not implausible given the likely adverse influence of high slug abundance relative to the other sites. The impact of geographic clustering of plots at Makaha rather than soil moisture or percent canopy openness or understory cover suggests some unaccounted variable(s) was responsible for highly varied numbers of seedlings among clusters of plots. Slugs are an unlikely influence given their relatively low abundance at that site. The influence of canopy openness as well as the interaction between canopy openness, understory cover, and soil moisture on seedling counts at Manuwai suggests multifaceted relationships may occur at some locations. Manuwai had higher understory cover than any other site, which may explain why the model for this site was the only one that involved a relationship between understory cover and seedling counts.

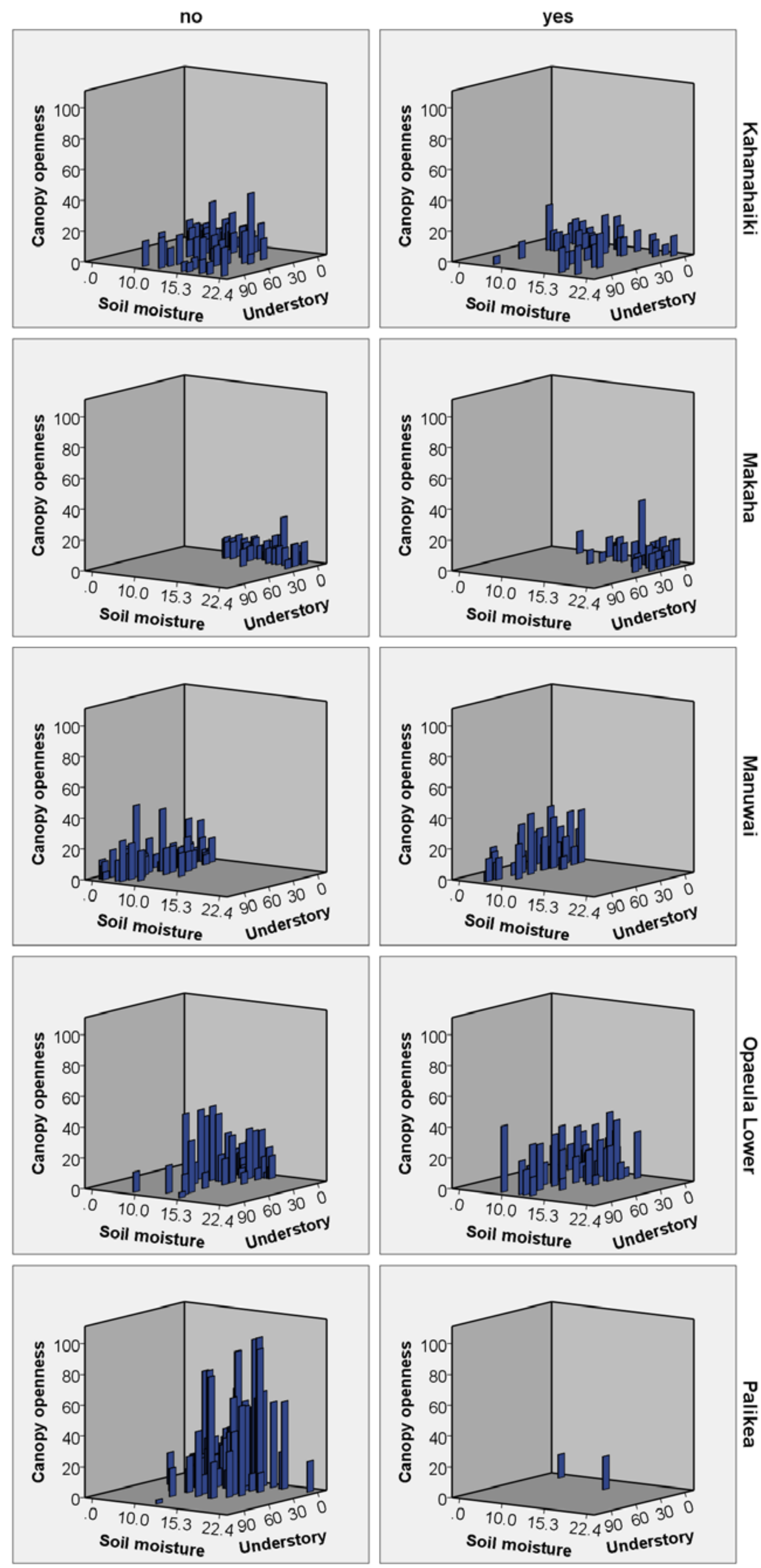

Figure 7. Three dimensional bar graphs of mean percent canopy openness by percent soil moisture and percent understory cover among plots with ("yes" column on right) vs. without ("no" column on left) seedlings in Kahanahaiki, Makaha, Manuwai, Opaeula Lower, and Palikea.

Given the differing seedling counts and environmental influences by site, it is not surprising that for across site analysis, site was an influential factor. The negative influence of slugs on seedling counts across sites was also expected, and it is not surprising that the strength of this influence would be such that it outweighed any positive influence of greater canopy openness across sites. While within site soil moisture measurements are assumed to be comparable, they are not comparable between sites. Soil moisture could vary in relation to weather at the time of monitoring (monitoring did not occur simultaneously), and soil structure and composition differs between sites, wherein soil moisture and the amount of available moisture presumably differ by site. Soil with fine particles holds moisture more tightly than coarse soil, and as such even if the volumetric water was equivalent, the amount of water available to plant roots between soil types would differ. Some of the sites contained thick layers of root mat with loose humus on the soil surface, and the presence of air pockets would result in lower moisture readings. If comparable data for soil moisture availability was obtained across the sites, it is possible that a nonlinear relationship with seedling counts could be found where seedling counts are highest across some midrange within the spectrum.

It is important to note that the number of seedlings observed is not necessarily indicative of how much germination occurred. It is possible that not all seeds germinated by the time of monitoring. Likewise, more seedlings may have germinated than were observed, but died prior to monitoring. The months following seed sowing were unusually dry for the time of year, and may have adversely influenced germination at some or all sites. Some heavy rains did occur, however, possibly resulting in seeds being buried by soil and debris, where they could have germinated and died. Seeds sown at Palikea in particular may have been vulnerable to burial from heavy rains, in addition to slug predation of seedlings.

Plants produce abundant amounts of seed to compensate for high rates of mortality in early life stages. Seed germination and early survivorship is contingent upon appropriate light, temperature and moisture regimes, and escape from predation and physical disturbance (by fallen litter, uprooting, water wash/erosion). These factors may be highly variable in time and location from one season to the next, and the results herein should be interpreted with a degree of caution. The degree of slug predation is likely a function of slug abundance, which is known to vary greatly over time in OANRP MUs, with much higher abundances possible at times than were observed in this study, even at relatively dry locations such as Kahanahaiki. Physical disturbance may have considerable impacts on seedling survival. This was exemplified in a seedling survival study in *Metrosideros/Cibotium* rain forest, with 20% estimated seedling mortality resulting from fallen *Cibotium* fronds per year (Drake and Pratt, 2001). During germination monitoring, it was often noted that seedlings were present under leaf litter. The extent to which seedlings may survive burial under leaf litter remains unknown.

While assessing environmental influences on initial seedling numbers may produce useful information, the survivorship of seedlings to at least the outplanting readiness size (>25 cm) and ultimately to reproductive stage will be of equal if not greater importance with respect to gaining insight into conditions necessary for self-sustaining populations. Conditions beneficial for higher seedling counts may not necessarily be the same as those that favor survivorship to outplanting size or reproductive stage.

Next steps

Monitoring survivorship: Survivorship of the seedlings will be monitored annually. The total number of plants within designated height classes (<1, 1-25, 25-50, 50-75, 75-100, >100 cm) and stages (immature, mature) will be recorded for each plot along with environmental data, as per germination monitoring methods. The germination rate was 90% for seeds kept in the dark for six months for soil seed bank proxy testing under laboratory conditions. Two percent of seeds kept in the dark did not germinate and maintained viability. These results suggest *C. superba* subsp. *superba* likely has a transient seed bank, where viable seeds do not persist in the soil beyond one year. Pending laboratory results of seeds kept in the dark for one year, it is anticipated that no further germination will occur beyond the first year following seed sowing, and monitoring of plots or sites with no surviving recruitment will be unnecessary after that time. Exact causes of mortality will remain unknown, and conclusions will be based on any observed relationships between survival and environmental variables. The results will give an indication of the recruitment potential for dispersed seeds, via either human-mediated dispersal, or bird dispersal should it occur, at each of the sites, as well as environmental factors associated with survivorship. Graduate student research of the potential for fruit dispersal by birds had success with conspecific attraction via bird call playback at sites, however birds were not observed consuming fruits (S. MacDondald, pers. comm.).

New seed sow trial at Palikea: Given the poor germination and/or survival results at Palikea, it would be worthwhile to explore the potential for germination and survival from sown seeds in areas with slug control, with further analysis of the influence of soil moisture, canopy openness, and understory cover. The outcome will not be comparable with the results of this study, as it will occur in a different season and will receive slug control, however it may help to demonstrate not only possible environmental influences at that site, but also the capacity for recruitment at a site planned for *C. superba* subsp. *superba* outplanting that will include slug control as a part of threat control management.

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OAHU ARMY NATURAL RESOURCES PROGRAM
MONITORING PROGRAM

GERMINATION RESULTS OF A *TETRAMOLOPIUM FILIFORME* VAR. *POLYPHYLLUM* SEED SOW TRIAL

INTRODUCTION

In order to meet IP stability goals, the OANRP five-year plan for the Kalena MFS PU for *Tetramolopium filiforme* var. *polyphyllum* was to locate and establish a new reintroduction site within Lihue or adjacent MU using plants or seeds from SBW-B greenhouse collections (OANRP 2014). It was presumed that several attempts would be necessary to establish a successful site and meet stability goals. This taxon generally grows on sparsely vegetated exposed rocky ridges and nearly vertical cliffs, and may hybridize with other *Tetramolopium* taxa. Two sites with appropriate habitat, that lack other *Tetramolopium* taxa, and have feasible access for management were located, including a site near Puu Hapapa (SBS-A), and a site near Kamaohanui (“Skeet Pass”) (SBW-D) (Figures 1 - 4). A trial was conducted to explore if OANRP can establish reproductive populations via seed sowing at these sites.

Map removed to protect rare resources

Figure 1. Locations of *T. filiforme* var. *polyphyllum* seed sowing trials at Hapapa (SBS-A) and Skeet Pass (SBW-D), and the Puu Kalena in situ site (SBW-B).

Figure 2. Habitat selected for *T. filiforme* var. *polyphyllum* seed sowing at Hapapa.

Figure 3. Habitat selected for *T. filiforme* var. *polyphyllum* seed sowing at Skeet Pass.

Figure 4. A memorable day in the field sowing seeds at Hapapa with Daniel Sailer. Note the big smile despite chilly and challenging conditions.

METHODS

Seeds were sown at Hapapa on November 30, 2016, and at Skeet Pass on December 20, 2016. Fifty 30 cm x 30 cm seed sow plots were established at each site, with an estimated 520 viable seeds per plot. Plots were located on terrain ranging from gentle slopes to cliffs requiring rappel use (categorized by degree of slope as <30°, 30-60°, and >60°), and in varying substrate (moss, lichen, crumbly eroded rock, rock crevice, rock ledge, and soil). Plots were separated by at least one meter, and marked using pre-numbered write-on aluminum tags along with a small amount of flagging nailed into the substrate (Figure 5). Because of concerns over seeds blowing away during or after sowing due to the lightweight, wind-dispersed seed structure, and the steep and windswept nature of the site, tackifier (Turbo Tack) was experimentally applied with squirt bottle in a thin layer on the substrate in half of the plots to help seeds adhere to the substrate. Tackifier is an additive commonly used in hydroseeding to enhance adherence to substrate. Seeds were generally sown on unmodified ground surfaces, though small weeds were occasionally hand-pulled prior to sowing, and any obstructive debris was removed. Seed used in the trial were from bulk collections of hand pollinated OANRP greenhouse SBW-B stock stored in the OANRP seed bank for less than one year.

Viability assays were conducted under laboratory conditions both with and without tackifier for seeds used at each site to examine if tackifier affects germination, and to estimate the number of viable seeds per plot. Seeds were sown on agar in petri dishes, including 50 seeds per sample (200 seeds total).

Figure 5. Scattered *T. filiforme* var. *polyphyllum* seeds and marker for Plot 22 at Hapapa. Yellow circles are shown around a few of the seeds for reference.

Petri dishes were stored in a Percival Controlled Environment Chamber (with diurnal light and temperature settings matching average monthly temperatures for the Nike missile installation at Pahole, at approximately 2100 feet elevation), and examined weekly for germination.

A subset of plots were monitored to assess germination at Hapapa on January 4, 2017 (5 week post-sowing), and at Skeet Pass on March 6, 2017 (11 weeks post-sowing). The monitoring was intended to provide a rough approximation of germination among plots, as well as to assess the utility of tackifier. It was anticipated that germination would likely be spread out over several weeks, and at the time of monitoring, some seeds might have already germinated and died, and others might not have germinated yet, depending on weather conditions. Seedlings of *T. filiforme* var. *polyphyllum* are very small, and it would be difficult to walk around or rappel to all plots for close inspection without damaging seedlings from stray seeds that ended up outside of plots. To minimize disturbance to the sites, only plots accessible off-rappel were monitored, and seed numbers were approximated. At Hapapa, 76% of the plots were monitored, and 66% were monitored at Skeet Pass. Seedling counts per plot were categorized as 0, 1-50, 50-100, 100-200, and >200 at Hapapa, and as 0, 1-25, 25-100, 100-200, and >200 at Skeet Pass.

Statistical tests included chi-square to compare germination with and without tackifier, and ordinal regression to assess the effects of tackfier use and slope on counts of seeds. All statistical analyses were performed in IBM SPSS Statistics Version 24.

RESULTS

Germination rates were similarly high under laboratory conditions for seeds sown with (87% germination) vs. without (94% germination) tackifier (chi-square: $p = 0.091$, $X = 2.85$) (Figure 6). Most seeds germinated within 1-2 weeks. Any observed differences in the field between plots with or without tackifier would be presumably due to differences in adherence rather than an inherent capacity for tackifier to enhance or inhibit germination.

Figure 6. *Tetramolopium filiforme* var. *polyphyllum* seedlings germinating in the OANRP seed lab with (left) and without (right) tackfier. Both treatments had similarly high germination.

All monitored plots at Hapapa had germinated seedlings. Among the observed plots, 29% had 1-50 seedlings, 34% had 50-100 seedlings, 34% had 100-200 seedlings, and 3% (a single plot) had >200 seedlings. Most plots had small seedlings, comprised of cotyledons with emerging true leaves, though 8% had larger seedlings with cotyledons and expanded true leaves (Figure 7).

Figure 7. Examples of *T. filiforme* var. *polyphyllum* seedlings observed at Hapapa, showing larger seedlings with expanding true leaves (left), as well as smaller ones consisting primarily of cotyledons (right).

Seedlings were present in 61% of the monitored plots at Skeet Pass. Among plots with seedlings, 75% had less than 25 seedlings, 20% had 25-100 seedlings, and 5% (1 plot) had 100-200 seedlings.

Tackifier use did not influence the number of germinated seedlings within plots at either site (Hapapa: $p = 0.876$; Skeet Pass: $p = 0.344$) (Figure 8), nor did the degree of slope (Hapapa: $p = 0.425$; Skeet Pass: $p = 0.210$) (Figure 9).

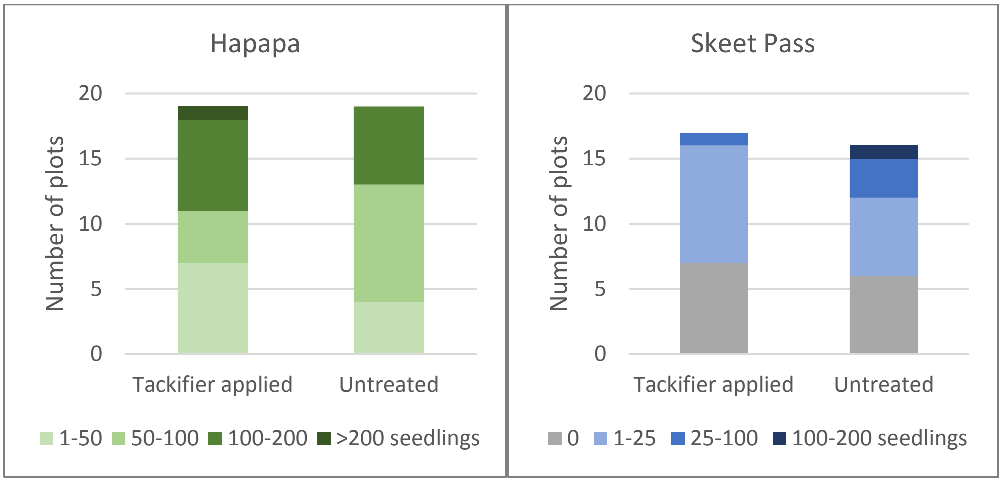

Figure 8. Number of germinated *T. filiforme* var. *polyphyllum* seedlings observed during monitoring in plots with and without the application of tackifier during seed sowing at Hapapa and Skeet Pass. Tackifier use did not impact germination results.

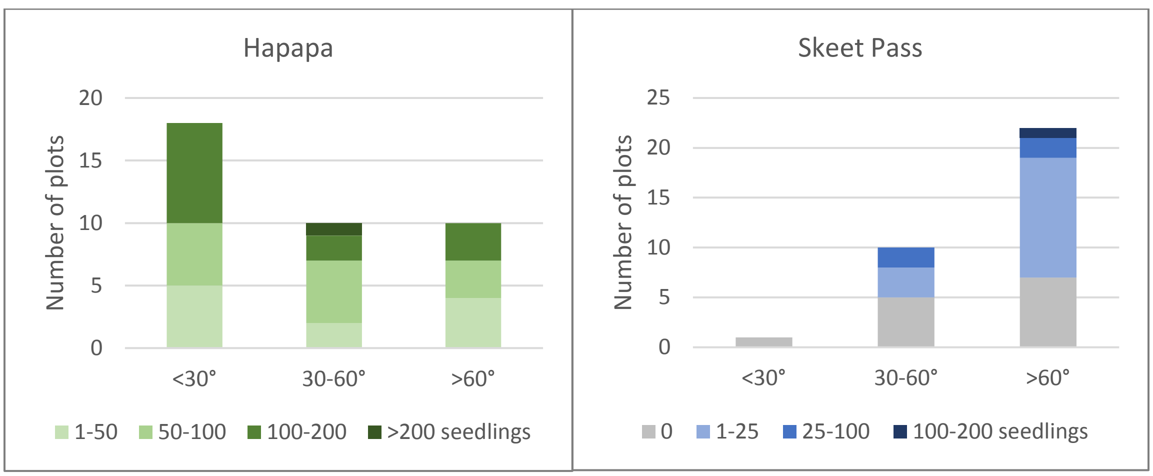

Figure 9. Number of germinated *T. filiforme* var. *polyphyllum* seedlings observed during monitoring in plots on gentle (<30°), moderate (30-60°), and steep (>60°) slope at Hapapa and Skeet Pass. The vast majority of available substrate at Skeet Pass was on moderate to steep slope, and as such the gentle slope category was only minimally represented. Slope did not impact germination results.

DISCUSSION AND FUTURE DIRECTIONS

While more seedlings were observed at Hapapa than at Skeet Pass, differences in germination between the sites cannot be compared, as the amount of time between sowing and monitoring differed considerably between the two sites. Regardless, it is apparent that germination does occur at both sites in the majority of seed sow plots, and as such both sites hold the potential for the formation of reproductive populations. Future monitoring of survivorship will provide a better indication of the ability to successfully establish reproductive populations via seed sowing.

Tackifier is unnecessary for sowing *T. filiforme* var. *polyphyllum* seeds. While the degree of slope did not affect the number of seedlings among observed plots, the plots requiring rappel were not monitored, and their relative influence could not be assessed. The ultimate influence of slope will be evaluated in accordance with survival to reproduction during more thorough monitoring. Similarly, substrate type will also be assessed in association with survival.

Survivorship monitoring will occur annually at each site (all plots will be monitored). An estimated 52,038 viable *T. filiforme* var. *polyphyllum* SBW-B seeds remain in storage, which may be used for future sowing attempts at these or other sites, as needed.

REFERENCES

Oahu Natural Resources Program. 2014. Chapter 2: Five Year Rare Plant Plans *in* Status Report for the Makua and Oahu Implementation Plans.

INTRODUCTION

These plans are intended to include all pertinent species information for stabilization, serve as a planning document and as an updated educational reference for OANRP staff. In many cases, data or information is still being gathered and these plans will continue to be updated. A brief description of each section is given here:

- **Species Description:** The first section provides an overview of each taxon. The IP stability requirements are given, followed by: taxon description, biology, distribution, population trends, and habitat.
- **Reproductive Biology Table:** This information was summarized by OANRP based on best available data from the MIP, OIP, USFWS 5-year Status Updates, OANRP field observations and other published research. Phenology is primarily based on observations in the OANRP rare plant database. The suspected pollinator is based on casual observations, pollinator syndromes as reported in the MIP and OIP, or other published literature. The information on seeds is from data collected at the Army seed lab and from collaborative research with the Harold L. Lyon Arboretum.
- **Known Distribution & Historic Collections Table:** This information was selected from Bishop Museum specimen records and collections listed in published research, the Hawaii Biodiversity and Mapping Program and other collectors notes.
- **Species Occurrence Maps:** These maps display historic and current locations, MUs, landmarks and any other useful geographic data for each taxon. Other features may be used on public documents to obscure locations of rare elements.
- **Population Units:** A summary of the PUs for each taxon is provided with current management designations, action areas and management units.
- **Habitat Characteristics and Associated Species:** These tables summarize habitat data taken using the Hawaii Rare Plant Restoration Group's Rare Plant Monitoring Form. The data is meant to provide an assessment of the current habitat for the in situ and outplanting sites. Temperature and rainfall estimates are also included for each site when available.
- **Pictures:** These photos document habitat, habit, floral morphology and variation; and include many age classes and stages of maturing fruit and seed. This will serve as a reference for field staff making collections and searching for seedlings.
- **Taxonomic Background:** This section provides information pertaining to the history of the taxonomy of the species.
- **Population Structure & Trends:** Data from monitoring the population structure for each species is presented with a plan to establish or maintain population structure at levels that will sustain stability goals. A review of population estimates for each Population Unit (PU) is displayed in a table. Estimates come from the MIP, OIP, USFWS 5-year Status Updates and OANRP field observations. In most cases, these estimates cannot be used to represent a population trend.
- **Reintroduction Plan:** A standardized table is used to display the reintroduction plans for each PU. Every outplanting site in each PU is displayed showing the number of plants to be established, the PU stock and number of founders to be used and type and size of propagule (immature plants, seeds, etc.). Comments focus on details of propagation and planting strategies.
- **Threats & Stabilization Goals Update:** For each PU, the status of compliance with all stability goals is displayed in this table. All required MFS PUs are listed for each taxon. 'YES, NO or PARTIAL' are used to represent compliance with each stability goal. For population targets, whether or not each PU has enough mature plants is displayed, followed by an estimate on whether a stable population structure is present. The major threats are listed separately for each PU. The boxes are shaded to display whether each threat is present at each PU. A dark shade identifies PUs where the threat is present and the lighter boxes where the threat is not applicable. The corresponding status of threat control is listed as 'YES, NO or PARTIAL' for each PU. A summary of the status of genetic storage collections is displayed in the last column.
- **Genetic Storage Section:** This section provides an overview of propagation and genetic storage issues. A standardized table is used to display information recorded for each taxon or PUs where applicable. The plan for genetic storage is displayed and discussed. In most cases, seed storage is the preferred genetic storage technique; it is the most cost-effective method, requires the least amount of maintenance once established, and captures the largest amount of genetic variability. For taxa that do not produce enough mature seed for collection and testing of storage conditions, micropropagation is considered the next best genetic storage technique. The maintenance of this storage method is continual, but requires much less resources and personnel than establishing a living collection in the nursery or a garden. For those taxa that do not produce storable seed and cannot be established in

micropropagation, a living collection of plants in the nursery or an inter situ site is the last preferred genetic storage option. In most cases, current research is ongoing to determine the most applicable method. For species with substantial seed storage data, a schedule may be proposed for how frequently seed bank collections will need to be refreshed to maintain genetic storage goals. This schedule is based only on storage potential for the species; other factors such as threats and plant health must be factored into this schedule to create a revised collection plan. Therefore, the frequency of refresher collections will constantly be adjusted to reflect the most current storage data. The re-collection interval is set prior to the time period in storage where a decrease in viability is detected. For example, *Delissea waianaeensis* shows no decrease in viability after ten years. OANRP would not have to re-collect prior to ten years as the number of viable seeds in storage would not have yet begun to decrease. The re-collection interval will be 10 years or greater (10+ yrs). If its viability declines when stored collections are tested at year 15, the interval will be set between 10 and 15 years. Further research may then be conducted to determine what specific yearly interval is most appropriate. The status of seed storage research is also displayed and discussed. Collaborative research with the USDA National Center for Genetic Resources Preservation (NCGRP) and Lyon Arboretum Seedlab is ongoing.

- **Management Discussion & 5-Year Action Plan:** A summary of the management approach, overall strategy and important actions for each taxon. This section displays the schedule of actions for each PU. All management is planned by 'MIP or OIP Year' and the corresponding calendar dates are listed. This table can be used to schedule the actions proposed for each species into the OANRP scheduling database. Comments in this section focus on details of certain actions or explain the phasing or timeline in some PUs.

Cyanea longiflora

Scientific name: *Cyanea longiflora* (Wawra) Lammers
Hawaiian name: *Haha*
Family: Campanulaceae (Bellflower family)
Federal status: Listed Endangered

Requirements for Stability:

- **3 Populations**
- **75 reproducing individuals in each population (short-lived perennial with fluctuating population numbers and trend of local decline)**
- **Threats controlled**
- **Stable population structure**
- **Complete genetic representation in storage**

Description and biology: *Cyanea longiflora* is a perennial shrub with woody stems 1-3 m long. In juvenile individuals the stems are muricate, eventually becoming smooth with age. The leaves measure 30-55 cm long, 6-12 cm wide, and are elliptic or oblanceolate shaped. The leaves are muricate in juvenile individuals and irregularly cleft or lobed. As the plant matures, the leaves become glabrous with margins entire or callose-crenulate, apex acute, sessile, or on petioles 0.3-3 cm long. The inflorescences are 5-10-flowered, peduncles 30-60 mm long, and pedicles 5-15 mm long. *C. longiflora* has a glabrous, obconical hypanthium 6-10 mm long and calyx lobes connate into an irregularly toothed sheath 2-4 mm long. The corollas are curved, and dark magenta 6-9 cm long. Additionally, the staminal column is also dark magenta and glabrous. The anthers are also glabrous, the lower two with apical tufts of white hairs. The berries are obpyriform, orange at maturity, and measure 10-12 cm long.

Flowering and fruiting specimens have been collected throughout the year, and timing varies among different populations. As with other *Cyanea*s with long tubular flowers, *C. longiflora* is thought to have been pollinated by nectar-feeding birds. It is capable of self-pollination, as evidenced by the fact that isolated plants produce viable seeds. The species' orange berries are indicative of seed dispersal by fruit-eating birds. Each berry typically contains approximately 300 seeds, with a maximum of 865 observed in one fruit. Seeds remain viable in storage at 20% relative humidity and 4 degrees Celsius for up to 10 years, with less than 30% viability loss after five years in storage. The longevity of individual plants has been recorded for up to 10 years for both *in situ* and *ex situ* individuals. Therefore, the species presumably lives for up to 10 years, like other *Cyanea* species of its size, and is thus short-lived for the purposes of the Implementation Plan (MIP 2003).

Figure. 1. Description and *ex situ* Conservation (from left to right): seedlings growing in growth chambers, plants growing in the nursery, dark magenta flowers with apical tufts of white hairs.

Table 1. Reproductive Biology Summary of *C. longiflora*

	Observed Phenology			**Reproductive Biology**		**Seeds***	
Population Unit	Flower	Immature Fruit	Mature Fruit	Breeding System	Suspected Pollinator	Average Seeds / Fruit	Dormancy
Kapuna to West Makaleha	Feb-Aug	April-Oct	May-Nov	Hermaphroditic	Bird**	359	Not Dormant
Makaha and Waianae Kai	Jan-Sept	April-Sept	May-Jan			488	
Pahole	April-Aug	April-Sept	July-Oct			196	

*There are 31-865 seeds per fruit. Calculations are an average from all collections made in each Population Unit.
**Smith, T.B., L.A. Freed, J.K. Lepson, J.H. Carothers. 1995. Evolutionary Consequences of Extinctions in Populations of a Hawaiian Honeycreeper. Conservation Biology 9: 1, 107-113.
Lammers, T.G. & C.E. Freeman. 1986. Ornithophily among the Hawaiian Lobelioideae (Campanulaceae): Evidence from nectar sugar compositions. American Journal of Botany 73: 1613-1619.

Known distribution: *C. longiflora* has been recorded in both the Waianae and Koolau ranges on Oahu. It is currently known from three general areas in the Waianae range spanning from Pahole to Makaleha to Makaha. Historical points in the Koolau range, dating as far back as the late 1800's, span Palolo to Helemano, but *C. longiflora* hasn't been observed in the Koolau range for almost a century. *C. longiflora* occurs in mesic to wet forest at elevations ranging from 645-836 m (2120-2740ft.)

Map removed to protect rare resources

Figure 2. Map 1. Current and Historical Populations of *C. longiflora* on Oahu.

Table 2. Selected Historic Collections of *C. longiflora* (Bishop Museum Records)

Area	Year	Collector	Population Unit	Notes
Honolulu Harbor	1869	Wawra, H.		Field site unknown
Konahuanui	1884	Lydgate, J.M.		
Makaha Valley	1918	Rock, J.F.C.	Makaha and Waianae Kai	
Makaleha	1918	Rock, J.F.C.	Kapuna to West Makaleha	
Waianae Valley	1951	Loring	Makaha and Waianae Kai	
Pahole	1978	Kimura, B.	Pahole	

Table 3. Population Units for *C. longiflora*. Includes Current and Proposed Management Designations for all populations. MFS = Manage for Stability; GS = Manage for Genetic Storage. MMR = Makua Military Reservation; SBW = Schofield Barracks West Range. See Population Structure and Management Discussion sections below for discussion on proposed changes.

Population Unit	Management Designation	PU Type	Action Area	Management Units for Threat control
Kapuna to West Makaleha	MFS	*In situ* and Reintro	MMR	Kapuna Upper Makaleha West
Makaha and Waianae Kai	MFS	*In situ* and Reintro	None	Makaha II
Pahole	MFS	*In situ* and Reintro (Proposed)	MMR	Pahole

Map removed to protect rare resources

Figure 3. Map 2. Populations of *C. longiflora* in the Northern Waianae Mountains.

Habitat: *C. longiflora* is found in both mesic and wet forests. The majority of plants are found on north facing slopes and range in location from lower slope to the top of upper slopes. Plants found in mesic vegetation and on moderate slopes tend to have intermediate canopy cover, while plants found on steeper slopes favor a closed canopy that is comprised of more native species. A mix of native grasses, shrubs, and trees comprise the general habitat of the mesic and wet forest containing *C. longiflora*. However, like most rare plant habitat, these native patches face encroachment from alien species.

Table 4. Habitat characteristics of each Population Unit. Average Annual Rainfall data is from the Rainfall Atlas of Hawaii (Giambelluca et al. 2013). All other data from OANRP observations.

Population Unit	Population Reference Codes	Elev. (ft.)	Slope	Canopy Cover	Topography	Aspect	Average Annual Rainfall (mm)
Manage for Stability Population Units							
Kapuna to West Makaleha	LEH-A, B; PIL-B, C, F	2140-2740	Moderate - Vertical	Intermediate-Closed	Lower Slope-Upper Slope	N	1681
Makaha and Waianae Kai	MAK-B; WAI-A	2400 - 2520	Moderate	Intermediate	Upper Slope	N	1698
Pahole	PAH-A, H, I	2120-2370	Moderate-Steep	Intermediate-Closed	Lower Slope-Upper Slope	N	1582

Table 5. List of Associated Species (six letter code = first three letters of genus, followed by first three letters of species) for each Population Unit for both canopy and understory. Species observed by OANRP staff are listed in alphabetical order.

Population Unit	Population Reference Codes	Canopy	Understory
Kapuna to West Makaleha	LEH-A, B; PIL-B, C, F	AcaKoa, AlySte, AntPla, BidTor, BobEla, BroArg, BudAsi, ChaObo, ChaTom, CibCha, CibGla, CopFol, CyrDen, CopFol, DioHil, GreRob, GynTri, IleAno, Kadaff, MetPol, MetTre, PerSan, PipAlb, PisSan, PisUmb, PlaSan, PsiCat, PsiGua, PsyMar, PsyOdo, Schter, WikOahOah XylHaw	AdiRad, AdeCon, AgeAde, AlySte, AntPla, AspAcu, AspMac, AthMic, BidTor, BleApp, CarWah, CibCha, CliHir, CycPar, CopFol, CycDen, DepPet, Diclin, DipSan, Dodvis, DooKun, DryFus, DryGla, KadAff, LanCam, MelOah, MetTre, MicStr, NepBro, NepExaHaw, OplHir, PasCon, PepMem, PisSan, Psicat, PsiGua, RubRos, SchTer, SphChi, StaAus, VerLit, VioCha, VanDav, WikOahOah
Makaha and Waianae Kai	MAK-B; WAI-A	AcaKoa, AntPla, BobEla, CibCha, DodVis, GreRob, KadCor, Metpol, NesSan, Psicat, Syzsan, XylHaw	AlySte, Bidtor, BleApp, CarWah, CibCha, Clihir, CopFol, CyaAcu, DicLin, DodVis, DooKun, EupMul, KadAff, NepBro, PlaCorDec, PsiCat, PsyMar, RubArg, VioCha, WikOahOah
Pahole	PAH-A, H, I	AcaKoa, AntPla, BobEla, CibCha, CibGla, CyrDen, GreRob, IleAno, KadAff, MelPed, MelPol, PlaSan, PsiCat, PsiGua, PsyHat, PsyMar, SchTer, VioCha, XylHaw	AlySte, AntPla, AspCau, AspMac, AspNid, AthMic, BidAlb, BidTor, BleApp, CarWah, CibCha, CibGla, CliHir, CopFol, CopLon, CycPar, CyrDen, DepMar, DicLin, DooKun, DryGla, EupMul, FreArb, KadAff, MelMin, MicStr, NepExaHaw, OdoChi, PsiCat, RubRos, Schnut, WikOahOah

Figure 4. *C. longiflora* development from seedlings to immature plants, displayed left to right.

Figure 5. Phenotypic variation among *C. longiflora* mature plants.

Figure 6. Flower shape and distribution along the stem for *C. longiflora*.

Figure 7. *C. longiflora* fruit development and maturity. Immature fruit is generally yellow and matures to an orange-purple color. Top left picture shows size of seeds (yellow circle) in relation to the fruit.

Taxonomic background: *C. longiflora* is endemic to the island of Oahu, and was formerly known as *Rollandia longiflora*. The species was historically found across both the Koolau and Waianae Mountain Ranges. Some historic populations in the Koolau Mountains have since been described as a separate species, *C. sessilifolia*. Currently managed populations are restricted to Waianae Mountains, and range from Pahole to Makaha to Makaleha. Although there are some phenotypic variation in plants, no genetic studies have been undertaken to determine if genetic separation exists between different population units.

Population Structure and Trends: Shortly after the finalization of the Makua Implementation Plan, the total number of mature plants plummeted from about 180 plants to just 60 in the span of three years. However, since 2003, the total number of mature *in situ* plants has remained fairly stable, increasing in the Pahole PU, while a slight decline occurred in Kapuna to West Makaleha PU. Population structure for *C. longiflora* is relatively weak. OANRP staff have observed seedlings in only three of nine Population Reference Sites. With the exception of 2014, when over 70 seedlings were observed across the Pahole PU, less than 20 seedlings have been seen since, and similar numbers observed across the remaining PUs. The high number of seedlings found in 2014 was the result of increased monitoring, however, many of the seedlings did not survive to the following year. The low number of seedlings observed in the Pahole PU since 2014 is surprising, since molluscicide has been used to control slug predation of developing seedlings. Rat damage to stems has also been observed across populations, and may contribute to a lack of seedling establishment and a decrease in overall plant numbers (Figure 12). While few seedlings were observed during monitoring, some seedlings are expected to have survived, as fruit has been observed on mature plants at all PUs, and the number of immature plants has remained stable or increased across all PUs. Reintroductions in the Kapuna to West Makaleha PU and the Makaha and Waianae Kai PU have resulted in an increase in the total number of immature and mature plants. However, a limited number of seedlings have been observed in these reintroduction sites.

Population Trends

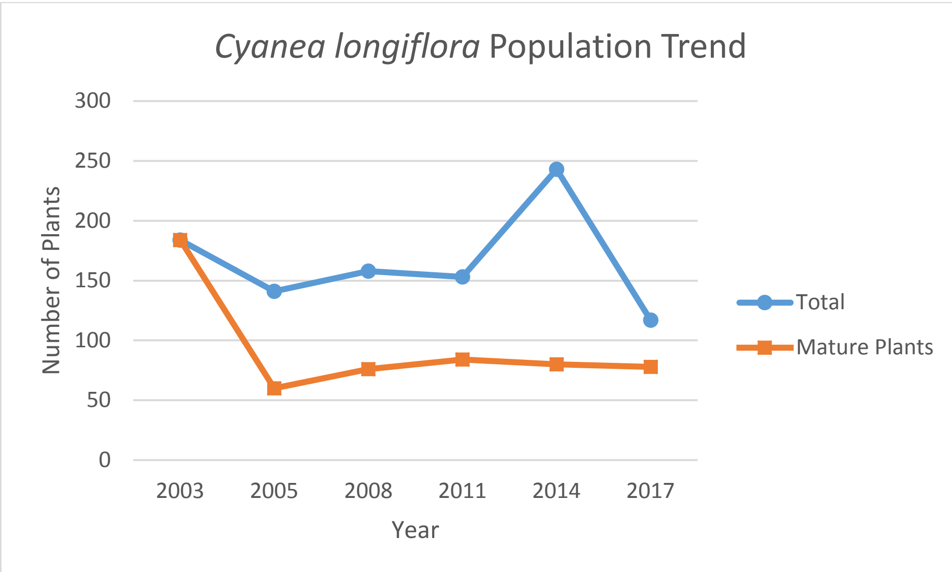

Figure 8. Overall combined total number of *in situ* plants compared with mature in situ plants only for all PUs.

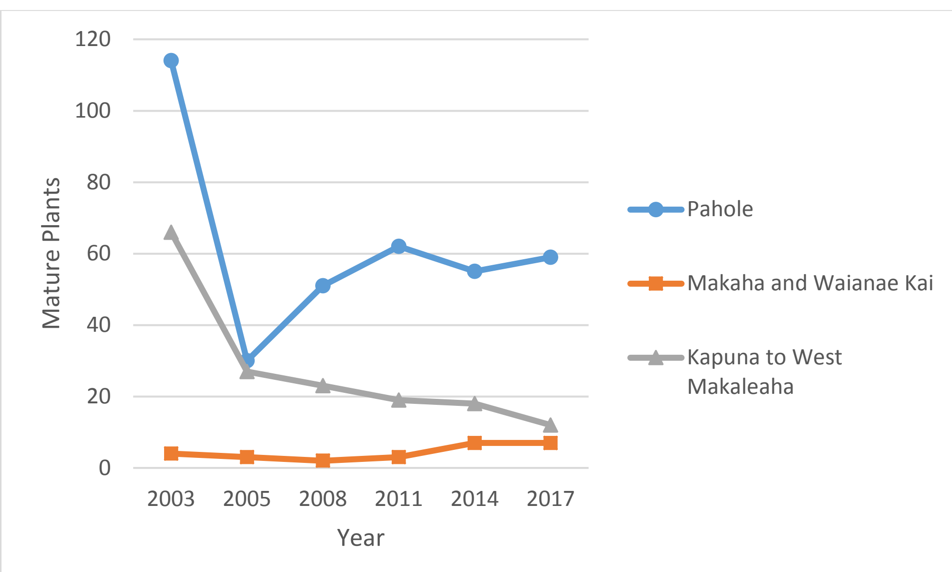

Figure 9. Number of *in situ* mature plants separated by PU.

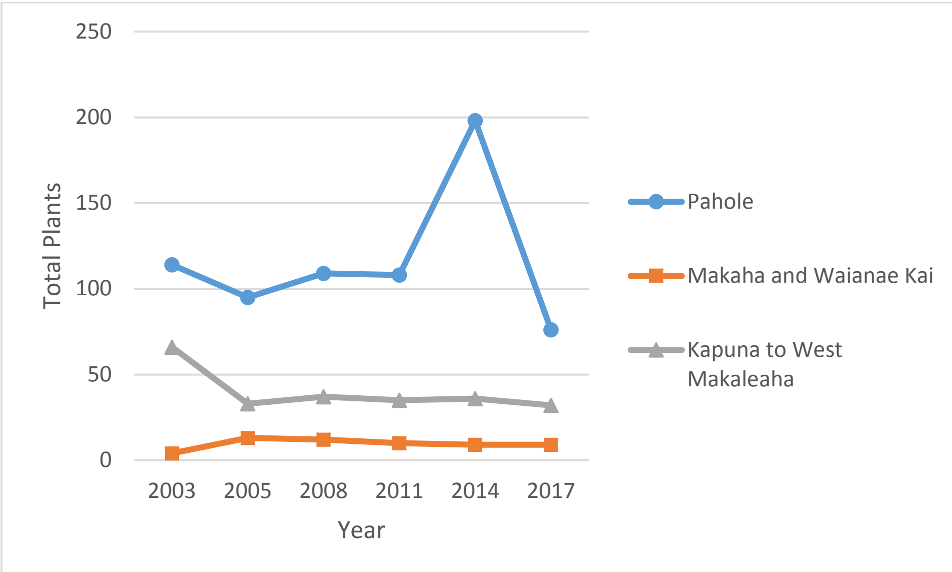

Figure 10. Total number of *in situ* plants separated by PU.

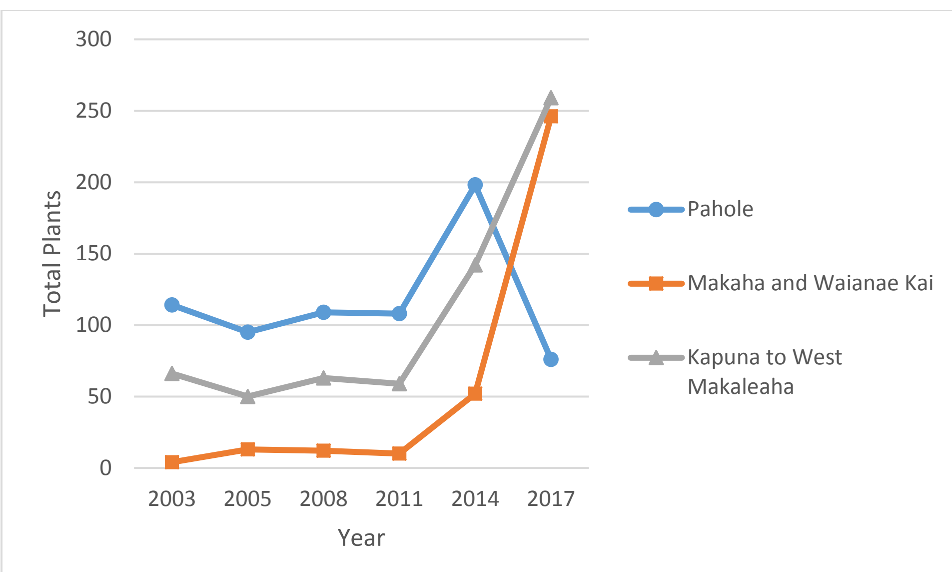

Figure 11. Total number of *wild* and reintroduced plants separated by PU.

Figure 12. Rat damage observed on stems of *C. longiflora* in Pahole PU.

Current status:

The known population units of *C. longiflora* in the Waianae Mountains totals 581 plants, consisting of mature and immature plants, and seedlings. About 30% of this total is represented by *wild* plants, and the remaining 70% from reintroduced populations. Currently, only one PU (Makaha and Waianae Kai) has more than 75 reproducing individuals. While the total number of mature plants in the Pahole PU has steadily increased over time since 2005, a lack of seedling development and immature plant survival has led to a decrease in overall plant numbers in the PU. The threat of fire is highest for the Makaha and Waianae Kai PU and Pahole PU. Fire damage has been observed in the Makaha and Waianae Kai PU in the past and lead to a decrease in mature plants post-fire (Figure 13). With the addition of reintroduction sites from 2013-2015, plant numbers have increased and are expected to remain stable based on high plant survival following reintroduction.

Figure 13. Mature *C. longiflora* plants damaged by fire at the Makaha and Waianae Kai PU.

STABILIZATION EFFORTS

The following section uses the above information, plus additional information we have learned about this taxon, to determine appropriate stabilization efforts for the next five years (July 2017 – June 2022). The following actions are requirements for stabilization:

- **3 Populations (PU)**
- **75 reproducing individuals in each population**
- **Threats controlled**
- **Stable population structure**
- **Complete genetic representation in storage**

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

	PU Stability Target			MU Threat Control				Genetic Storage
Population Unit	75 reproducing plants	Stable Population Structure	Ungulate	Slugs	Rodent	Fire	Weeds	% Completed
Kapuna to West Makaleha	No	No		No	Partial		Yes	77%
Makaha and Waianae Kai	Yes	No	Yes	No	Yes	Yes	Yes	40%
Pahole	No	No		Yes	No		Yes	96%

Outplanting considerations from 2003 MIP: "*Cyaneas* and *Cyanea* relatives potentially occurring with or near *C. longiflora* in the Waianae Mountains include *C. grimesiana* subsp. *obatae*, *C. superba* subsp. *superba*, *C. angustifolia*, *C. membranacea*, *C. calycina*, *C. acuminata*, *Delissea waianaensis*, and the *Clermonitias; C. persicifolia* and *C. kakeana*. It is common to find several *Cyanea* species and *Cyanea* relatives growing together, yet to date there is no good evidence of hybridization occurring between species of *Cyanea* or between a Cyanea and *Delissea* or *Clermontia* species. Consequently, concerns are minimal with respect to the possibility of inadvertently allowing unnatural hybridization to occur through the outplanting of *C. longiflora*. Additionally, *C. longiflora* has never been found in the southern Waianae Mountains and consequently, that region is not considered to be a part of *C. longiflora's* natural range. An outplanting line has been drawn across the mid-section of the Waianae Mountains restricting potential reintroduction sites to the northern Waianae Mountains. Reintroduction to the Koolau Mountains should not be considered unless Koolau plants are rediscovered."

Map removed to protect rare resources

Figure 14. Map 3. Outplanting considerations for *C. longiflora* from 2003 Makua Implementation Plan

Current Outplanting considerations and plan: There have been four outplantings of *C. longiflora*. Three of these have been in the Kapuna to West Makaleha PU, and one in the Makaha and Waianae Kai PU. The Kapuna to West Makaleha PU outplantings began in 2005, located at 3-Points (LEH-B), followed by two separate locations in Keawapilau (PIL-E and PIL-F). The lone outplanting in the Makaha and Waianae Kai PU was an augmentation in Makaha (MAK-B). The 3-Points (2005) and Keawapilau PIL-E (2008) reintroductions are the oldest plantings, and as such, have the lowest survival rate at 27%. Important to note is that these outplantings consisted of founders from single PUs, while later outplantings consisted of mixture of founders from all three PUs. In contrast, more recent outplantings at Makaha (2013) and

Keawapilau PIL-F (2013), showed higher survival rates at 60% and 55%, respectively. However, initial outplanting survival (first 3 years) for all reintroductions is comparable (Figure 15). Survival data shows that founder stock from Pahole PU had the highest outplanting survival compared to founder stock from the other two PUs in the mixed-founder outplantings (Figures 16). Of note is that in the Keawapilau PIL-E outplanting, only 1 of 91 outplants from 2013 survived, while over 60% of outplants from 2014 have survived. The 2014 outplanting at this site included individuals from Pahole and Kapuna founders, while the 2013 outplanting was restricted to Keawapilau founders. These results indicate success of reintroductions may not only be restricted to location, but also the founder stock. The Kapuna to West Makaleha PU also has shown a decline in mature *in situ* plants over the past 10 years, while Pahole PU has shown an increase in mature plants.

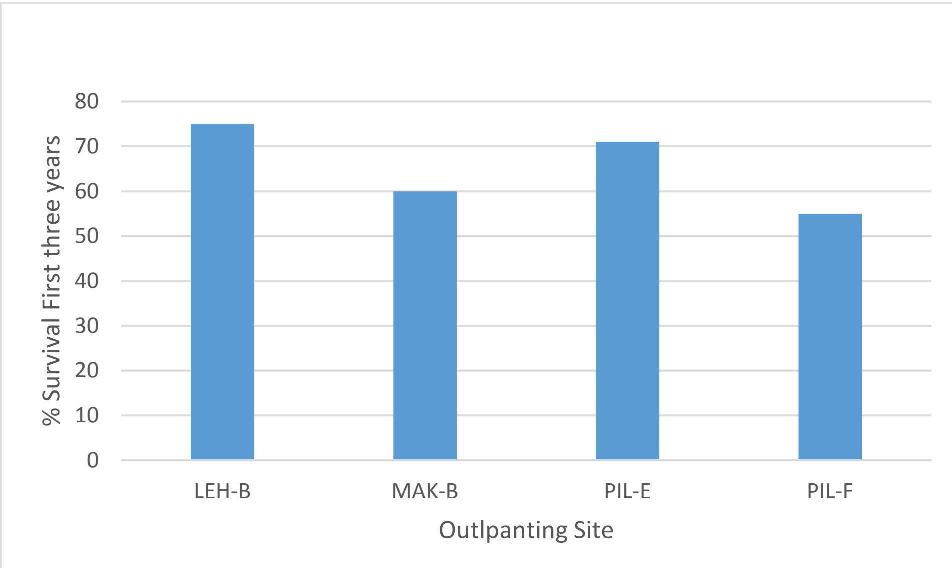

Figure 15. Initial outplanting survival in first three years post-planting.

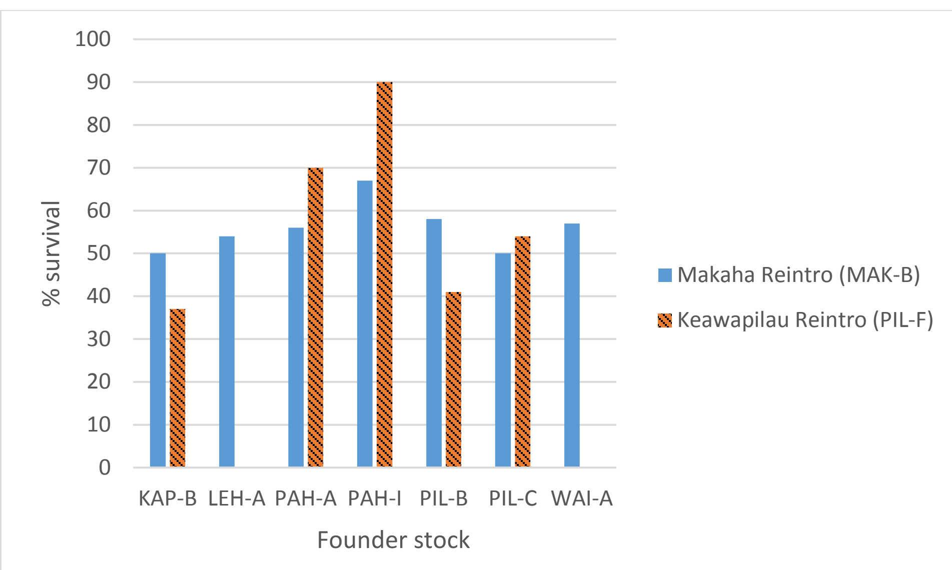

Figure 16. Outplanting survival of individuals separated by founder plant PU
(Note: LEH-A and WAI-A founder stock not used in Keawapilau PIL-F reintroduction)

Figure 17. Reintroduction of *C. longiflora*

Reintroduction Plan

The proposed outplanting sites are designed to meet the stability goal for the number of reproducing individuals, as currently only one meets this goal.

We plan to monitor the newer Makaha (MAK-B) and Keawapilau (PIL-F) reintroduction sites to see how they perform over the next two years before making additional plantings to these sites. Both sites have shown an increase in immature plants, and as they mature, both of these PUs should reach stability goals, barring unexpected die-off. We recognize that the Pahole PU will need to be augmented to reach that PU’s stability goal, and propose to proceed with augmentation over a three year timeframe to develop population structure into the site. As the Pahole *in situ* stock appears to be the healthiest, we should pursue site selection and proceed with a single source outplanting in this PU. Additionally, this stock has the most overall founders of all PUs and highest outplanting survival at previous outplanting sites, so it may also be beneficial to incorporate more Pahole founders into outplantings at other PUs in the future. The Pahole population is lower in elevation than other sites, but in a similar rainfall range with the majority of sites. It will also be important to determine the impact of drought on the ability for a plant to survive outplanting, and choose sites accordingly. Initial plant survival and outplanting survival over time suggest that previous outplantings at non-Pahole PUs may be sufficient to produce enough reproducing individuals to meet stabilization goals. Site selection for Pahole augmentation will be critical, as the current *in situ* population is in a native, sensitive habitat, and should not be disturbed during outplanting. The proposal is for 300 total outplants, and is based on data from reintroductions in 2005 and 2008, showing 27% of outplants reaching maturity. Given this rate of survival to maturity, 300 outplants should yield a sufficient number of reproducing mature plants to meet the stabilization goals for the Pahole PU.

Table 7. Current and Proposed Outplantings of *C. longiflora* to meet stabilization goal of 75 reproducing individuals per Population Unit (PU). 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. Note: We know how many mature plants are currently at population reference sites, but we recognize that the number of actively reproducing individuals (a requirement for stability) would likely be lower than the total number of mature plants.

Population Unit	Reintroduction Site(s)	Number of Plants Outplanted	Existing Mature Plants in PU	Propagule Population(s) Source
Kapuna to West Makaleha	LEH-B PIL-E PIL-F	36 11 334	61	LEH-A PIL-B/ PIL-C KAP-B/ PAH-A/ PAH-I/ PIL-B/ PIL-C/ PIL-D
Makaha and Waianae Kai	MAK-B	385	116	KAP-B/ LEH-A/ PAH-A/ PAH-B/ PAH-H/ PAH-I/ PIL-B/ PIL-C/ PIL-D/ WAI-A
Pahole	PAH-J*	300 total* (100/year)	59	PAH-A/ PAH-B/ PAH-H/ PAH-I

Threats: The primary threats to *C. longiflora* that were known at the time the Makua Implementation Plan was finalized (2003) included feral pigs and goats. 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. Various alien plant species threaten *C. longiflora* by altering its habitat and competing with it for sunlight, moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the potential for incidence and destructiveness of wildfires. Weed control is essential to maintain reproducing populations and continued recruitment of immature plants. However, care must be taken not to alter native habitat in steeper terrain where *C. longiflora* occurs. 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 have girdled plants in many MUs, and slugs have been seen on seedlings. Rat and slug control has been initiated in many populations where native snails are absent, however, results from these threat control methods have been limited to few seedlings and immature plants. Fungal pathogens are not currently an issue with this species but should be monitored for any potential impacts. Long-billed, nectar-feeding native Hawaiian birds, which are the presumed pollinators of *C. longiflora*, have been totally eliminated from the taxon's historic range in Waianae Mountains. OANRP would like to identify effective pollinators and dispersers and investigate whether or not there are other sites on Oahu where pollinators and fruit dispersers are more abundant. We will continue to assess how these threats are impacting population stability as we monitor the populations, and the effects of rat predation and climate change on population survival is unknown.

Genetic Storage Plan

Besides collections of fruit made for genetic storage and propagation, all other fruit has been left to mature on the plants. The fruit not eaten by rats was left to senesce and fall below the plants where new regeneration 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 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.

Table 8. Action plan for how to maintain genetic storage representation, and provide propagules for reintroduction, for *C. longiflora*

What propagule type is used to meet genetic storage goals?	What is the source for the propagules?	What is the Genetic Storage Method used to meet the goal?	What is the proposed re-collection interval for seed storage?	Is seed storage testing ongoing?	Plan for maintaining genetic storage
Seeds	*in situ* & outplantings	Collecting infructescences	10 years	Yes	Collect seeds and maintain reintroductions for re-collecting

Management discussion

The primary strategy for this taxon for the next five years will be to collect fruit from wild and reintroduction sites to meet genetic storage goals and for propagation of outplants for Pahole PU. Pahole PU will need reintroductions in order to achieve goals for mature plant numbers. Management efforts will also include monitoring as well as seed collections from diverse founders to store for future outplanting as needed The remaining PUs' management will focus on monitoring and collecting from wild and reintroduced plants over the next few years to meet genetic storage goals as well as increase the number of founders available if additional outplantings are needed at established populations. Collections will be prioritized in the next few years to secure genetic storage of the remaining unrepresented founders for all PUs. OANRP will use results from *in situ* monitoring to finalize timeline, stock, and locations for the next reintroductions. In order to establish restoration 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 Pahole PU. 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.

Lack of pollinators: OANRP could conduct pollinator observations to determine if certain sites have more visitation 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. However, focusing on rodent and slug control should be prioritized instead.

Fruit Dispersal: OANRP could support ongoing fruit disperser research to identify species and quantify fruit dispersal. Human-assisted fruit dispersal has been done in the past opportunistically, however, OANRP could conduct trials to better determine how efficient this method is at increasing seedling abundance.

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. Dieback of some outplants has been observed recently and the cause has been undetermined. Root rot may have led to insect infestations which damaged the stem and leaf tops of the plants, however, this is speculative and the exact cause is unknown. Plant disease and insect threats should be monitored to determine their impacts if additional dieback is observed in the future. All outplantings are contained in fences to control ungulates, have weed and rat control, and 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.

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Propagule Management and Genetic Storage

Schofield Barracks Landfill Kahua Seed Propagation Site

Introduction: The Army is required to stabilize numerous endangered species under U.S. Fish and Wildlife Service issued Biological Opinions (BOs), and the majority of these taxa are endangered plants. To meet stabilization goals for managed plant species, these plant populations are represented genetically *ex situ* in seed storage, greenhouses, or as clones in a garden-style living collection. In an effort to reduce greenhouse space for the living collections of some species, as well as reduce field time needed for seed collection, a fence was constructed in March of 2017 at the now decommissioned site of the former Schofield Barracks Landfill. This fence and surrounding area will be referred to as the Kahua Site (Figure 1). The fenced space is used to plant some of the living collection species in a seed-orchard setting. The surrounding area outside the fence will be planted with common natives, with the goal of producing seed for long term storage and habitat restoration. This fenced are may be extended in the future if the initial outplantings are successful.

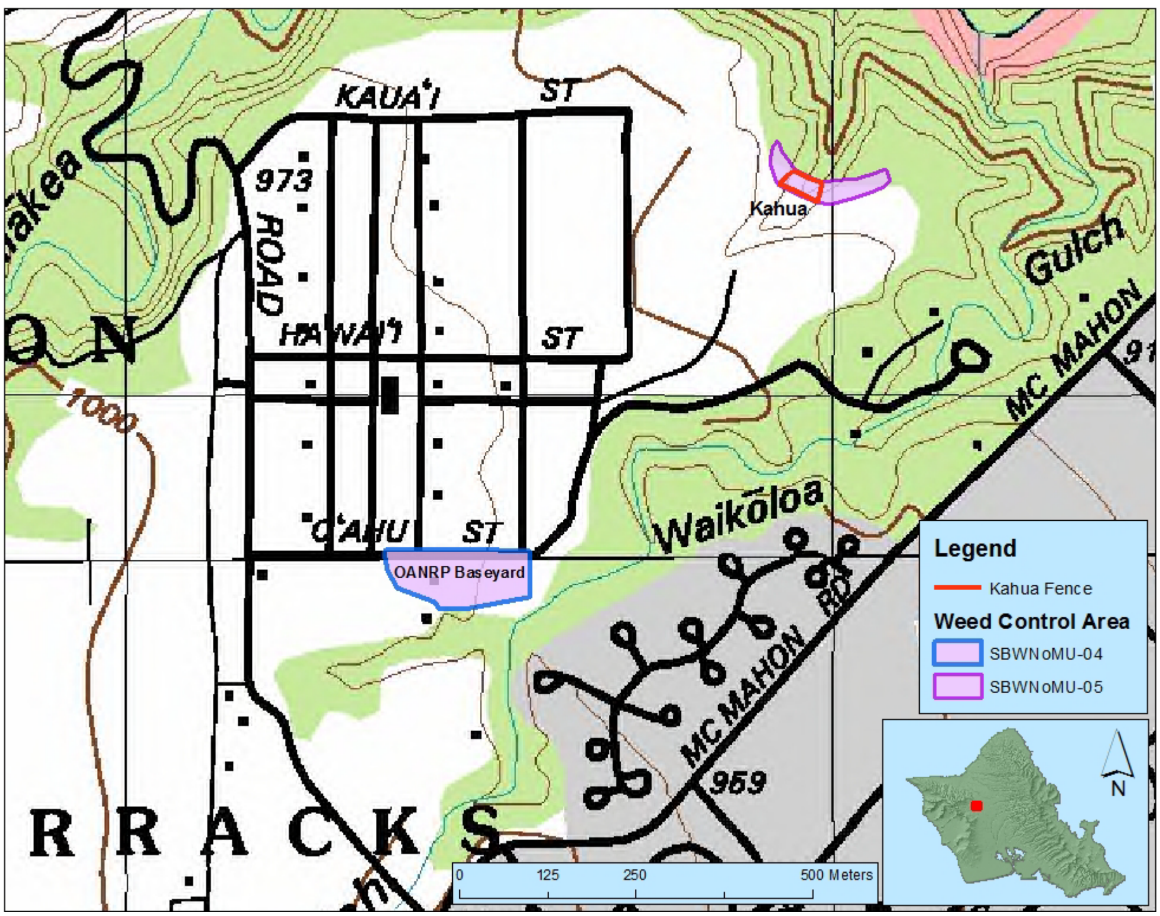

Figure 1. GIS map of Kahua fence (red outline)

Kahua Site

The Kahua site is a north facing slope on the edge of the former landfill, and is approximately 1.9 acres in size (Fig. 2 and 3). A 400 gallon water tote catchment was constructed near the fence to provide water for new plantings (Fig. 4). Currently, Natural Resource Program living collections exist on greenhouse benches at the Natural Resource Program baseyard. Limitations of the greenhouse setting include: limited production space, time consuming to maintain, and plants may not reproduce due to restricted growth in greenhouse pots. The benefit of the Kahua site are numerous and include: increased spacing between plants, reduction in time spent watering, and increased plant size as the roots are not restricted to pots. Potential downsides of the site include weed control, but this is being mitigated by the use of weed mat and mulch around outplants and fenced area. Currently, *Hibiscus brackenridgei* subsp. *mokuleianus*, *Neraudia angulata*, and *Nototrichium humile* are present at the Kahua site, and were planted in April, 2017. (Figs. 5-8).

Figure 2. Slope of landfill site showing Kahua fence location in red.

Figure 3. Kahua fence from bottom corner looking upslope.

Figure 4. Water catchment system at Kahua site.

Figure 5. Top fenceline and grass control area surrounding the fence. Rare plants are near the bottom of the fence and include: *Hibiscus brackenridgei* subsp. *mokuleianus, Neraudia angulata, and Nototrichium humile*.

Figure 6. *Neraudia angulata* planted at Kahua fence.

Figure 7. *Hibiscus brackenridgei* subsp. *mokuleianus* planted at Kahua fence.

Figure 8. *Nototrichium humile* planted at Kahua fence.

Future outplantings

We plan to expand the Kahua site in the future to include numerous species of rare plants, depending on the survival of currently planted species (Table 1). Currently there are 85 total plants from three different rare species planted at the site. Additionally, common native species will be incorporated into the area for use as windbreaks, as well as for future seed collection to be used in restoration efforts. Following planting, maintenance activities will include controlling invasive grasses and shrubs using herbicide and hand tools, and applying approved insecticides to control insect pests. Once plants begin to flower and fruit, the collection of propagules for seed storage and use in reintroductions will commence.

Table 1. Current rare plants in Kahua fence and potential species for future plantings.

Rare plant species	Population Unit	Number of Plants Outplanted	Current genetic storage goals of all founders(% complete)	Propagule Founder Source	Number of Potential Founders for PU
Neraudia angulata	Makua	27	42	MMR-A	54
Hibiscus brackenridgei subsp. *mokuleianus*	Keaau	15	86	KEA-A	7
Nototrichium humile	Kaimuhole and Palikea Gulch	43	100	ALI-A/ ALI-C	42
**Euphorbia celastroides var. kaenana*	Puaakanoa	100*	56	MMR-E/ G/ H/ I	124
**Cenchrus agrimonioides var. agrimonioides*	Kahanahaiki and Pahole	150*	28	MMR-A -MMR-K/ PAH-A –PAH-F	104
**Eugenia koolauensis*	Pahipahialua	75*	38	PHI-A	42

* =Future outplantings

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 75%	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 90%	Partial 100%	No	No
Waianae Kai	Genetic Storage	0	No	Partial	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: Cenchrus agrimonioides var. agrimonioides

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Kahanahaiki and Pahole	Manage for stability	200	Yes	Partial 78%	Partial 32%	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	184	Yes	Partial 100%	Yes	No	No
Makaha and Waianae Kai	Manage for stability	161	Partial 97%	Partial 100%	Partial 97%	No	No
South Huliwai	Genetic Storage	17	No	Partial 100%	No	No	No

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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	70	Yes	Partial 100%	Partial 30%	Partial 30%	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	124	Yes	Partial 100%	Partial 98%	No	No
Makaha	Genetic Storage	13	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	911	Yes	Partial 100%	Yes	Partial 14%	No

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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	61	Yes	Partial 98%	No	Partial 84%	No
Pahole	Manage for stability	59	Yes	Partial 98%	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

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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	48	Partial 100%	Partial 100%	Yes	Partial 46%	No
Pahole to Kapuna	Manage reintroduction for stability	95	Yes	Partial 92%	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	27	Yes	Partial 100%	Yes	No	No
Manuwai	Manage reintroduction for stability	0	Yes	Partial	Partial	No	No

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Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

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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	33	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 54%	Partial 54%	Partial 54%	No
Pahole to West Makaleha	Manage for stability	330	Partial 100%	Partial 90%	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

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Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	185	Yes	Partial 100%	Partial 16%	No	No
Kaluakauila	Manage reintroduction for storage	15	Yes	Partial 100%	No	No	No
Kapuna	Manage reintroduction for storage	113	Yes	No	No	No	No
Palikea Gulch	Genetic Storage	1	No	No	No	No	Partial 100%
South Mohiakea	Genetic Storage	10	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 100%	Yes	Partial 99%	No
Kaluaa	Manage for stability	499	Yes	Partial 100%	Partial 56%	Partial 56%	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

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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 2%	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	52	No	No	Partial 56%	No	No
Waianae Kai	Genetic Storage	10	No	Partial 100%	No	No	No

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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	135	No	Partial 44%	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	43	No	No	No	No	No
Waianae Kai	Genetic Storage	34	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: Euphorbia herbstii

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Kapuna to Pahole	Manage for stability	54	Yes	Partial 98%	No	Partial 83%	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	0	Yes	Partial	No	No	No
Makaha	Manage reintroduction for storage	2	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

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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	6	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	9	Partial 44%	Partial 33%	Partial 44%	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

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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	51	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	3	Yes	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

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	Yes	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

= 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

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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	124	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	117	No	Partial 99%	No	No	No
Manuwai	Manage reintroduction for stability	102	Yes	Partial 100%	No	No	No
Waialua	Genetic Storage	49	Partial 37%	No	No	No	Partial 100%

[shaded] = Threat to Taxon within Population Unit

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Yes=All PopRefSites within Population Unit have threat controlled

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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 98%	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	77	Partial 96%	Partial 96%	No	No	No
Central Makaleha and West Branch of East Makaleha	Manage for stability	22	No	Partial 14%	No	No	No
East branch of East Makaleha	Genetic Storage	0	No	No	No	No	No

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Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

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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	129	Yes	Partial 50%	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 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

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	571	Partial 100%	Partial 91%	No	No	Partial 10%

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 4%	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

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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	100	Yes	Partial 100%	No	No	No
Kapuna	Genetic Storage	0	No	No	No	No	No
Makua	Manage for stability	67	Yes	Partial 97%	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)	131	Partial 98%	Partial 98%	No	No	No
Manuwai	Manage for stability	97	Yes	Partial 100%	No	No	No
Waianae Kai Makai	Genetic Storage	13	Yes	Partial 100%	No	No	Partial 100%
Waianae Kai Mauka	Manage for stability	11	Yes	No	Partial 100%	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

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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	79	Partial 100%	Partial 23%	Partial 23%	No	No
Kaluakauila	Manage for stability	140	Yes	Partial 100%	No	No	No
Keaau	Genetic Storage	20	No	No	No	No	No
Keawaula	Genetic Storage	70	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	204	Partial 98%	Partial 98%	No	No	Partial 98%

[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

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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	No	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] = 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

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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	39	Yes	No	No	No	No
Ohikilolo	Manage for stability	28	Partial 100%	Partial 100%	No	No	No
Pahole	Genetic Storage	4	Yes	No	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	12	Yes	Partial 100%	No	No	No

[shaded box] = Threat to Taxon within Population Unit

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Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

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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	85	Yes	Partial 88%	Partial 88%	No	No
Ohikilolo East and West Makaleha	Manage reintroduction for stability	6	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	Partial 100%	No	No	No

[shaded box] = Threat to Taxon within Population Unit

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Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

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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	No	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 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

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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	45	Yes	Partial 98%	No	Partial 96%	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	164	Yes	Partial 100%	No	Partial 2%	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	172	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

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	88	Yes	Partial 99%	Partial 93%	Partial 97%	No
Kapuna-Keawapilau Ridge	Manage for stability	55	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	91	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

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	229	Yes	Partial 100%	Partial 89%	Partial 90%	No
Keawapilau to West Makaleha	Manage for stability	42	Partial 69%	Partial 83%	No	Partial 43%	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	76	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

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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	24	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	1903	Partial 100%	Partial 45%	No	No	No
Puhawai	Manage for stability	3	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 100%	No	No	No

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Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	191	Yes	Partial 8%	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	No	No	No	No
Kamaileunu	Genetic Storage	35	No	No	No	No	No
Makaha	Manage for stability	68	Yes	No	Partial 74%	No	No
Makaleha	Genetic Storage	19	No	No	No	No	No
Puu Hapapa	Genetic Storage	6	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
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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 52%	Partial 52%	No	No	Partial 15%
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	57	Yes	Partial 100%	Partial 95%	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	13	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

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	96	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 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

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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

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Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

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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	21	Partial 0%	No	No	No	No
Kaleleiki	Genetic Storage	14	Partial 50%	Partial 50%	No	No	No
Kaunala	Manage for stability	20	Partial 95%	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	22	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%

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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	74	Partial 100%	Partial 97%	Partial 89%	No	No
Helemano and Poamoho	Manage for stability	22	Partial 5%	No	No	No	No
Kaiwikoele, Kamananui, and Kawainui	Genetic Storage	13	No	No	No	No	No
Lower Peahinaia	Manage for stability	10	Partial 60%	Partial 60%	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	2	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

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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	Genetic Storage	1	No	No	No	No	No

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No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

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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	294	Partial 89%	Partial 91%	Partial 56%	Partial 56%	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	9	Partial 100%	Partial 0%	No	No	No

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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	96	Partial 100%	Partial 98%	No	Partial 89%	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	111	Partial 98%	Partial 97%	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	1	Partial 0%	Partial 0%	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	87	Yes	Partial 100%	Yes	Yes	No
Waiamano	Genetic Storage	1	No	No	No	No	No

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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	72	Yes	Partial 100%	No	No	No
Pualii	Manage reintroduction for stability	11	Yes	Partial 100%	No	No	No
Waieli	Genetic Storage	1	Partial 100%	No	No	No	No

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Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

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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

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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	230	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	26	Yes	Partial 100%	No	No	No
Makaha	Manage reintroduction for stability	0	Yes	Partial	Yes	No	No

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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

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Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	1	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	13	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	3	0	0	0	0	0	0	0	0	0	0	0	0%
Makaha	Manage for stability	29	0	1	0	0	0	18	0	0	0	9	9	30%
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
52	0	3	0	0	0	22	0	0	0	12	12

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														
Cenchrus agrimonioides var. agrimonioides														
Kahanahaiki and Pahole	Manage for stability	65	26	46	75	57	0	2	37	14	0	0	14	28%
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	61	52	29	44	21	0	40	15	2	0	29	30	60%
Makaha and Waianae Kai	Manage for stability	5	7	6	5	3	0	9	0	0	0	3	3	27%
South Huliwai	Genetic Storage	17	17	19	27	19	0	20	10	4	0	16	17	47%

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
149	105	100	151	100	0	72	62	20	0	49	65

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 grimesiana subsp. obatae														
Pahole to West Makaleha	Manage for stability	6	11	10	14	14	0	6	14	14	0	1	14	88%
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	1	2	100%
Palikea (South Palawai)	Manage for stability	8	4	11	15	15	5	6	15	15	5	1	15	79%

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
16	16	24	34	34	7	14	34	34	7	4	34

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	12	18	15	20	20	8	4	20	20	8	2	20	74%
Pahole	Manage for stability	59	15	19	47	47	1	10	45	45	1	4	49	98%
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
78	35	37	71	71	10	16	69	69	10	8	73

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	3	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	3	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	33	142	3	17	17	0	2	16	16	0	2	16	44%
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	45	45	0	1	45	45	0	1	45	90%
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
403	806	3	64	64	0	3	63	63	0	3	63

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														
Delissea waianaeensis														
Kahanahaiki to Keawapilau	Manage for stability	5	1	10	14	14	1	0	14	14	1	0	14	93%
Palikea Gulch	Genetic Storage	1	0	6	7	7	3	0	7	7	3	0	7	100%
South Mohiakea	Genetic Storage	10	15	5	14	14	0	0	12	12	0	0	12	80%
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	2	3	8	8	0	0	8	8	0	0	8	100%
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	40	84	84	4	0	80	80	4	0	80

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	17	18	0	0	27	13	0	0	20	20	50%
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	18	29	0	0	31	23	0	0	24	24

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	28	76	73	0	0	55	45	0	0	45	90%
North Kahanahaiki	Genetic Storage	115	36	3	12	12	0	0	9	6	0	0	6	12%
Puaakanoa	Manage for stability	135	15	4	50	44	0	0	31	28	0	0	28	56%
Action Area: Out														
Euphorbia celastroides var. kaenana														
East of Alau	Manage for stability	20	2	6	26	26	0	0	23	18	0	0	18	69%
Kaena	Manage for stability	880	274	1	59	58	0	0	56	45	0	0	45	90%
Keawaula	Genetic Storage	43	1	6	31	27	0	0	18	10	0	0	10	20%
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
1325	331	48	257	242	0	0	192	152	0	0	152

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	13	8	45	32	30	0	15	17	15	0	8	18	36%

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
13	8	45	32	30	0	15	17	15	0	8	18

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														
Flueggea neowawraea														
Kahanahaiki to Kapuna	Manage for stability	5	0	2	1	1	0	3	1	1	0	1	2	29%
Ohikilolo	Manage for stability	1	0	1	1	0	0	1	0	0	0	1	1	50%
West Makaleha	Genetic Storage	6	0	0	1	1	0	6	1	1	0	1	2	33%
Action Area: Out														
Flueggea neowawraea														
Central and East Makaleha	Genetic Storage	4	0	3	1	1	0	7	1	1	0	5	5	71%
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	9	0	2	0	0	0	10	0	0	0	4	4	36%
Mt. Kaala NAR	Genetic Storage	2	0	2	1	1	0	2	1	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
31	0	11	5	4	0	32	4	4	0	15	18

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	51	0	6	57	50	0	7	48	33	0	2	33	66%
Action Area: Out														
Gouania vitifolia														
Waianae Kai	Genetic Storage	3	0	0	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
54	0	6	57	50	0	9	48	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	0	1	1	1	0	3	0	0	0	0	0	0%
Waianae Kai	Genetic Storage	0	1	2	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
6	1	3	1	1	0	4	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														
Hibiscus brackenridgei subsp. mokuleianus														
Keaau	Manage for stability	0	3	7	1	1	0	6	1	1	0	0	1	14%
Makua	Manage for stability	16	5	28	35	34	0	35	34	33	0	32	36	82%
Action Area: Out														
Hibiscus brackenridgei subsp. mokuleianus														
Haili to Kawaiu	Manage for stability	1	5	15	0	0	0	16	0	0	0	9	9	56%
Waialua	Genetic Storage	49	85	24	7	5	0	57	3	0	0	57	57	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
66	98	74	43	40	0	114	38	34	0	98	103

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	21	77	77	0	2	68	63	0	0	63	100%
Action Area: Out														
Kadua degeneri subsp. degeneri														
Alaiheihe and Manuwai	Manage for stability	19	18	19	32	32	1	0	31	29	1	0	30	79%
Central Makaleha and West Branch of East Makaleha	Manage for stability	22	10	24	40	38	0	0	37	31	0	0	31	67%
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
143	128	64	149	147	1	2	136	123	1	0	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														
Kadua parvula														
Ohikilolo	Manage for stability	76	86	28	47	43	0	3	41	37	0	0	37	74%
Action Area: Out														
Kadua parvula														
Halona	Manage for stability	31	4	29	35	33	0	4	25	18	0	3	20	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
107	90	57	82	76	0	7	66	55	0	3	57

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														
Melanthera tenuifolia														
Kahanahaiki	Genetic Storage	1	0	22	11	0	0	10	5	0	0	10	10	43%
Kaluakauila	Genetic Storage	4	80	0	9	0	0	13	1	0	0	13	13	100%
Keawaula	Genetic Storage	200	50	0	0	0	0	0	0	0	0	0	0	0%
Ohikilolo	Manage for stability	571	11	19	16	0	0	8	13	0	0	6	6	12%
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
1722	411	41	36	0	0	31	19	0	0	29	29

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	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	7	7	33%
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	72	72

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	79	5	1	0	0	0	12	0	0	0	9	9	18%
Kaluakauila	Manage for stability	140	48	2	2	1	0	0	1	1	0	0	1	2%
Keaau	Genetic Storage	20	31	0	0	0	0	0	0	0	0	0	0	0%
Keawaula	Genetic Storage	70	70	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	36	0	0	0	34	34	68%
Action Area: Out														
Nototrichium humile														
Kaimuhole and Palikea Gulch	Genetic Storage	29	1	12	0	0	0	43	0	0	0	40	40	98%
Keawapilau	Genetic Storage	1	0	4	0	0	0	5	0	0	0	3	3	60%
Kolekole	Genetic Storage	12	0	0	0	0	0	10	0	0	0	10	10	83%
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	204	101	0	0	0	0	2	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
		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**	
		801	341	21	2	1	0	116	1	1	0	103	104	

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	0	0	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	0	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	1	0	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	39	12	9	20	20	0	0	19	19	0	0	19	40%
Ohikilolo	Manage for stability	0	0	17	19	18	0	2	14	14	0	0	14	82%
Pahole	Genetic Storage	4	5	2	5	4	0	1	4	4	0	1	5	83%
Action Area: Out														
Plantago princeps var. princeps														
Ekahanui	Manage for stability	5	50	67	68	66	0	2	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
55	76	119	136	132	0	5	120	99	0	1	100

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	28	27	44	40	0	0	24	4	0	0	4	15%
Ohikilolo	Manage for stability	0	97	51	56	40	0	1	22	16	0	0	16	32%
Action Area: Out														
Sanicula mariversa														
Kamaileunu	Manage for stability	31	182	26	69	69	0	0	54	46	0	0	46	92%
Puu Kawiwi	Genetic Storage	0	0	2	3	3	0	0	3	1	0	0	1	50%

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	307	106	172	152	0	1	103	67	0	0	67

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 kaalae														
Pahole	Manage for stability	2	0	0	2	2	2	2	2	2	2	0	2	100%
Action Area: Out														
Schiedea kaalae														
Kahana	Genetic Storage	5	0	4	2	1	9	8	0	0	9	5	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	5	3	5	50%
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	0	1	100%
South Ekahanui	Manage for stability	9	2	8	16	15	12	12	12	7	12	5	15	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
27	2	14	23	21	32	28	16	11	31	14	34

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	6	0	41	39	37	2	42	32	15	2	39	41	87%
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
6	0	43	41	39	2	44	34	16	2	41	43

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	0	5	5	1	0	5	100%
Keawapilau to West Makaleha	Manage for stability	24	363	73	80	79	0	0	79	77	0	0	77	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
24	363	78	85	84	1	0	84	82	1	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														
Tetramolopium filiforme														
Kahanahaiki	Genetic Storage	40	0	28	92	54	0	0	52	1	0	0	1	2%
Kalena	Manage for stability	24	93	7	9	8	0	7	9	8	0	7	8	26%
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	1903	1464	38	147	64	0	0	52	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
2367	1798	78	270	146	0	7	119	20	0	7	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	191	52	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	0	3	1	0	0	2	2	9%
Kamaileunu	Genetic Storage	35	0	0	0	0	0	0	0	0	0	0	0	0%
Makaha	Manage for stability	68	11	0	0	0	0	0	0	0	0	0	0	0%
Makaleha	Genetic Storage	19	9	2	8	0	0	11	1	0	0	8	8	38%
Puu Hapapa	Genetic Storage	6	1	7	7	0	0	6	4	0	0	5	5	38%

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
419	88	15	32	0	0	28	9	0	0	22	22

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	176	0	18	13	0	0	13	1	0	0	1	4%
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	5	37	9	11	10	0	1	10	6	0	0	6	43%
Halona	Genetic Storage	10	5	0	3	1	0	0	2	0	0	0	0	0%
Makaha Makai	Manage for stability	92	133	1	73	70	0	1	65	58	0	0	58	100%
Makaha Mauka	Genetic Storage	13	1	8	25	17	0	0	22	2	0	0	2	10%
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
156	363	20	133	113	0	3	114	67	0	1	68

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														
Alectryon macrococcus var. macrococcus														
Kahanahaiki to Keawapilau	Manage for stability	1	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	13	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	3	0	0	0	0	0	0	0	0	0	0	0	0%
Makaha	Manage for stability	29	0	1	0	0	0	18	0	0	0	9	9	30%
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
52	0	3	0	0	0	22	0	0	0	12	12

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 acuminata														
Helemano-Punaluu Summit Ridge to North Kaukonahua	Manage for stability	96	109	0	8	8	0	0	8	8	0	0	8	16%
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	9	9	0	0	9	9	0	0	9	18%
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
500	357	0	18	18	0	0	18	17	0	0	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														
Cyanea grimesiana subsp. obatae														
Pahole to West Makaleha	Manage for stability	6	11	10	14	14	0	6	14	14	0	1	14	88%
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	1	2	100%
Palikea (South Palawai)	Manage for stability	8	4	11	15	15	5	6	15	15	5	1	15	79%

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
16	16	24	34	34	7	14	34	34	7	4	34

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

		# 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														
Cyrtandra dentata														
Kahanahaiki	Manage for stability	33	142	3	17	17	0	2	16	16	0	2	16	44%
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	45	45	0	1	45	45	0	1	45	90%
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
403	806	3	64	64	0	3	63	63	0	3	63

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														
Delissea waianaeensis														
Kahanahaiki to Keawapilau	Manage for stability	5	1	10	14	14	1	0	14	14	1	0	14	93%
Palikea Gulch	Genetic Storage	1	0	6	7	7	3	0	7	7	3	0	7	100%
South Mohiakea	Genetic Storage	10	15	5	14	14	0	0	12	12	0	0	12	80%
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	2	3	8	8	0	0	8	8	0	0	8	100%
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	40	84	84	4	0	80	80	4	0	80

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	5	5	45%
Kaiwikoele and Kamananui	Genetic Storage	21	26	4	0	0	0	31	0	0	0	19	19	76%
Kaleleiki	Genetic Storage	14	54	12	0	0	0	23	0	0	0	2	2	8%
Kaunala	Manage for stability	20	39	8	0	0	0	35	0	0	0	14	14	50%
Malaekahana	Genetic Storage	0	4	0	0	0	0	4	0	0	0	3	3	0%
Ohiaai and East Oio	Genetic Storage	1	1	1	0	0	0	3	0	0	0	1	1	50%
Oio	Manage for stability	6	2	9	0	0	0	14	0	0	0	6	6	40%
Pahipahialua	Manage for stability	22	6	20	0	0	0	31	0	0	0	15	15	36%
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 Vaible Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
94	142	60	0	0	0	159	0	0	0	69	69

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	1	1	0	3	1	1	0	1	2	29%
Ohikilolo	Manage for stability	1	0	1	1	0	0	1	0	0	0	1	1	50%
West Makaleha	Genetic Storage	6	0	0	1	1	0	6	1	1	0	1	2	33%
Action Area: Out														
Flueggea neowawraea														
Central and East Makaleha	Genetic Storage	4	0	3	1	1	0	7	1	1	0	5	5	71%
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	9	0	2	0	0	0	10	0	0	0	4	4	36%
Mt. Kaala NAR	Genetic Storage	2	0	2	1	1	0	2	1	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
31	0	11	5	4	0	32	4	4	0	15	18

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														
Gardenia mannii														
Haleauau	Manage for stability	3	0	6	0	0	0	5	0	0	0	3	3	33%
Helemano and Poamoho	Manage for stability	22	1	2	1	1	0	18	1	1	0	13	13	54%
Kaiwikoele, Kamananui, and Kawainui	Genetic Storage	13	0	0	0	0	0	1	0	0	0	0	0	0%
Lower Peahinaia	Manage for stability	10	0	2	0	0	0	8	0	0	0	6	6	50%
South Kaukonahua	Genetic Storage	2	0	0	0	0	0	2	0	0	0	0	0	0%
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	2	0	1	0	0	0	2	0	0	0	1	1	33%
Kamananui-Malaekahana Summit Ridge	Genetic Storage	3	0	0	0	0	0	2	0	0	0	1	1	33%
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
61	1	11	1	1	0	39	1	1	0	25	25

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														
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	9	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	9	8	3	6	8	8	3	4	11

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 hirsuta														
Haleauau to Mohiakea	Manage for stability	11	2	6	7	7	7	10	2	2	7	6	10	59%
Helemano and Opaeula	Genetic Storage	1	4	4	2	2	1	4	1	0	1	2	3	60%
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	3	4	0	0	3	3	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	3	2	1	2	2	6	7	1	0	4	6	7	100%
Action Area: Out														
Phyllostegia hirsuta														
Hapapa to Kaluaa	Genetic Storage	1	27	10	8	7	7	10	4	4	7	3	8	73%
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	0	0	0%
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
29	38	23	20	19	24	36	8	6	22	20	32

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 kaalaensis														
Keawapilau to Kapuna	Manage reintroduction for stability	0	0	1	0	0	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	0	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	1	0	8	8	0	0	8	8	8

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 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	1	2	1	0	1	2	2	100%
Kaluaa	Manage for stability	0	0	1	1	1	0	1	1	1	0	1	1	100%
Pualii	Manage reintroduction for stability	0	0	1	1	1	1	1	0	0	1	1	1	100%
Waieli	Genetic Storage	1	0	5	5	5	5	6	4	4	5	6	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
2	0	16	15	15	14	17	9	7	14	15	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	39	12	9	20	20	0	0	19	19	0	0	19	40%
Ohikilolo	Manage for stability	0	0	17	19	18	0	2	14	14	0	0	14	82%
Pahole	Genetic Storage	4	5	2	5	4	0	1	4	4	0	1	5	83%
Action Area: Out														
Plantago princeps var. princeps														
Ekahanui	Manage for stability	5	50	67	68	66	0	2	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
55	76	119	136	132	0	5	120	99	0	1	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	2	0	0	2	2	2	2	2	2	2	0	2	100%
Action Area: Out														
Schiedea kaalae														
Kahana	Genetic Storage	5	0	4	2	1	9	8	0	0	9	5	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	5	3	5	50%
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	0	1	100%
South Ekahanui	Manage for stability	9	2	8	16	15	12	12	12	7	12	5	15	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
27	2	14	23	21	32	28	16	11	31	14	34

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	13	81	80	2	0	80	78	2	0	79	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	13	81	80	2	0	80	78	2	0	79

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	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	191	52	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	0	3	1	0	0	2	2	9%
Kamaileunu	Genetic Storage	35	0	0	0	0	0	0	0	0	0	0	0	0%
Makaha	Manage for stability	68	11	0	0	0	0	0	0	0	0	0	0	0%
Makaleha	Genetic Storage	19	9	2	8	0	0	11	1	0	0	8	8	38%
Puu Hapapa	Genetic Storage	6	1	7	7	0	0	6	4	0	0	5	5	38%

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
419	88	15	32	0	0	28	9	0	0	22	22

APPENDIX 5-1

MANAGEMENT ACTIONS TO PREVENT THE CONTINUED DECLINE OF ESU-C *ACHATINELLA MUSTELINA* IN HALEAUAU GULCH IN SCHOFIELD BARRACKS WEST RANGE

BACKGROUND

Achatinella mustelina were first documented at Haleauau SBW-A in Schofield Barracks West Range in 1997 when John Obata and Daniel Chung accompanied Oahu Army Natural Resources Program (OANRP) staff into the valley (Figure 1). On February 3, 2003 a total of ten snails were collected for captive rearing at the Snail Lab at the University of Hawaii at Manoa (UH). On June 29, 2013 a total of 13 *A. mustelina*, descendants of the original ten, were translocated to SBW-B.

Map removed to protect rare resources

Figure 1. Locations of *Achatinella mustelina* ESU-C population reference sites, and the proposed location for a snail enclosure at Kaala. The vast majority of remaining ESU-C snails are located in the manage for stability sites. The no management sites have few to no snails remaining.

On June 29, 2013 staff counted a total of 80 *A. mustelina* at SBW-A in Haleauau (Figure 2 and Table 1). OANRP translocated ten of them to the UH Snail Lab for pulsing with the intent of returning them in six months to a year However, due to their decline and the threat of disease while in captivity, those snails remained in the lab. When staff returned to SBW-A on December 16, 2015 only 42 snails were counted (Table 2). Many of the host trees had died and the snails appeared to be in decline. Staff camped there on January 24, 2017 to complete a current night survey and better document population trends. A total of 30 *A. mustelina* were counted (Table 3). Timed-count monitoring methods (time spent searching, geographic area surveyed, time of day, etc.) were the same for the 2013, 2015, and 2017 counts.

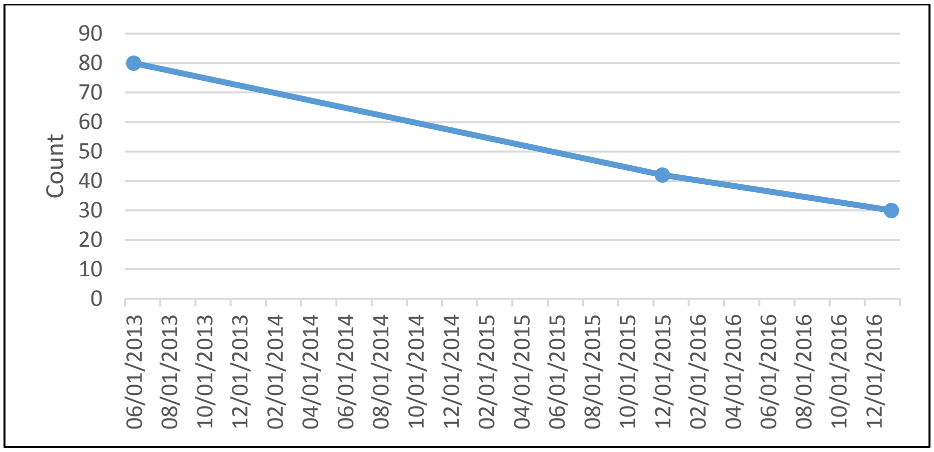


Figure 2. Timed-counts of *Achatinella mustelina* at SBW-A, North Haleauau Hame Ridge. On June 29, 2013, 10 snails were removed to the University of Hawaii Tree Snail Conservation Laboratory.

Table 1. Haleauau SBW-A population and host taxa count on June 29, 2013. Native host taxa are in boldface.

Taxon	Snails	Host
Alyxia stellata	1	1
Antidesma platyphyllum	35	20
Coprosma foliosa	3	2
Freycinetia arborea	1	1
Ilex anomala	1	1
Melicope spp	1	1
Nestegis sandwicensis	6	1
Planchonella sandwicensis	5	1
Psidium cattleianum	24	14
Schinus terebinthifolius	2	1
Toona ciliata	1	1
Total snails counted: 80 (5 small, 39 medium, 36 large)		

Table 2. Haleauau SBW-A population and host taxa count on December 16, 2015. Native host taxa are in boldface.

Taxon	Snails	Host
Alyxia stellata	2	2
Antidesma platyphyllum	14	11
Nestegis sandwicensis	2	1
Plachonella sandwicensis	2	1
Psidium cattleianum	22	15
Total snails counted: 42 (0 small, 18 medium, 24 large)		

Table 3. Haleauau SBW-A population and host taxa count on January 24, 2017. Native host taxa are in boldface.

Taxon	Snails	Host
Antidesma platyphyllum	11	8
Psidium cattleianum	17	9
Psycotria spp	1	1
Planchonella sandwicensis	1	1
Total snails counted: 30 (0 small, 14 medium, 16 large)		

The number of host trees at SBW-A continue to decline. The number of *Antidesma platyphyllum* with snails have dropped from 20 to 8 trees and *Psidium cattleianum* from 14 to 9 trees. Some of the flagged trees previously known to have snails are now dead. Most host trees had only one snail counted, so most remaining snails are unlikely to encounter each other and reproduce. In addition, trees adjacent to the flagged host trees were surveyed. The lack of *A. mustelina* in adjacent trees reinforces the observation that numbers are due to a true decline and not because of migration to other neighboring host trees.

Conversely, there is a sizeable and apparently stable *A. mustelina* population at Skeet Pass SBW-W. The population is on very steep terrain, and ropes are necessary to access some areas. Developing repeatable methods for monitoring snails has been challenging. Though the surveys to date have not incorporated comparable methods, it is apparent from the most recent timed-count of 231 snails on September 20, 2016 that many snails are present at the site (Table 4). Anecdotal reflections of observers indicate that numbers have remained stable.

Table 4. Skeet Pass SBW-W population and host taxa count on September 20, 2016. Native host taxa are in boldface.

Taxon	Snails	Host
Bidens torta	6	3
Broussaisia arguta	9	2
Cibotium chamissoi	1	1
Coprosma longifolia	29	21
Dianella sandwicensis	3	3
Dicranopteris linearis	3	3
Dubautia laxa	8	2
Ilex anomala	3	3
Melicope spp	1	1
Metrosideros polymorpha	119	48
Metrosideros rugosa	1	1
Perrottetia sandwicensis	45	21
Rubus argutus	1	1
Scaevola gaudichaudiana	1	1
Verbena litoralis	1	1
Total snails counted: 231 (20 small, 76 medium, 135 large)		

The reasons for the population decline at Haleauau are not entirely clear. *Euglandina rosea* are present, but not ubiquitous. One adult male Jackson's Chameleon was found very close to the snail population several years ago, but no other chameleons have been found since. Rat control has been fairly consistent for the SBW-A population (Victor snap traps are maintained twice quarterly from July to November, and monthly from December to June), but given the low numbers of *A. mustelina*, the likely loss of a few snails due to rat predation every so often is detrimental over time. Poor habitat, population fragmentation, and low fecundity are likely other contributing factors to the overall decline. The primary host tree in Haleauau is currently *P. cattleianum*, whereas the host plants at Skeet Pass are 98% native.

As agreed upon by the Implementation Team (IT) at the snail IT meeting on December 13, 2016, an enclosure will be constructed at Mt. Kaala for the protection of ESU-C snails in 2018, to include snails from the two manage for stability population reference sites, SBW-A Haleauau and SBW-W Skeet Pass, as well as the few remaining snails from the 12 "no management" sites. The Army has no plans to ever build an enclosure in the back of the SBW where the access is unreliable. Access is only available to Haleauau one week per month. This is not adequate time for construction. For the existing snail enclosures, months of time were needed to prepare, construct and remove predators. Similarly, this limited time allowance is not adequate for snail enclosure threat control management with regards to regularly scheduled and emergency maintenance requirements for the barriers and predators. Also the amount of earthwork required to install a snail enclosure is beyond what would be possible in an area studded with unexploded ordnance. The only site near ESU-C for *A. mustelina* with a suitable slope and access is atop Mt. Kaala. And with global warming, Mt. Kaala offers a wetter environment at higher elevation.

DISCUSSION AND RECOMMENDATIONS

At the snail IT meeting on December 13, 2016, OANRP recommended moving Haleauau SBW-A snails to a site with *A. mustelina* at Skeet Pass SBW-W, on the ridgeline from Kaala to Puu Kamaohanui, where a sizeable population of snails persists, given the population decline observed from 2013 to 2015 at Haleauau. **Given the further decline documented in January of 2017 at Haleauau SBW-A, OANRP propose moving SBW-A snails as soon as possible to Skeet Pass SBW-W.** Otherwise, by the time the Kaala enclosure is completed, the numbers will likely be greatly reduced. Dr. Melissa Price presented at the IT meeting and proposed translocation falls into the following categories:

- **Predation.** *Euglandina rosea*, rats and Jackson's chameleons are present at Haleauau. Standardized monitoring has documented a dramatic decrease in snails at the site, suggesting predation pressures may be adversely impacting the population, despite on-going rat control. Though rats and *E. rosea* are also present at Skeet Pass, the population appears to be resilient to predation pressures. Rats appear to be effectively controlled, and *E. rosea* are presumed to be in low numbers, given the stable population of *A. mustelina* at SBW-W.
- **Assisted evolution.** Representing Haleauau snails in the future predator exclosure is important for preserving genetic diversity that increases the likelihood of adaptation to climate change.
- **Assisted colonization.** Haleauau is the lowest elevation with extant snails in ESU-C, therefore snails from this site are more likely to survive warming temperatures and drying conditions which could potentially be important for survival of the species.

The SBW-A snails are at 2400 ft and the Skeet Pass SBW-W snails are at 3200 ft in elevation. The distance between them is approximately 2,500 ft. (or approximately 750 m). Translocating snails from SBW-A to 3800 ft at Mt. Kaala would likely be a greater shock to the snails than moving them to Skeet Pass SBW-W. Moving them to SBW-W a year or so in advance of enclosure completion may allow them to acclimatize gradually to increases in elevation. Instead of being moved a total of 1400 ft in elevation at once, they would first be moved 800 ft and then another 600 ft a year or two later. They will possibly have a better chance of surviving at Kaala with an acclimation period at SBW-W than if they were to be moved 1400 ft in elevation all at once. They would also be moving from a drier, weedier, habitat to a wetter, more native one.

ACTION PLAN

Goals:

- Protect *A. mustelina* at Haleauau area from immediate threat of predation
- Assisted evolution
- Assisted colonization

Objectives:

- Find remaining *A. mustelina* individuals at Haleauau SBW-A and translocate them to the Skeet Pass SBW-W population
- Release the snails into native forest in Skeet Pass where they can more readily intermix and increase genetic diversity
- Gradually acclimatize snails to a wetter/higher location prior to translocation to the Kaala snail enclosure, while preserving genes adapted to drier conditions

Snail translocation protocol:

Extraction: Snails will be collected during the day and night at Haleauau and placed into plastic terraria with good ventilation and preferred vegetation. The collection trip will require two days and one night in the field.

Transportation: Staff plan to camp in Haleauau for one night, hike out in the morning, drive to Dragon X (the landing zone (LZ) on Schofield Barracks) and fly by helicopter to Puu Kamaohanui, 500 meters to the east of Skeet Pass. Snail terraria will be carefully carried in a backpack into the helicopter for the five minute ride across Schofield Barracks West Range. The hike from the LZ to SBW-W takes about 30 minutes. All measures will be taken to ensure snails are not exposed to high temperature and direct sunlight during transportation.

Monitoring: OANRP will photograph all snails moved from Haleauau to Skeet Pass for use with HotSpotter photo identification software, and when snails are moved to Kaala, survivorship of the Haleauau group will be estimated. Staff will monitor snails at Skeet Pass after the translocation to access mortality and with timed-counts annually with methods comparable to prior surveys. Photo identification methods will not be incorporated into the timed-counts, as the steep nature of the terrain precludes sufficient proximity to snails for appropriate photographic resolution. Skeet Pass is too steep for ground shell monitoring. Any snails seen opportunistically will be evaluated with HotSpotter to determine if they are from SBW-A.

Threat control: The Skeet Pass snail population is protected by a rat grid that is maintained every six weeks, as well as an ungulate fence. The rat grid consists of two types of devices, Kamate snap traps, and Goodnature A-24 repeater traps. Threat control will continue until all snails are translocated to the Kaala enclosure.

APPENDIX 5-2

MANAGEMENT ACTIONS TO PREVENT THE CONTINUED DECLINE OF *ACHATINELLA MUSTELINA* AT PUU KUMAKALII IN SCHOFIELD BARRACKS WEST RANGE

BACKGROUND

OANRP staff have been observing ESU-D *Achatinella mustelina* at Puu Kumakalii in Schofield Barracks West Range since performing rare plant surveys and weed control here in 1995 (Figure 1). For years there were only incidental observations of snails while hiking along the main ridge to access Puu Kalena and areas in the West Range of Schofield Barracks. No thorough snail surveys were conducted here until 2009. Puu Kumakalii is the first puu to the north of Kolekole Pass and Puu Hapapa is the first puu to the south. They lie 2.5 kilometers apart. There are four different sites where *A. mustelina* have been observed at Puu Kumakalii. There is a predator exclosure atop Puu Hapapa that contains ESU-D1 snails from Kaluaa and Waieli gulches and the Puu Hapapa area.

Map removed to protect rare resources

Figure 1. Locations of ESU-D and D1 *Achatinella mustelina* near Puu Kumakalii and Puu Hapapa.

RECENT EFFORT AND CURRENT STATUS

At the snail IT meeting on December 13, 2016 OANRP discussed the possibility of translocating snails from declining populations of *A. mustelina* at Puu Kumakalii to the snail enclosure at Puu Hapapa.

When staff were collecting genetic samples at Puu Kumakalii on November 5, 2014, Dr. Melissa Price asked why these snails were not in the enclosure since they were found sharing trees with Jackson's chameleons. At the time OANRP did not have permission to move these snails. At the 2016 IT meeting it was agreed that these snails could be moved because they are found at similar elevation and moisture levels as the snails at Puu Hapapa. Other *A. mustelina* found closer to Mt. Kaala would be moving from wetter to drier areas and would not be acceptable to move, but these snails are thought to have comparable climate and moisture levels and thus could be translocated.

USFWS recommended that OANRP complete a current survey to better document population trends at Kumakalii using the same methods of prior surveys before translocating any snails. All of the surveys that were performed in 2017 consisted of the same amount of staff, search time, and geographic search area as the surveys from 2009. To the best of our ability all repeatable variables were identical. Four separate sub-populations were surveyed in 2009 and 2017: SBW-K, SBW-L, SBW-M, and PHW-A. It is unlikely that many more snails are in immediately adjacent areas given the extent of habitat degradation and unsuitability of drier areas at slightly lower elevations.

The main population over the past 15 years has been SBW-M, the area closest to the peak. Staff surveyed here in 2002 but the first thorough survey was done on June 9, 2009 when a total of 150 snails were counted (Figure 2 and Table 1). Only 39 snails were counted on the recent survey completed on February 22, 2017 (Table 2). Drastic habitat change in the past eight years is the most notable change at SBW-M. *Psidium cattleianum* has almost completely taken over this environment and the native trees have been squeezed out. All three major predators of *A. mustelina* are present here: *Euglandina rosea*, rats and Jackson's chameleons. No predator control has ever been conducted in this area. Rat control for elepaio takes place at significant distances away, and only a few chameleons have been removed opportunistically. Four Jackson's chameleons were found on the recent survey on February 22, 2017. No live *E. rosea* were seen recently but many shells were found on the ground.

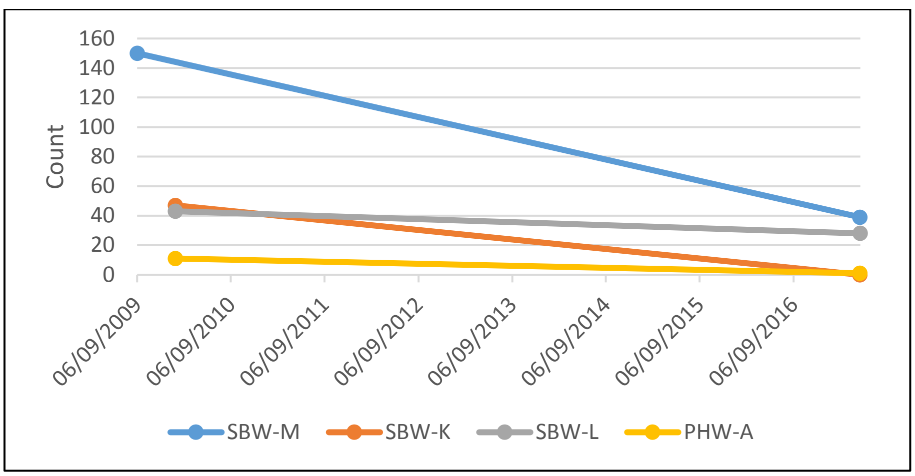


Figure 2. Timed-counts of *Achatinella mustelina* PRS near Puu Kumakalii.

Table 1. SBW-M population and host taxa count on June 9, 2009. Native host taxa are in boldface.

Taxon	Snails	Host
Antidesma platyphyllum	2	1
Carex wahuensis	1	1
Coprosma longifolia	1	1
Metrosideros polymorpha	6	6
Myrsine lessertiana	130	78
Psidium cattleianum	9	8
Pittosporum glabrum	1	1
Total snails counted: 150 (29 small, 31 medium, 90 large)		

Table 2. SBW-M population and host taxa count on February 22, 2017. Native host taxa are in boldface.

Taxon	Snails	Host
Myrsine lessertiana	39	24
Total snails counted: 39 (3 small, 10 medium, 26 large)		

Approximately 400 meters further west is SBW-K. This area was surveyed on November 5, 2009, with 47 snails counted (Table 3). During the surveys conducted on February 22, 2017 no *A. mustelina* were seen at SBW-K. The habitat is extremely degraded with *P. cattleianum*, *Clidemia hirta* and *Rubus rosifolius*.

Table 3. SBW-K population and host taxa count on November 5, 2009. Native host taxa are in boldface.

Taxon	Snails	Host
Antidesma platyphylla	12	1
Myrsine lessertiana	21	5
Psidium cattleianum	2	2
Zanthoxylum dipetalum	12	1
Total snails counted: 47 (8 small, 9 medium, 30 large)		

SBW-L lies one gulch to the east of SBW-K, between SBW-K and SBW-M. During the survey on November 4, 2009 a total of 43 snails were counted (Table 4). On the recent survey on February 23, 2017 only 28 snails were counted (Table 5).

Table 4. SBW-L population and host taxa count on November 4, 2009. Native host taxa are in boldface.

Taxon	Snails	Host
Antidesma platyphyllum	1	1
Metrosideros polymorpha	2	2
Myrsine lessertiana	31	17
Psidium cattleianum	9	9
Total snails counted: 43 (11 small, 10 medium, 22 large)		

Table 5. SBW-L population and host taxa count on February 23, 2017. Native host taxa are in boldface.

Taxon	Snails	Host
Myrsine lessertiana	28	13
Total snails counted: 28 (2 small, 10 medium, 16 large)		

On the Navy (south) side of the main ridge is Puhawai Gulch. The snails here are population PHW-A. When this area was last surveyed on November 5, 2009 a total of 11 snails were found (Table 6). Only one snail was found during the survey on February 22, 2017 (Table 7). The native trees throughout this area continue to decline and in some places even *P. cattleianum* is showing signs of a dieback.

Table 6. PHW-A population and host taxa count on November 5, 2009. Native host taxa are in boldface.

Taxon	Snails	Host
Myrsine lessertiana	11	9
Total snails counted: 11 (1 small, 0 medium, 10 large)		

Table 7. PHW-A population and host taxa count on February 22, 2017. Native host taxa are in boldface.

Taxon	Snails	Host
Myrsine lessertiana	1	1
Total snails counted: 1 (0 small, 1 medium, 0 large)		

The total number of *A. mustelina* observed during timed-counts at Kumakalii declined from 251 to 68 snails between 2009 and 2017. This represents a population decline of 73% in 8 years.

DISCUSSION AND RECOMMENDATIONS

Given the substantial decline documented in 2017, OANRP propose to translocate all the *Achatinella mustelina* from each of the four sites around Puu Kumakalii found during one overnight trip into the Puu Hapapa snail enclosure as soon as possible. Dr. Melissa Price provided her reasons to move snails in her presentation at the IT meeting in December. This proposed translocation falls into the following categories:

- **Predation**. Rats, *E. rosea*, and Jackson's chameleons are present at the Kumakalii sites. Predation pressures are likely adversely impacting the population, as standardized monitoring has documented a dramatic decrease in snails at the site (73% reduction).
- **Assisted evolution.** Kumakalii is the lowest elevation with extant snails in ESU-D within Schofield Barracks West Range, and representing these snails in the Hapapa predator exclosure is important for preserving genetic diversity that increases the likelihood of adaptation to climate change. In addition, these snails will be the only ones from ESU-D in Schofield Barracks that are represented in a predator free exclosure.
- **Assisted colonization.** Kumakalii is the lowest elevation with extant snails in ESU-D on Schofield Barracks, therefore snails from this site are more likely to survive warming temperatures and drying conditions.

If the Kumakalii snails are never moved, they will likely blink out in a few years due to loss of habitat and high predation threat. Although there are already more than the required 300 snails at Puu Hapapa, the snails at Puu Kumakalii are important because they are on Army training lands and in imminent danger of becoming eliminated by predators. Additionally, there is a small increase in elevation for some of the snails from SBW-L, and this may contribute positively to the genetic composition of the Puu Hapapa ESU D snails in terms of assisted evolution. The Army is not proposing translocating snails from higher elevation sites at SBW (e.g. Puu Kalena) to the Hapapa enclosure.

OANRP contacted Cory Campora from the Navy and he is in support of translocating any snails that remain in Puhawai Gulch to the enclosure at Puu Hapapa. Our staff advised him that if the Navy can survey their area at night, they will likely find a few more survivors than the single snail found during this recent daytime operation.

ACTION PLAN

Goals:

- Genetic rescue of *A. mustelina* from the Puu Kumakalii area.
- Protect from immediate threat of predation.
- Encourage population growth given bottleneck of fragmented sub-populations.

Objectives:

- In the next three months, find and safely translocate remaining individuals to the Puu Hapapa snail enclosure from the Puu Kumakalii area (SBW-K, L, M and PHW-A subpopulations).
- Release the snails into a *M. lessertiana* patch (since most Puu Kumakalii snails were found in *M. lessertiana*) where they can more readily intermix and increase genetic diversity.

Snail extraction and translocation protocol:

Extraction: Snails will be collected during the day and night. They will be placed into plastic terraria with good ventilation and preferred vegetation. The collection trip will require two days and one night in the field. Multiple trips for this translocation effort are not being considered at this time.

Transportation: Staff plan to camp on Puu Kumakalii for one night and fly by helicopter to Puu Hapapa the following day. Snail terraria will be carefully carried in a backpack into the helicopter for the 5 minute ride across Kolekole Pass. The hike from the Hapapa LZ to the snail enclosure takes about 10 minutes. All measures will be takes to ensure snails are not exposed to high temperature and direct sunlight during transportation. Due to range access limitations (one designated week per month), it is difficult to schedule collection trips before any favorable (i.e., rainy) weather events.

Monitoring: Staff will continue to monitor snails in the Hapapa enclosure in accordance with the current protocol of quarterly timed-counts and ground shell plot monitoring.

Long-term management: The Puu Hapapa enclosure has been operational for five years now. Staff have outplanted numerous native plants and helped to improve the overall diversity and density of plants, as well as decrease surface soil temperatures and raise local microclimate humidity levels. A nearly continuous sub-canopy has been created to assist with snail movements across the enclosure for a functionally single population of *A. mustelina* snails. Predator control is performed quarterly involving setting rat snaps and tracking tunnels, *E. rosea* sweeps while weeding, and keeping a lookout for Jackson's chameleons during timed-count monitoring. This substantial amount of attention will continue into the future, and as time goes on the enclosure should continue to become an even better habitat for rare snails.

At Puu Kumakalii, management will continue to focus largely on ungulate control, fence maintenance, and rare plant management on the cliff areas. An experimental research effort to aerially broadcast rodenticide across the larger Lihue Management Unit is planned for 2018, pending permitting and environmental reviews. However, this rodent control effort is expected to only have a short-term benefit for Puu Kumakalii snails given their remote location. If the translocation effort is not approved, OANRP is not considering any expanded threat control efforts at Puu Kumakalii given that Jackson chameleons and *E. rosea* are primary threats and no control methods exist beyond intensive hand searching, the efficacy of which is insufficient. Also the habitat is too far degraded to consider any habitat restoration efforts beyond the more intact cliff areas for other managed plant taxa.

Achatinella spp. Snail Relocation in Conjunction with Intensive Weed Management Protocol for O`ahu Army Natural Resource Program

November 28, 2016

O`ahu tree snails (*Achatinella* species) protected by the Endangered Species Act (ESA) may need to be relocated to avoid incidental take during intensive weed management that includes the use of chipping equipment. When disturbance of snail habitat cannot be avoided and snails need to be relocated, the following steps will be performed:

1. A thorough survey of the weed management area containing the snails must be conducted during the night on 3 separate occasions using binoculars no more than 1 month prior to the start of cutting and chipping.
2. During each of these three nighttime survey periods, trees or other vegetation containing snails will be flagged, and the number of individual snails and their size (or age class) and the vegetation they are on will be recorded.
3. Minimum survey time at night will be 6 person hours per quarter hectare (50 meter block). Staff will conduct sweeps entailing 4-8 staff walking in a phalanx formation back and forth to ensure 100% visual survey coverage of the sector. Staff will communicate constantly to ensure that gaps are not left between surveyors.

    a. If zero snails are found in a sector for three consecutive night surveys, area can be cut and chipped.

    b. If at any point a snail(s) is found in the sector, an area is delineated five meters out from the snail on all sides. All staff will be briefed about special care required when working in this area.

        i. For dense stands (approximately 50 stems per meter squared) of small diameter (approximately 1-3 inches at base) trees, removal can be conducted by using pruning saws to cut each individual stem at approximately 5feet height above ground. Each cut stem will be lowered carefully to minimize disturbance of any potential snail attached to the tree. The inspector will observe the stem as it is lowered to monitor for any snails that could be dislodged while lowering, and each leaf surface will be visually inspected. Any snails found during this process are translocated following approved U.S. Fish and Wildlife Service translocation protocols. Then the cut stem may be chipped.

        ii. For trees with diameter greater than approximately 3inches, the canopy will be inspected using a climbing ladder (Werner 15 feet telescoping Multi Ladder) if possible or tree climbing equipment. Use of these survey tools will be conducted carefully to ensure minimal disturbance to any potential snails and only where surveys can be done safely. Leaf surfaces will be individually inspected within the limits of safety. This survey will be conducted once at night before declaring it safe to cut and chip.

As unusual circumstances arise, Annie Marshall, Joy Browning, or O`ahu Island Team Lead shall be notified within 24 hours to discuss modifications relative to the authorized activities in conjunction with this protocol.

Achatinella spp. Snail Relocation in Conjunction with Intensive Weed Management Protocol

August 30, 2016

Oahu tree snails (*Achatinella* species) protected by the Endangered Species Act (ESA) may need to be relocated to avoid incidental take during intensive weed management that includes the use of chipping equipment. When disturbance of snail habitat cannot be avoided and snails need to be relocated, the following steps will be performed:

1. A thorough survey of the weed management area containing the snails must be conducted during the night on 3 separate occasions using binoculars (Figure 1).
2. During each of these three nighttime survey periods, trees or other vegetation containing snails will be flagged, and the number of individual snails and their size (or age class) and the vegetation they are on will be recorded.
3. Minimum survey time at night will be 6 person hours per quarter hectare (50 meter block). Staff will conduct sweeps entailing 4-8 staff walking in a phalanx formation back and forth to ensure 100% visual survey coverage of the sector. Staff communicate constantly to ensure that gaps are not left between surveyors.

    a. If zero snails are found in a sector for three consecutive night surveys, area can be cut and chipped.

    b. If at any point a snail(s) is found in the sector, an area is delineated five meters out from the snail on all sides. All staff are briefed about special care required when working in this area.

        i. For dense stands (~50 stems per meter squared) of small diameter (~1-3” at base) trees, removal can be conducted by using pruning saws to cut each individual stem at ~5’ height above ground. Each cut stem will be lowered carefully to minimize disturbance of any potential snail attached to the tree. The inspector will observe the stem as it is lowered to monitor for any snails that could be dislodged while lowering, and each leaf surface will be visually inspected. Any snails found during this process are translocated following approved USFWS protocols. Then the cut stem may be chipped.

        ii. For trees with diameter >~3”, the canopy will be inspected using a climbing ladder (Werner 15’ telescoping Multi Ladder) if possible or tree climbing equipment. Use of these survey tools will be conducted carefully to ensure minimal disturbance to any potential snails and only where surveys can be done safely. Leaf surfaces will be individually inspected within the limits of safety. This survey will be conducted once at night before declaring it safe to cut and chip.

Map removed to protect rare resources

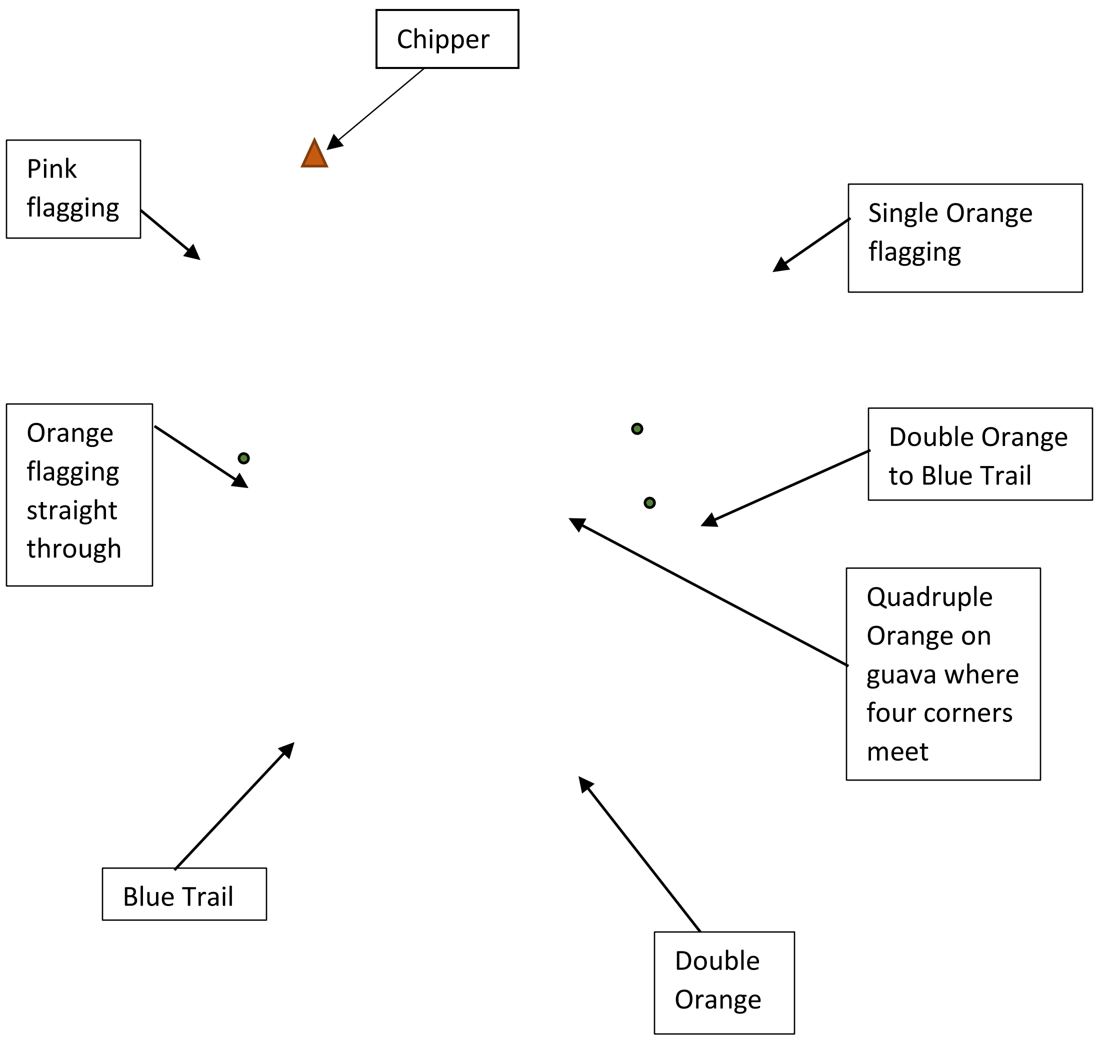


Figure 1. Palikea North Search Sectors

Palikea North Enclosure Restoration Plan

Goals of Restoration:

- Restore vegetation in the enclosure to 75-100% native canopy with a continuous mid-story in 10 years or less.
- Restore a diverse range of known host plants for *Achatinella mustelina*
- Restore native host plants and substrate requirements for *Drosophila substenoptera*.
- Restore canopy and midstory for Elepaio foraging and nesting requirements
- Utilize enclosure for rare plant restoration

Measures of Vegetation Rehabilitation Success:

- Increasing native ground cover 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
- Detection of *D. substenoptera* in enclosure

Restoration Approaches and Site Considerations:

- <u>***All gear, plants, and vegetation going into the enclosure should be thoroughly inspected for Euglandina rosea and slugs.***</u>
- Consider using weedblock to minimize herbicide use and weeding efforts and to help retain soil moisture in remnant native areas.
- Consider using planting beds in the enclosure or nearby for seed/propagule sources.
- Consider using fertilizer under direction of horticulturist on existing natives in enclosure and for outplants to increase growth rates and foliage cover.
- Consider using shade cloth or similar material supported upright to create shade and soil moisture for outplants.

Predator removal:

<u>Rats</u>

The enclosure area currently exists within the Palikea rat grid. After the hood is secured to the new enclosure wall, rat removal will begin inside. Six rat snaps, four A24s and four tracking tunnels will be utilized to ensure the safety of the *A. mustelina*. These tools will be monitored quarterly with the exception of the snap traps that will be set at least monthly for the first three 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.

E. 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 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: nine person hours performing a ground sweep in areas of minimal vegetation. three 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 is designed to remove any existing *E. rosea* from within the newly built snail enclosure and to ensure that all have been removed prior to habitat restoration.

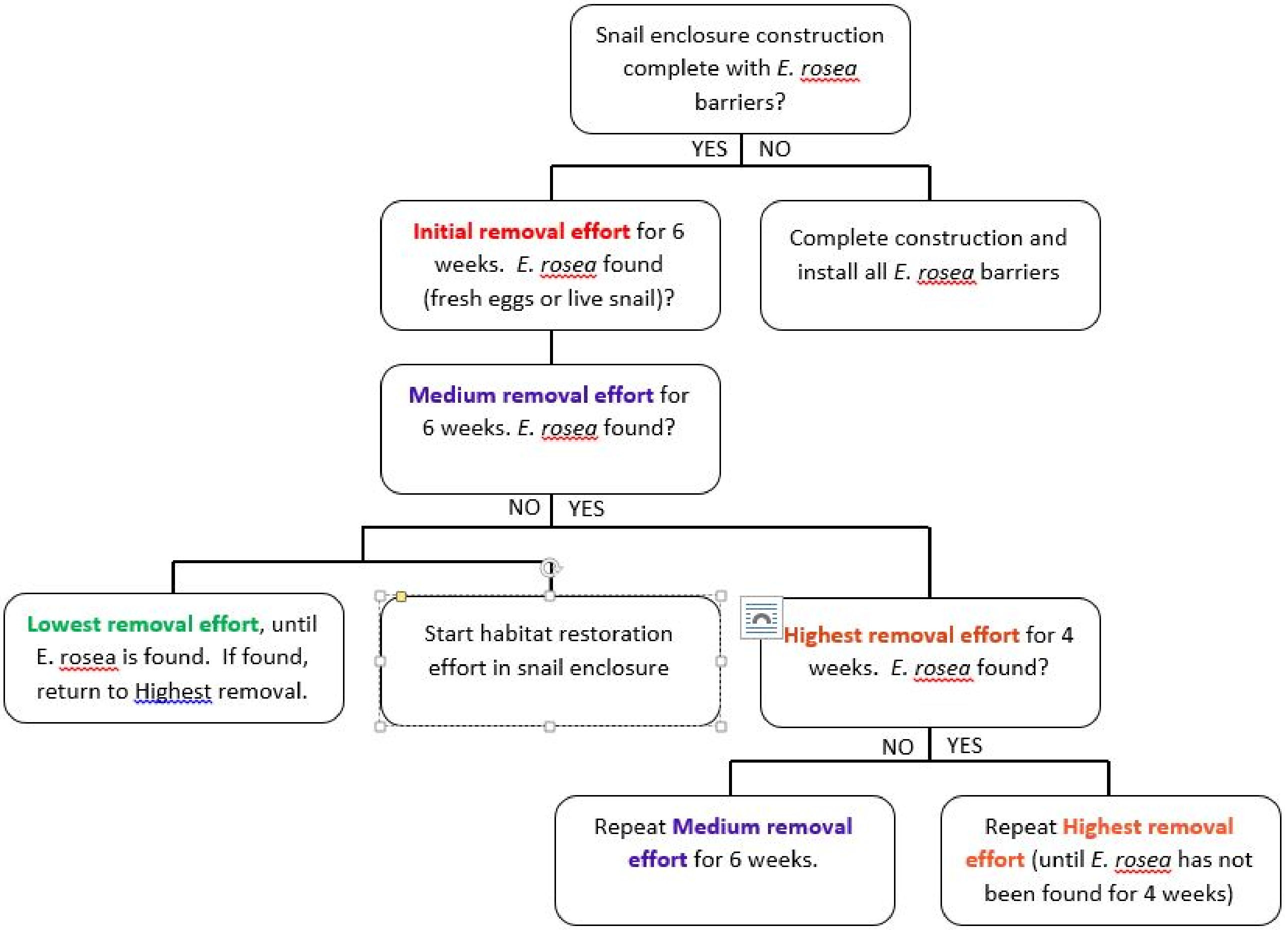
If *E. rosea* persist within the enclosure after three months of searching, the enclosure will be subdivided by installing a short wall with electrical barrier to section off the enclosure. Each section would then follow the flow chart independently.

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.

<u>Jackson's Chameleons</u>

During the tree clearing of the snail enclosure area, no Jackson's chameleons were found. However, two have been seen within close proximity in recent years. The density or abundance is unknown but they are present. During *E. rosea* searches, staff will also be looking for Jackson's chameleons and removing them. If any chameleons are discovered OANRP will develop removal protocols.

<u>Slugs</u>

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. During tree clearing, *A. mustelina* were discovered in the area and translocated into the Palikea snail enclosure. Extensive surveys were conducted during and after tree clearing to translocate *A. mustelina* from the area. The last few surveys performed didn't reveal any *A. mustelina* persisting in the area. However, to ensure non-targets are not harmed, the following protocol will be conducted as outlined below:

- A night snail survey will be conducted to encompass the area of proposed Sluggo use (snail enclosure)
- If snails are found, they will be moved into the Palikea snail enclosure and a subsequent survey must be performed on another night until no snails are found during a night survey

<u>Weeding</u>**:**

Prior to clearing, the enclosure area was dominated by a dense stand of *Psidium cattleianum* (OANRP 2016). *Clidemia hirta* patches covered much of the understory, and there was low alien plant diversity. The total area within the enclosure is approximately 2,460m², and few plants – native or alien – remain following clearing. This open zone may be quickly colonized by sun-loving alien plants, particularly grasses and asters, and *P. cattleianum* stumps likely will re-sprout. Maintaining low cover of weeds across the enclosure is the primary goal of weed control efforts. Extensive restoration is planned, but until outplants become established, regular sweeps will be necessary to maintain low weed cover. In some places, weed mat may be used to inhibit weed growth until native plants are ready for outplanting, or seed broadcasts can be done.

Alien plants at restoration site before and/or after clearing

Species	Growth Form	Species	Growth Form
Blechnum appendiculatum	Fern	*Paspalum conjugatum*	Grass
Clidemia hirta	Shrub	*Passiflora edulis*	Vine
Cyclosorus dentatus	Fern	*Passiflora suberosa*	Vine
Cyclosorus parasiticus	Fern	*Phytolacca octandra*	Herb
Ehrharta stipoides	Grass	*Psidium cattleianum*	Tree
Grevillea robusta	Tree	*Rubus rosifolius*	Herb
Melinus minutifolia	Grass	*Schinus terebinthifolius*	Tree
Morella faya	Tree	*Youngia japonica*	Herb

- Zero tolerance: *Blechnum appendiculatum, Ehrharta stipoides, Nephrolepis brownii, Paspalum conjugatum, Drymaria cordata*
- Control targets: *Clidemia hirta, Cyclosorus dentatus, Cyclosorus parasiticus, Passiflora edulis, Passiflora suberosa, Phytolacca octandra, Psidium cattleianum, Rubus rosifolius, Schinus terebinthifolius*, alien grasses, alien asters

Until the enclosure is completed (September), quarterly sweeps are needed across the entire weeded area. These should be done by both Green Team and Foundation staff. Sweeps should target all weeds, particularly those listed as ‘zero tolerance’ and any alien grasses, and should treat any re-sprouting *P. cattleianum* stumps. These stumps are best treated either by: cutting below the sprouts to create a new stump and treating the stump with 20% Garlon 4; or allowing the sprouts to become robust, then spraying them and the stump with 20% Garlon 4. Staff must take care to avoid non-target impacts when spraying, as inconspicuous native seedlings may be present.

Once the enclosure is built, weed control actions are scheduled separately for work done inside and outside of the enclosure. Within the enclosure, quarterly sweeps will be continued. Care should be taken when working around restoration plantings and seed sows. Garlon spraying will be prohibited around outplants. Weed cover should remain below 10%. Outside of the enclosure, weed sweeps should be conducted twice a year, and should focus on keeping levels of zero tolerance weeds low and promoting native cover to improve abiotic conditions. In addition, trees need to be removed or trimmed 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
7199	Foundation	W/ Weed Control	Palikea -11	Palikea North Snail Jail	Clear site in preparation for construction of snail exclosure. Treat understory herbs, spray alien grasses and ferns. Clearcut *P. cattleianum* and chip slash.	Clearing complete. Conduct follow-up till enclosure pau.
7201	Green	W/ Weed Control	Palikea -11	Palikea North Snail Jail	Maintain weeds within snail enclosure. Sweep entire enclosure quarterly to twice a year; treat all weeds. Focus on vines, woody weed keiki, and grasses. Zero tolerance inside enclosure for alien grasses and ferns.	Enclosure scheduled for completion in September.
7202	Green	W/ Weed Control	Palikea -11	Outside Palikea North Snail Jail	Control weeds outside of snail enclosure, across flats, and pushing up to ridgeline, twice a year. Use sweeps.	Enclosure scheduled for completion in September.
7464	Green	W/ Weed Control	Palikea -11	Outside Palikea North Snail Jail	Spray grasses outside of snail enclosure, across WCA, twice a year or as needed.	

***Re-vegetation*:**

Re-vegetation is expected to begin in November-December of 2017. A range of 2 months is given for each outplanting target time period to account for uncertainty. Ideally, the most intensive *E. rosea* searches will be complete by this time period. The predatory snail searches are more difficult to conduct around outplants, and sometimes these plants are harmed during the search process. However, due to the pressing need to establish as much native cover as possible, an early set of planting of around 350 plants is expected in the fall.

Re-vegetation efforts in the first year will focus in and around a small patch of existing native canopy in the Southwest corner, and expand cover out from this patch to surrounding open areas. As available, some canopy trees may be used to establish other ‘nodes’ of native plants with preference around a few existing *Freycinetia arborea* patches from which to work around in future years. High survival rates are expected due to anticipated staff vigilance at the site.

Staff aim to plant the first set of plants at a larger size, in 1 gallon tall pots, than is usually planted for common native species, in order to establish a mid-story structure more quickly. A second set of 450 plants should be ready by December of 2017 or January of 2018.

The majority of predator control efforts, any remaining construction, and remote sensing efforts should be nearly if not absolutely complete by March of 2018. At this point, restoring native cover will be the largest focus for the snail enclosure. At a minimum, 1,200 plants will be outplanted in March. It is unclear exactly how large of a vegetated footprint the first-year outplants will create; some of this will depend on planting densities. Staff should be able to learn from observing how approximately 2,000 outplants worked to fill in areas with little to no vegetation present, after which point there will be a better understanding of how many plants will be needed in the years to come.

Outplants will also be supplemented in the spring of 2018 with transplants of Hapu’u taken from outside the Palikea MU fence. This species was shown to grow well in the neighboring snail enclosure, and now provides dense mid-story cover with lots of understory shade.

Seed sows are also planned in the spring 2018 for open areas lacking outplants. If the open area is too large to revegetate with sows or any other means, it is possible that some portion will be covered with weed mat, or some appropriate material that can discourage weed growth until more plants are added.

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. Similarly, plantings will be avoided within 1 foot on either side of installed trails (see trail discussion below).

Fertilizer will be used to promote outplant growth. OANRP greenhouse staff will develop a strategy including what products to be used and a schedule of application. Fertilizer use will be evaluated annually and discontinued when appropriate.

An irrigation system has been installed and will be expanded as needed to water existing plant areas and outplantings. The catchment on the ridge crest has been expanded to accommodate the irrigation system.

Table 1 below summarizes the revegetation actions, species planned for use, and timeline.

Table 1. Re-vegetation Summary

Approximate date	Action	Species	Total #	Comments
November/ December 2017	Outplant	*Coprosma longifolia*, *Psychotria hathewayi, Cheirodendron trigynum, Metrosideros polymorpha, Perrottetia sandwicensis, Kadua affinis, Urera glabra, Pisonia sp.*, *Freycenetia arborea*	350	Plants grown in 1 gallon tall pots to be planted in Southwest corner.
December 2017/ January 2018	Outplant	*C. longifolia*, *C. trigynum*	450	These plants may be grouped with later planting if desired at a larger size and wanting to bulk planting efforts.
February/ March 2018	Outplant	*C. longifolia, C. trigynum, Carex wahuensis, K. affinis, P. brunoniana, P. hathewayi, P. sandwicensis, U. glabra*	1200	Continue to plant out from Southwest corner, and around *F. arborea* patches.
March 2018	Seed sows	*Bidens torta, Cyperus polystachyos, Pipturis albidis*	TBD	Conduct sows in open areas adjacent to outplanted area.
March 2018	Transplant	*Cibotium chamissoi*, *Dianella sandwicensis*.	TBD	Plant among outplants and expand to open areas as material is available.

Individual outplant survival will not be tracked rigorously, however some level of tracking of subsets of plants may be beneficial (gridding as discussed below could make some tracking very easy).

Trails/subunits:

A 10 meter grid system has been installed in the enclosure to facilitate predator removal, restoration efforts and snail monitoring. Some portion of the grid will become permanent trails to facilitate movement through the area. These will be determined in the next year as management actions increase. Endpoints of less used grid lines will be labeled on the enclosure wall to ensure consistent locations. Permanent markers will be ordered 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 – 1mAGL, 1 – 2m above ground level (AGL), and > 2mAGL along non-permanent transects to gain a better understanding of cover changes across varying strata, particularly relevant in the early restoration years, and as means of guiding restoration and weeding efforts. Detailed methods and pre-clearing results are in the 2016 Status Report for the Makua and Oahu Implementation Plans (OANRP 2016). 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 are five photopoints in the enclosure. They are currently marked with permanent galvanized pipe, orange flagging, and metal write-on tags with the Pole # and Palikea North on one side, and ESU-E on the other. At each pipe, photos are taken in the cardinal directions, using a compass and print-out of previous photopoints to line up each shot. Photos were taken prior to clearing (2016-06-02), and again post-clearing (2017-02-23). They should be taken quarterly for the first year following clearing, then annually for the next 5+ years. See the V/Photopoints/Palikea North ESU-E Snail Enclosure folder for notes, master sheet, and photos.

Action ID	Field Team	Category Code	WCA Code	Location	Team Action Comments	Update
7204	Foundation	W/ Photopoint Monitor	Palikea -11	Palikea North Snail Jail	Install and take photopoints at Palikea North Snail Jail. Re-take when clearing complete, then quarterly, then annually.	Taken 2016-06-02 (pre) and 2017-02-23 (post).

UAV imagery will be obtained (subject to equipment availability) and used to provide visual representations of upper canopy vegetation. Imagery was taken during the clearing and construction phases (see imagery of clearing efforts below) and will occur in conjunction with point-intercept monitoring, as possible.

Vegetation cover goals:

Preliminary vegetation cover goals were made to guides efforts, and which may be used to trigger changes in management strategies. The timing of initial outplantings (November/December 2017) will be considered the starting point of vegetation restoration, with respect to cover goals over time.

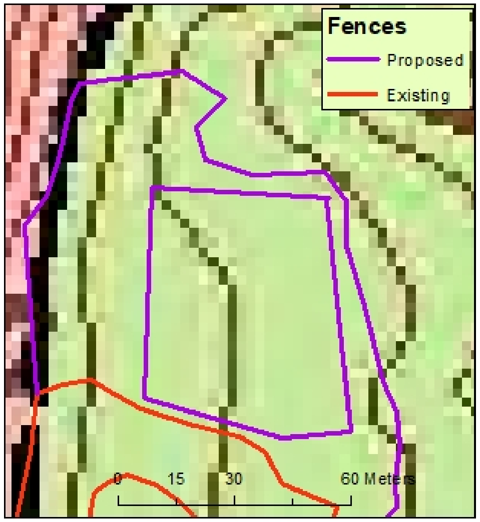
- **Goal for 0 - 1m AGL:** > 50% cover after 1 year and beyond. Given the sparsity of native vegetation post-clearing, restoration inputs will show up first in this category. Lower cover will trigger more seed sows and transplants of understory species. It is possible that cover in this category may decline as tree taxa grow into higher strata, and have fewer branches below 1m. The cover goal may then be maintained with the addition of more understory species.

- **Goal for 1-2m AGL:** > 50% by 2 years and beyond. Cover in this strata will serve as an indicator of progress towards creating a canopy during the initial phase of restoration. In later years, it will be indicative of habitat connectivity. As with the 0 – 1m AGL strata, it is possible that cover in this category may decline as tree taxa grow into higher strata, with fewer branches below 2m, and the cover goal may then be maintained with the addition of more understory and canopy species.
- **Goal for > 2m AGL:** > 50% by 5 years, > 75% by 10 years, and > 90% by 15 years. Given the limited amount of native canopy post-clearing, and the time required for vegetation to grow > 2mAGL, achievement of goals for the 1 – 2m AGL strata, as well as the cover of tree taxa within

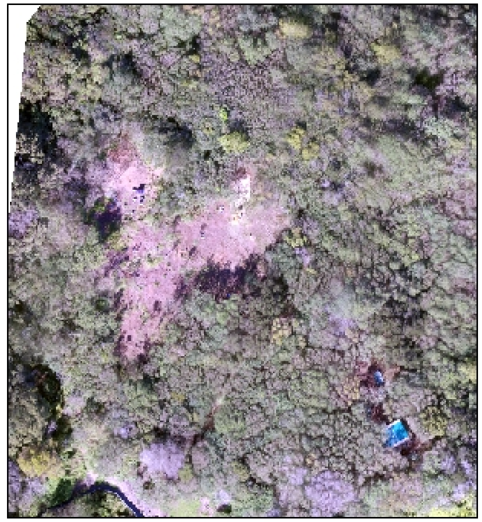
that category, should carefully assessed to ensure that progress towards cover goals for > 2mAGL is made.

- **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.

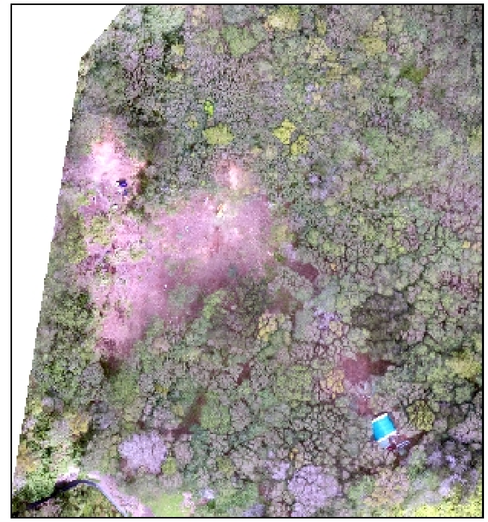
Palikea North Snail Enclosure Clearing Effort



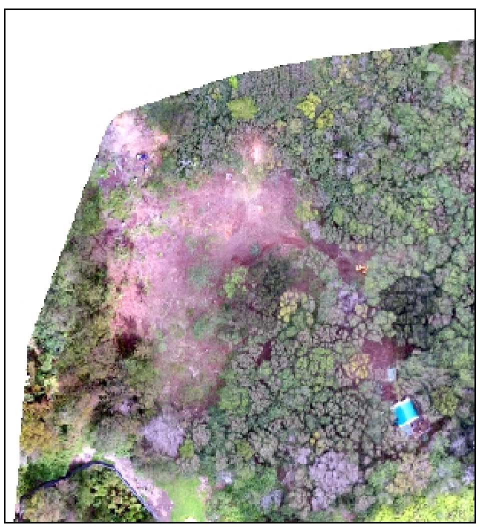
Palikea



Jan 17, 2017

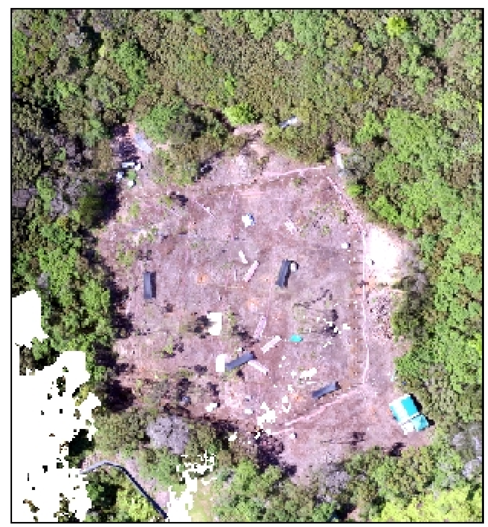


Jan 18, 2017



Jan 19, 2017

Feb 23, 2017



May 1, 2017

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 Tree Trimming and Removal of Trees at Bldg. 1170, MARS Station on 05 June 2017

Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in one dying Eucalyptus tree (*Eucalytus* spp.) and stump (DBH 60 in.) located left side of dirt road at garden club entrance (Figure 1). Remove five albizia trees (*<u>Falcataria</u>* <u>moluccana</u>) in brush outside of MARS security fence that are overhanging into compound. Spot prune 1 limb (18 inch diameter) from one albizia tree reaching over compound. If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

Survey

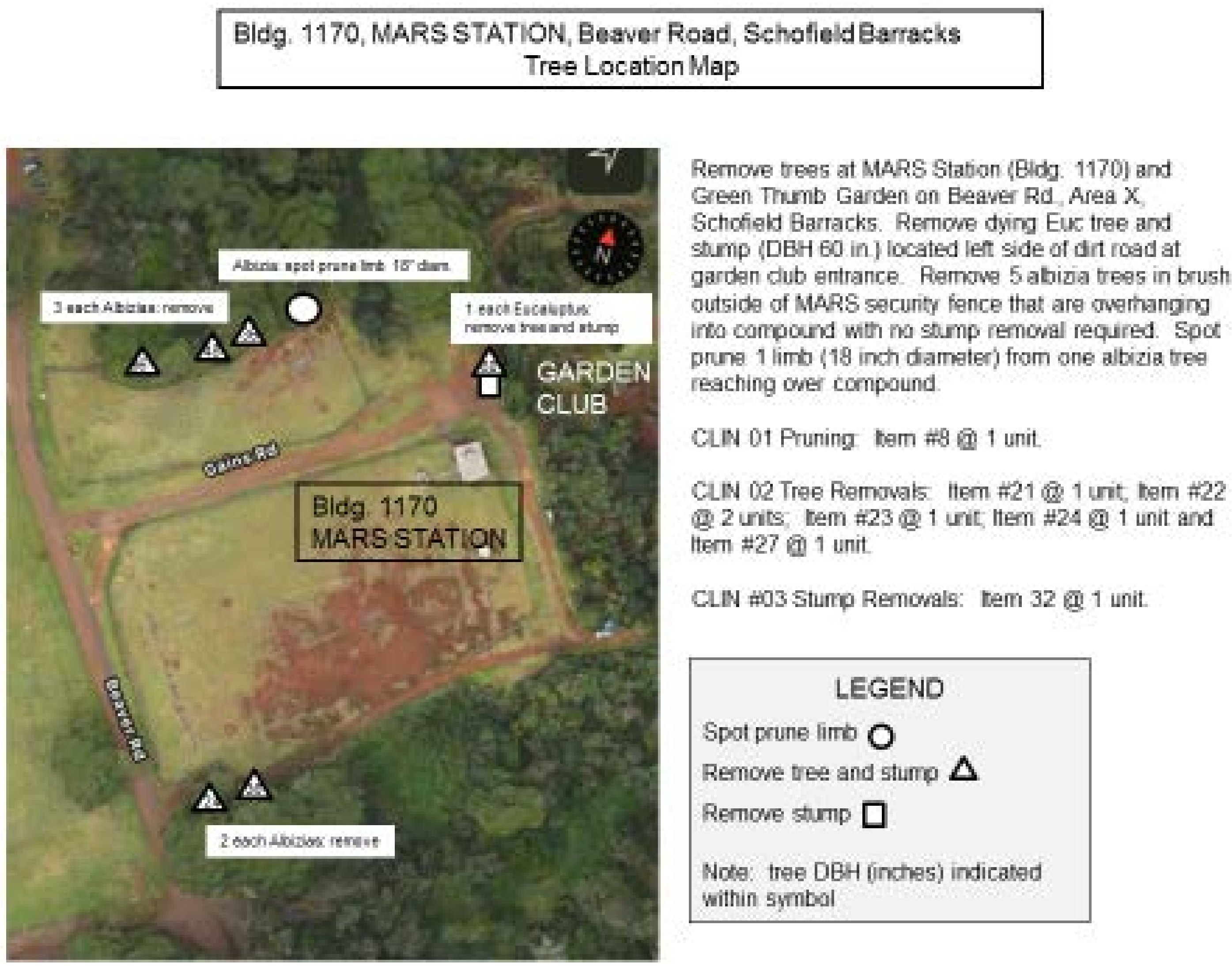


Figure 1. Map of project site with tree locations

Methods

Visual and acoustic surveys for bats were conducted on 05 June 2017, 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 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 Removal of Trees at Firing Point HALO, Schofield Barracks South Range on 19 July 2017

Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in 25 albizia trees (*Falcataria* moluccana) in area below Firing Point (FP) HALO at Schofield Barracks South Range (Figure 1 and 2). If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

Survey

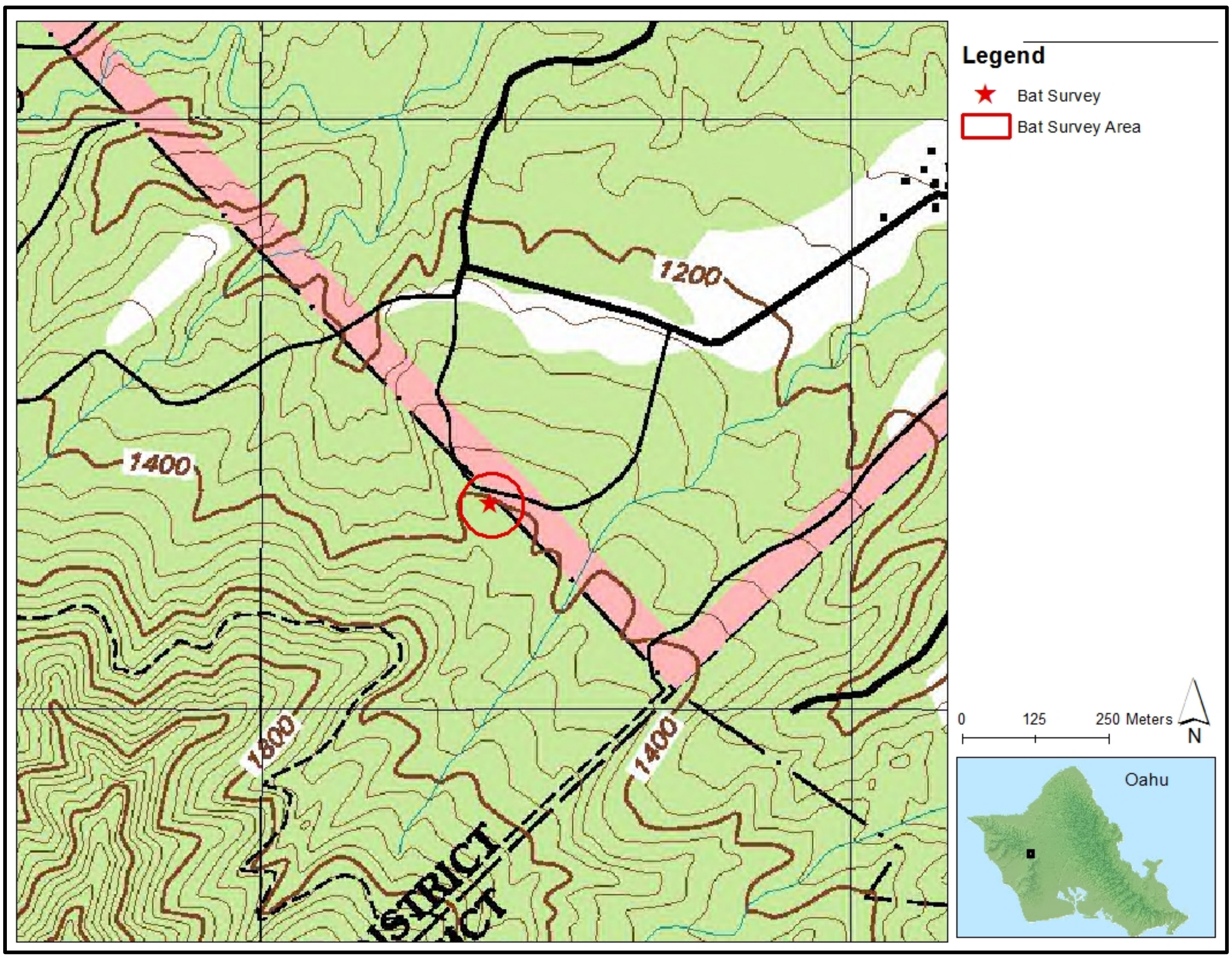


Figure 1. Map of project site at FP HALO

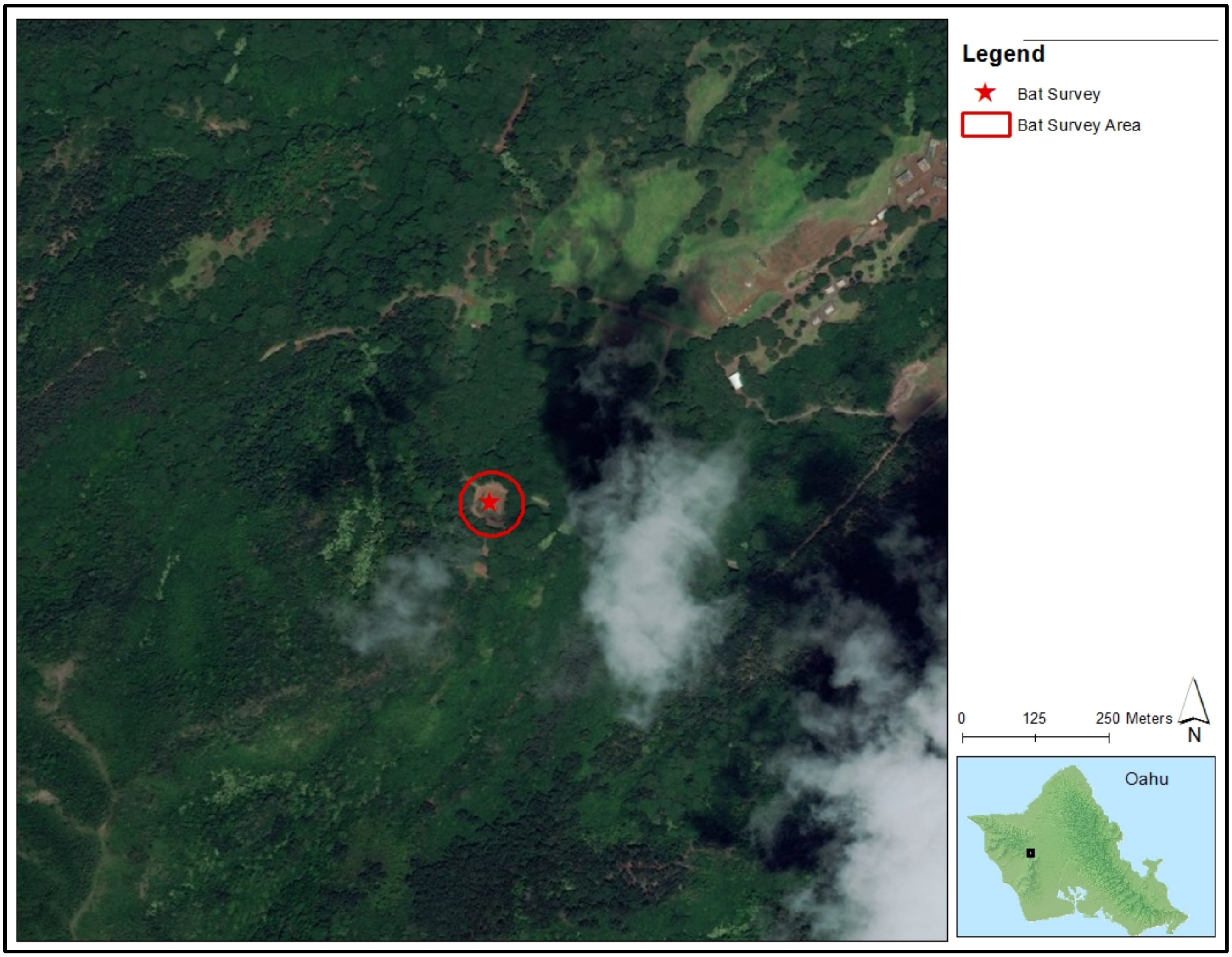


Figure 2. Image of project site at FP HALO

Methods

Preliminary, acoustics surveys were conducted from 07-16 July 2017 using SM2 Bat detector from Wildlife Acoustics that were set to record from 30 minutes prior to sunset to 30 minutes after sunrise. Visual and acoustic surveys for bats were conducted on 19 July 2017, 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 05:00-06:30 from the ground from different angles and locations.

Results and Discussion

The preliminary acoustic surveys were run for ten nights prior to the visual surveys. There were 115 files recorded over that time frame, nine of which were recorded bat calls. The calls were recorded three times over two nights (8-9July). They appeared to be calls from bats searching for food, a total of 189 pulses were recorded.

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 Removal of Trees on grounds of Solomon Elementary School, Schofield Barracks on 20 July 2017

Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in five Monkey Pod trees (*Albizia saman*) on the grounds of Solomon Elementary School, Schofield Baraacks (Figure 1). The trees need to be removed for construction project. If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

Survey

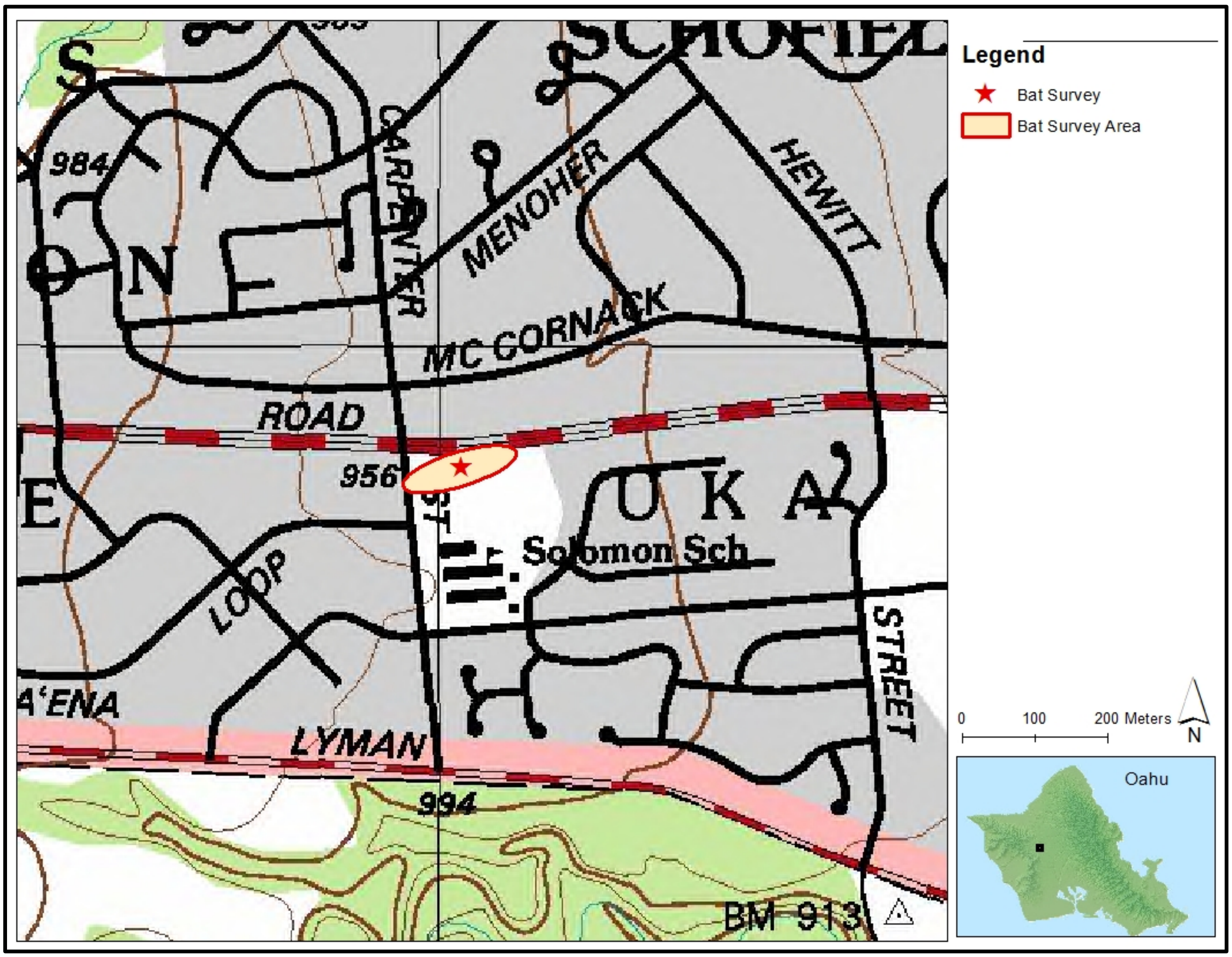


Figure 1. Map of project site at Solomon Elementary School

Figure 2. Image of project site at Solomon Elementary School

Methods

Visual and acoustic surveys for bats were conducted on 20 July 2017, 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 04:40-06:30 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 and Removal of Trees along Kunia Road at Wheeler Army Airfield and 9098 McMahon Road, Schofield Barracks on 21 July 2017

Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in two Monkey Pod trees (*Albizia saman*) on the grounds of the Dog Park at Wheeler Army Airfield (Figure 1) and four dead Eucalyptus (*Eucalyptus* spp.) just on outside of security fence near building 9098 McMahon Road on Schofield Barracks (Figure 2). The Monkey Pod trees are located along Kunia Road and are impeding traffic of larger trucks. The Eucalyptus trees are alongside the powerlines and could impact them when they fall. If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

Survey

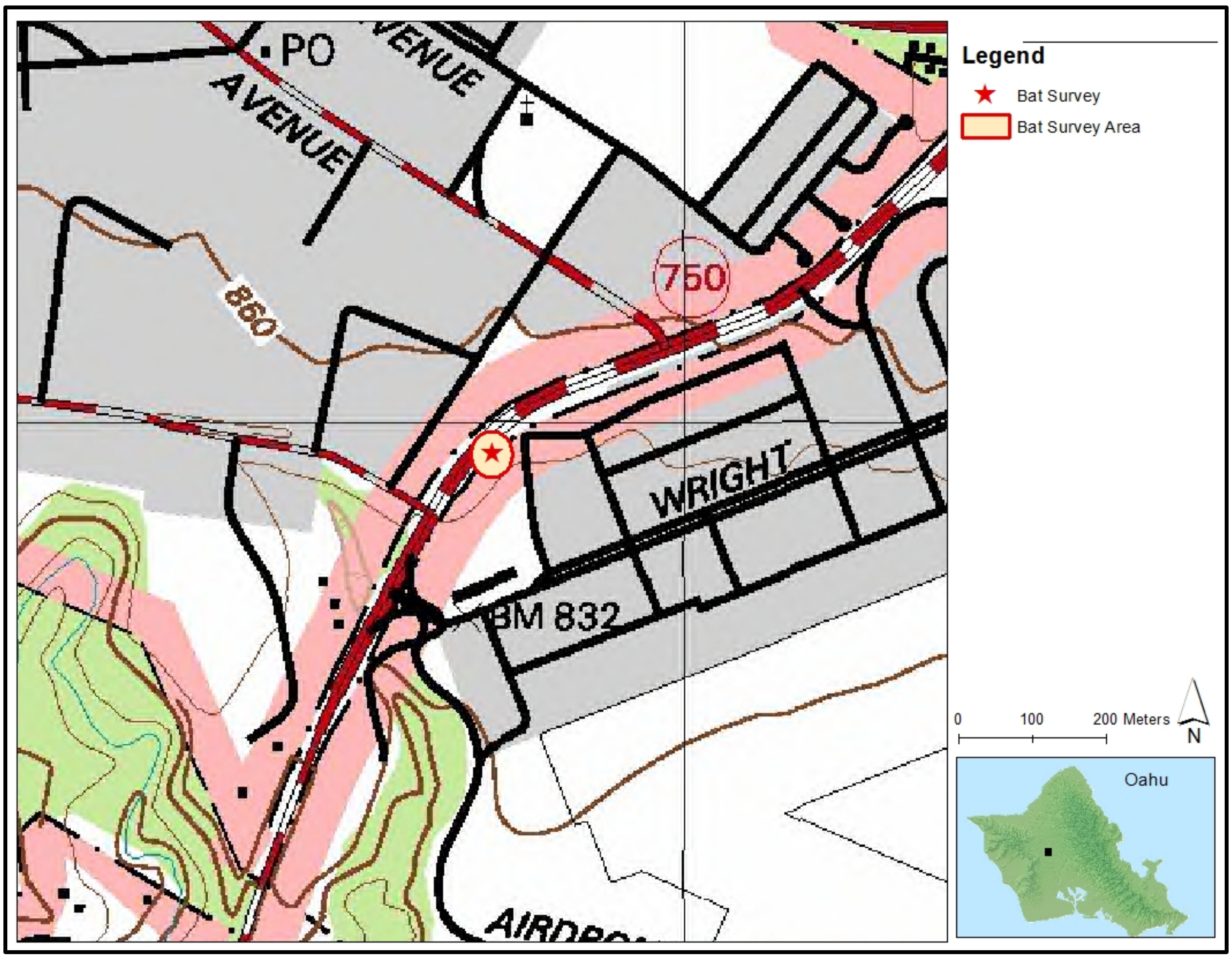


Figure 1. Map of project site at Wheeler Army Airfield.

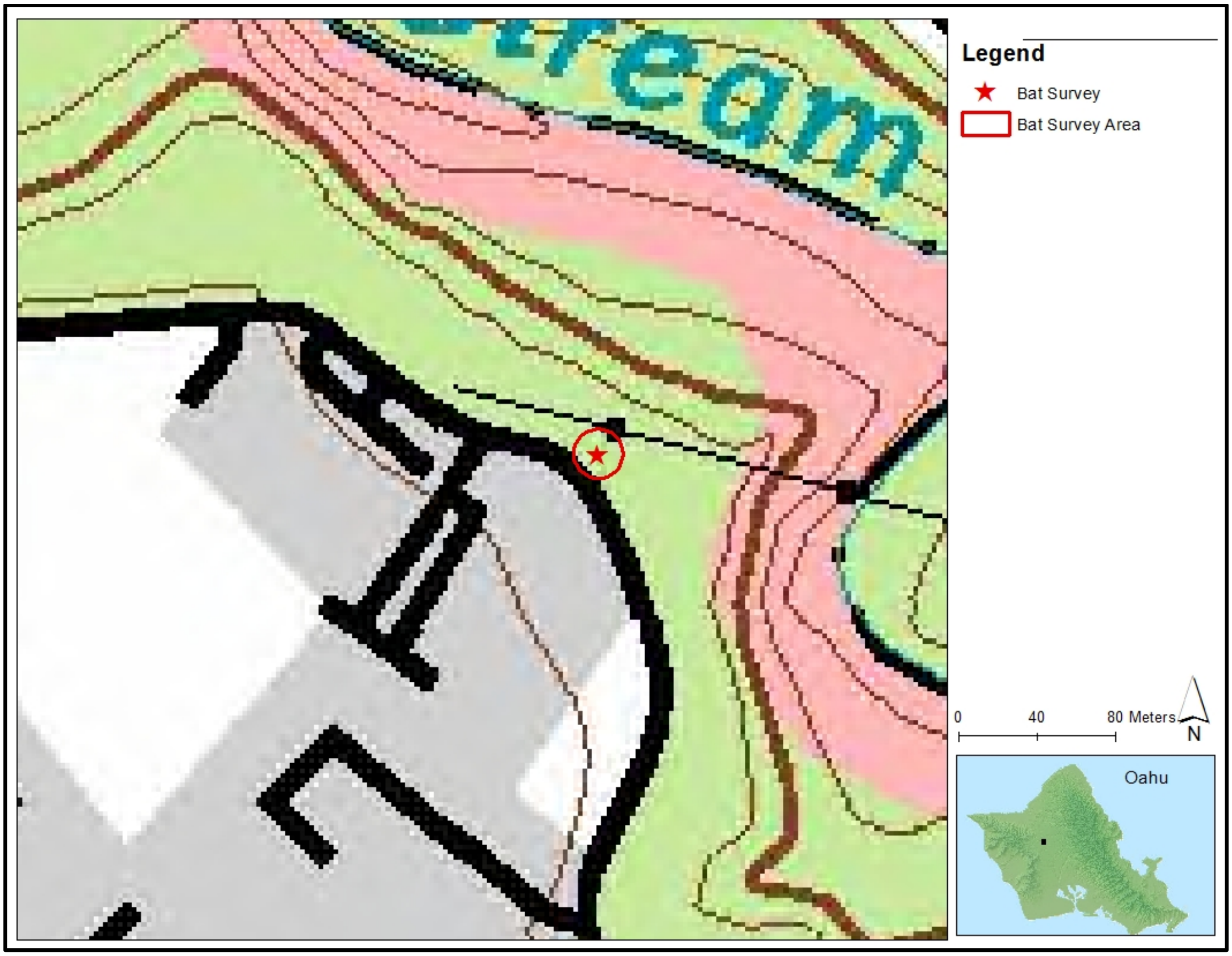


Figure 2. Map of project site at 9098 McMahon Road

Methods

Visual and acoustic surveys for bats were conducted on 21 July 2017, the day of the scheduled tree trimming (Figures 3 and 4). 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 04:40-07:30 from the ground from different angles and locations.

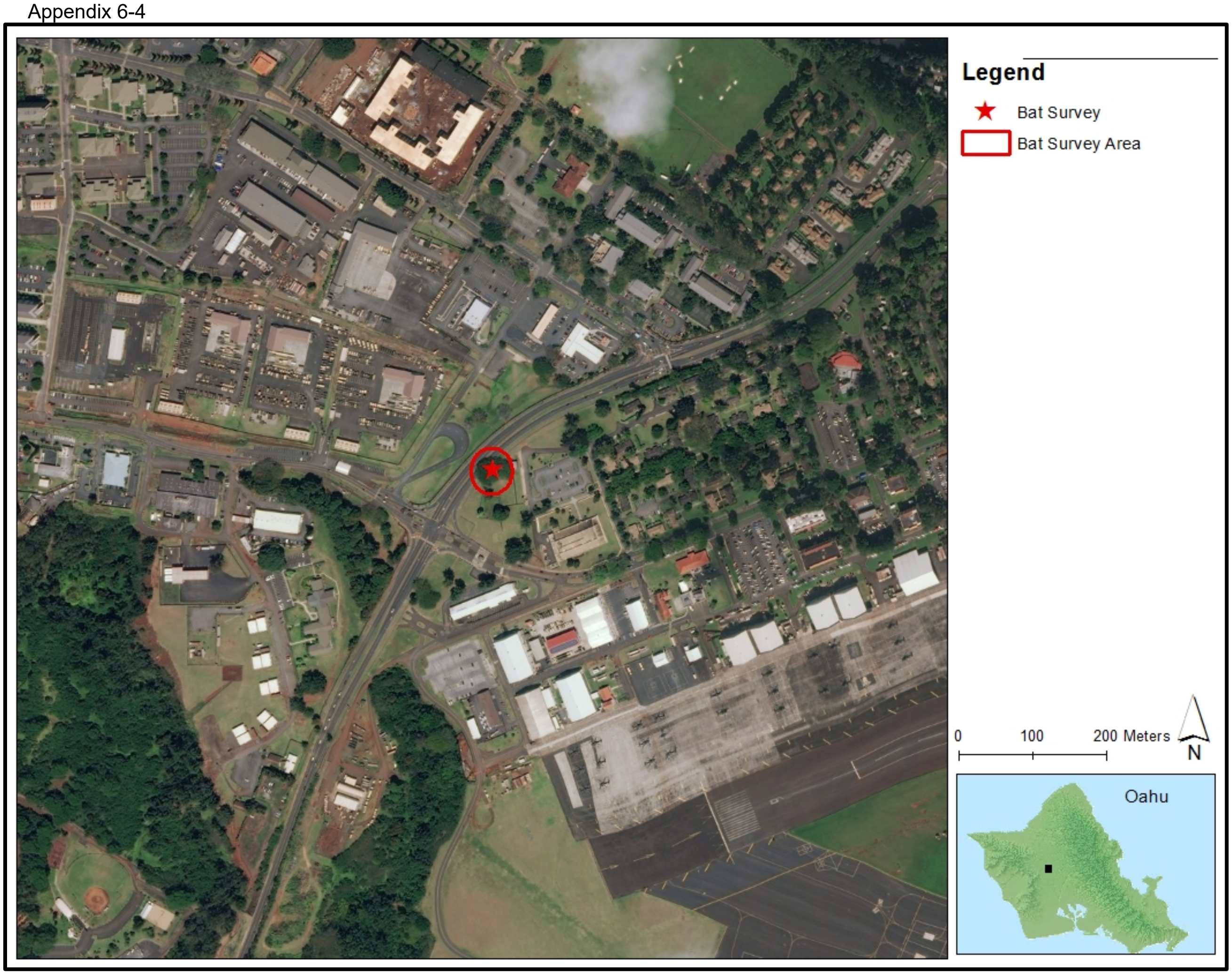


Figure 3. Image of project site at Wheeler Army Airfield

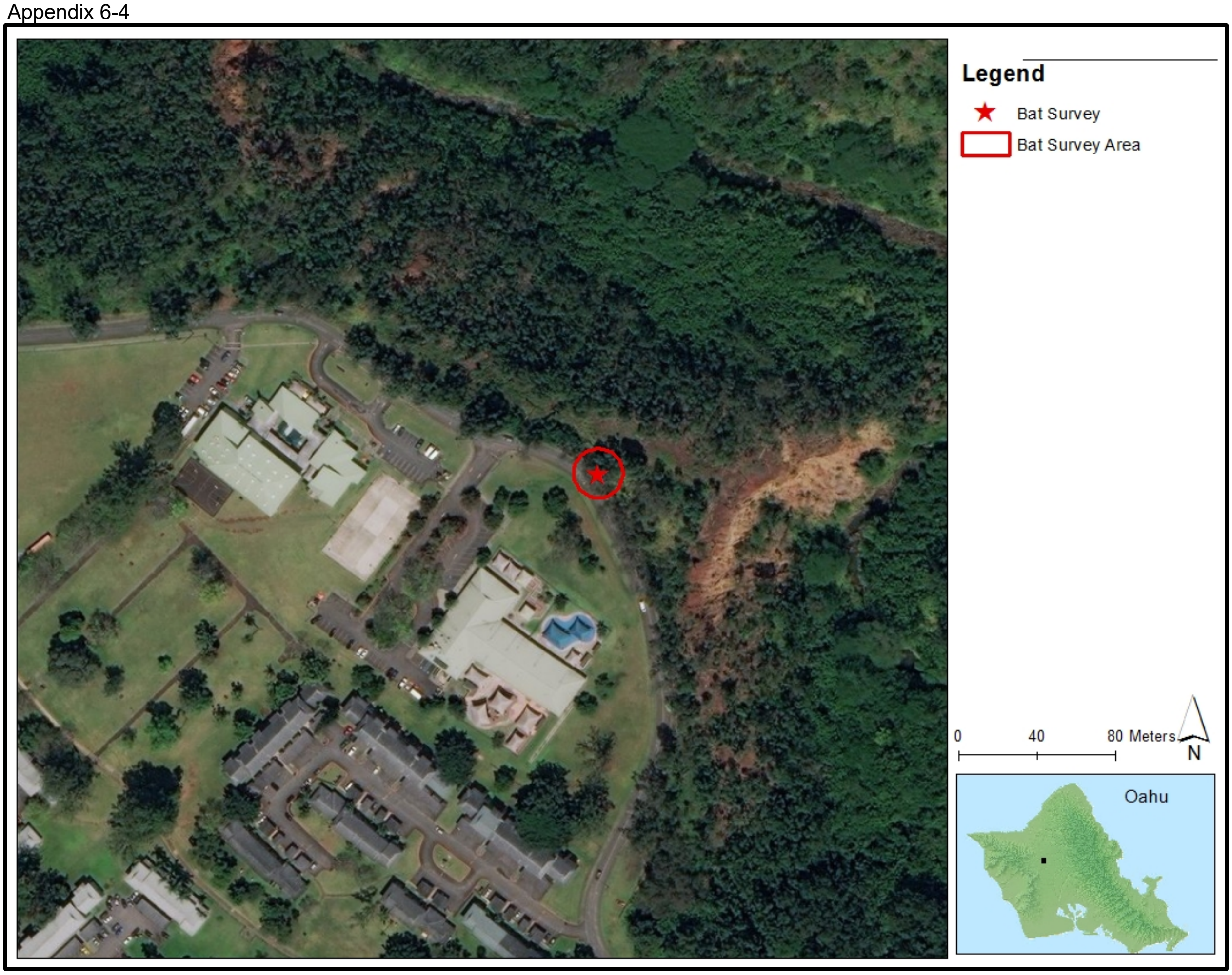


Figure 4. Image of project site at 9098 McMahon Road

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 and Removal of Trees at Daniel K. Inouye Elementary School, Schofield Barracks on 24 and 26 July 2017

Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in eight African Tulip (*Spathodea campanulata)*, 17 Eucalyptus (*Eucalyptus* spp>), one Monkey Pod trees (*Albizia saman*), one Albizia (*Albizia moluccana*), one Kukui (*Aleurites moluccanus*) and eight Ironwood (*Casuarina equisetifolia*) trees on the grounds of Danile K. Inouye Elementary School at Schofield Barracks Military Reservation (Figure 1). The trees are impacting the powerlines in the corridor at the school. If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

Survey

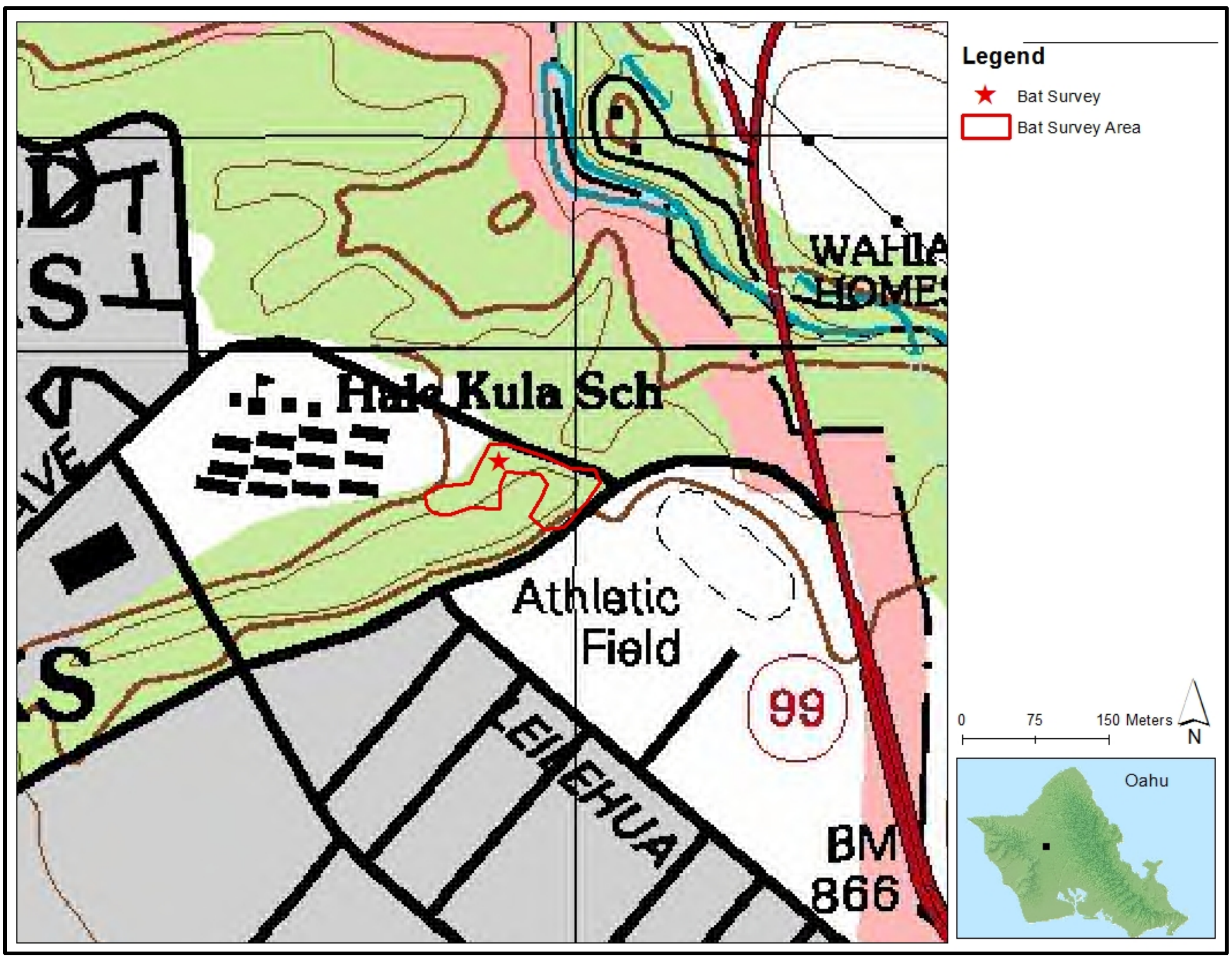


Figure 1. Map of project site at Daniel K. Inouye Elementary School

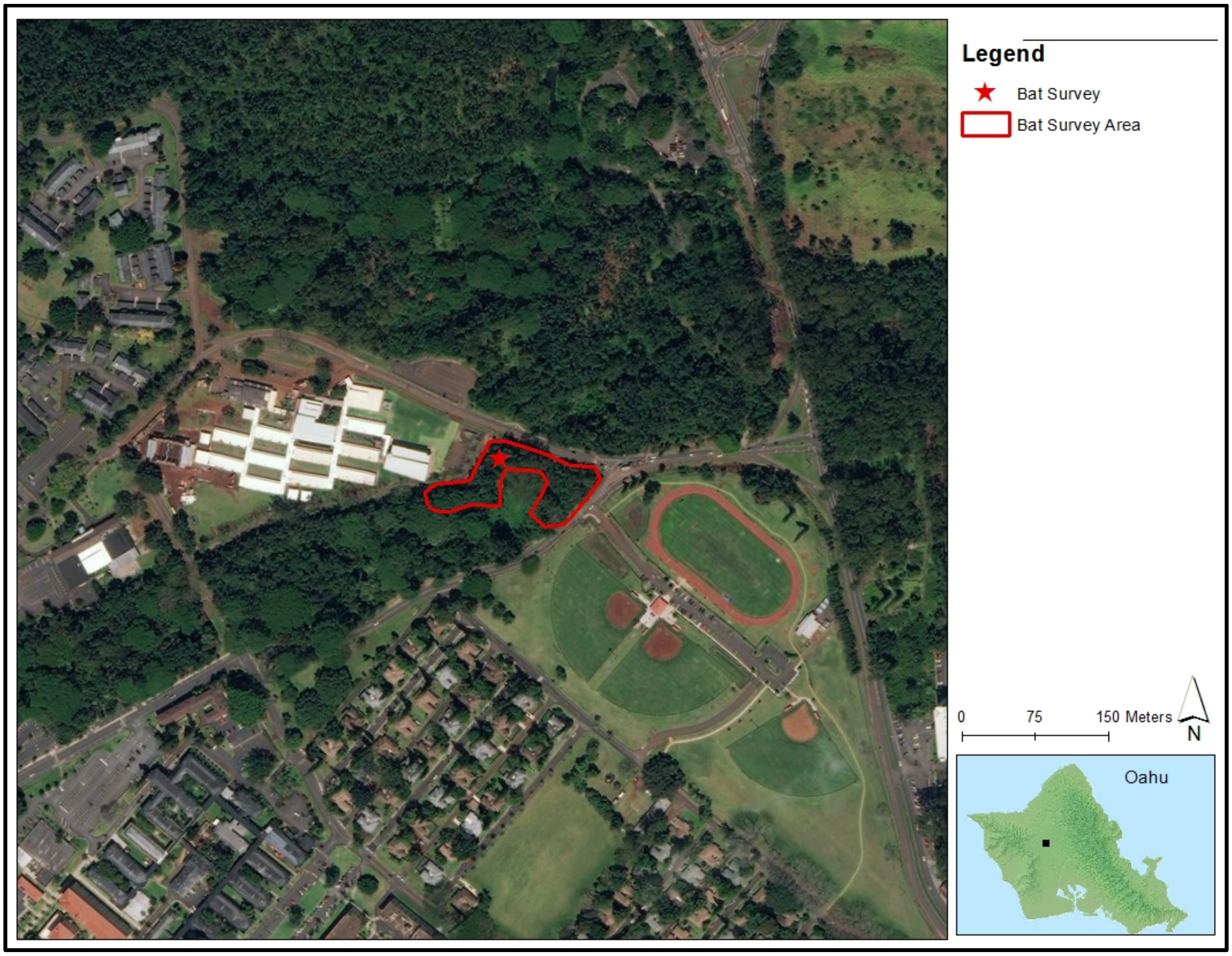


Figure 2. Image of project site at Daniel K. Inouye Elementary School

Methods

Visual and acoustic surveys for bats were conducted on 24 and 26 July 2017, the days 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 05:00-06:30 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 and Removal of Trees along fence at Water Tank, Tripler Army Medical Center (TAMC) on 03 August 2017

Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in three Monkey Pod trees (*Albizia saman*) along the fence at the water tank Tripler Army Medical Center (Figure 1). The trees are impacting the fence at this time. If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

Survey

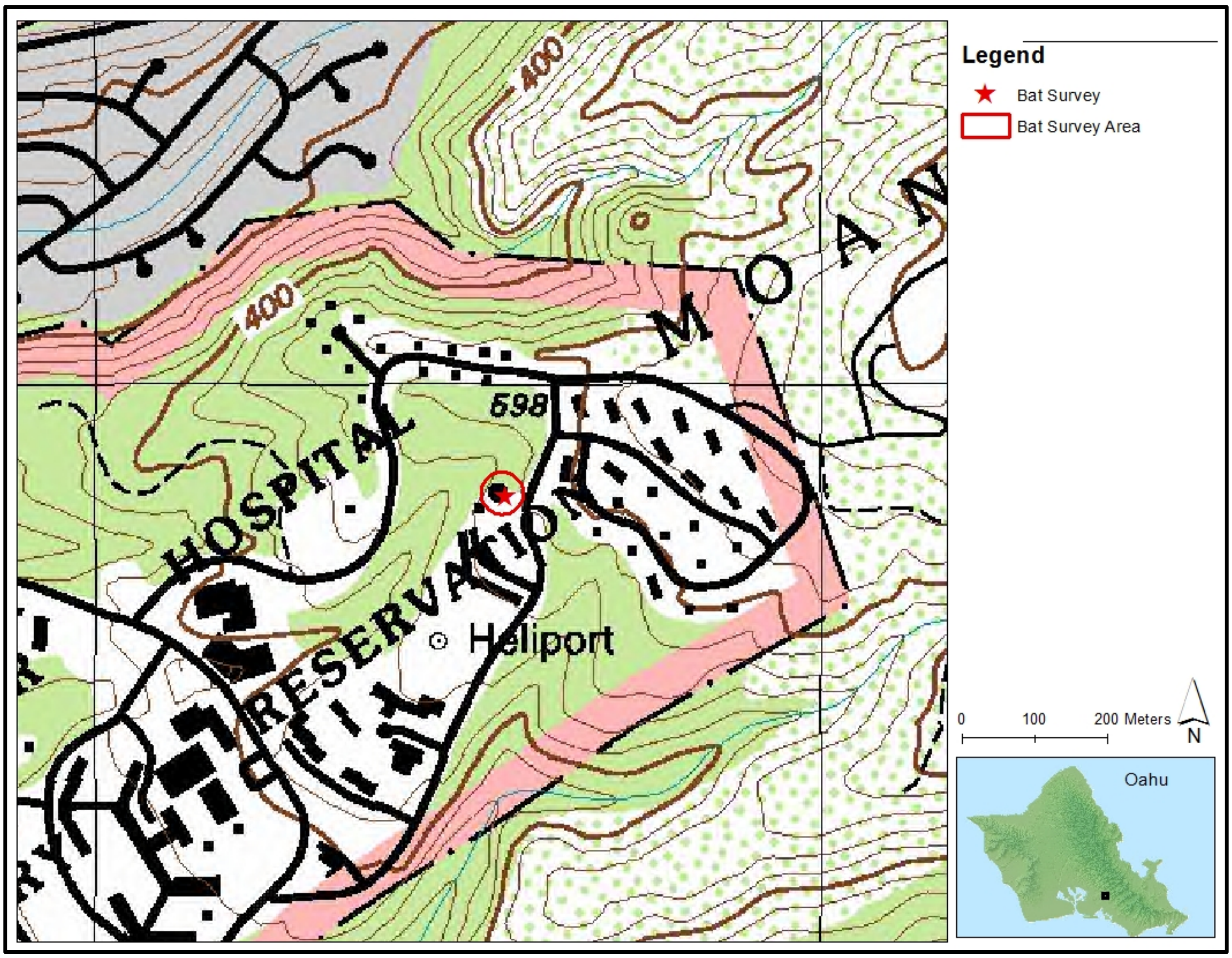


Figure 1. Map of project site at Tripler Army Medical Center

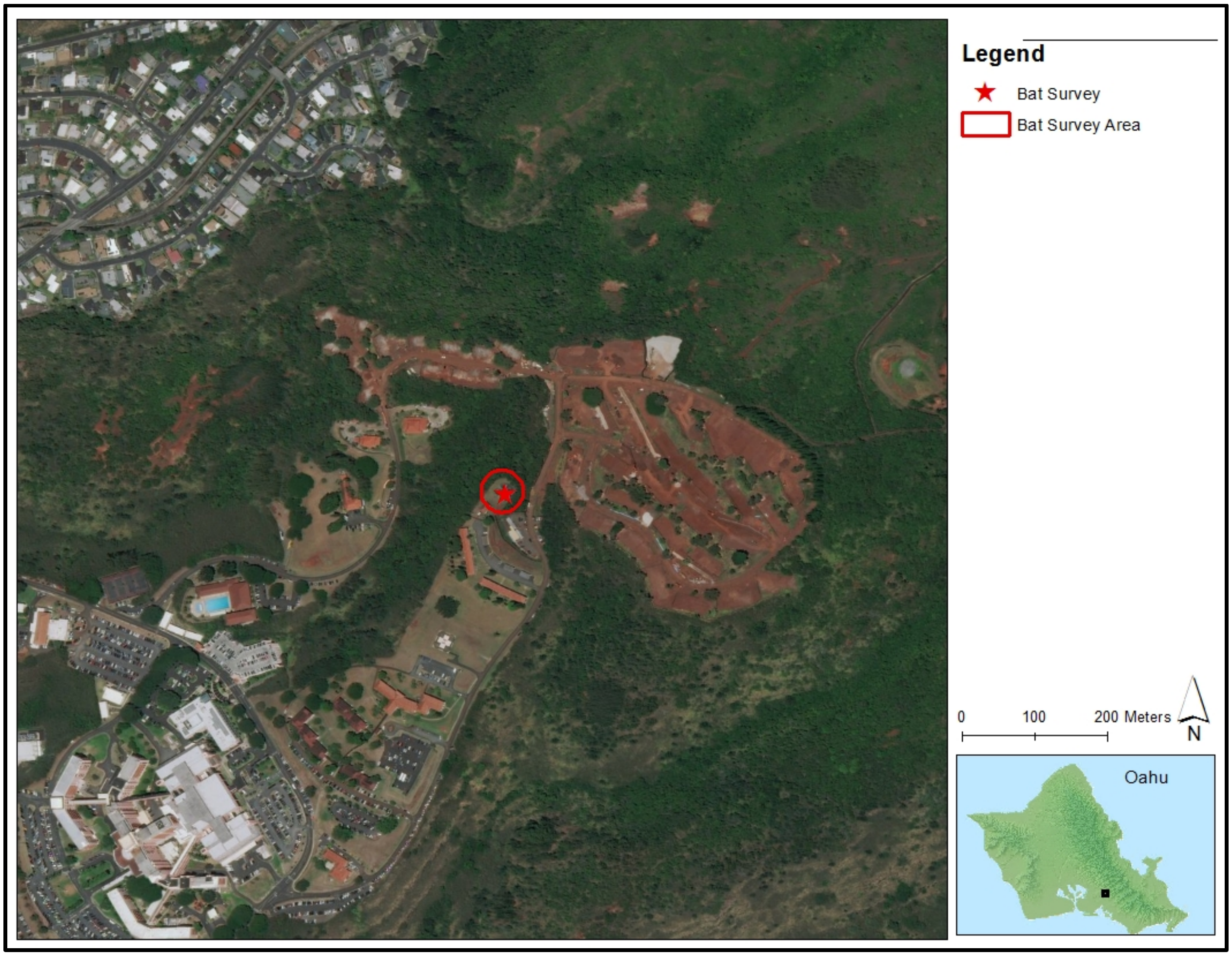


Figure 2. Image of project site at Tripler Army Medical Center

Methods

Visual and acoustic surveys for bats were conducted on 03 August 2017, 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 05:30-06:30 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 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, McCarthy Flats Mohiakea Gulch, for powerline maintenance tree clearing 24 August 2017

Survey Goals

Establish whether or not Hawaiian Hoary bats (*Lasiurus cinereus semotus*) are roosting with pups in Ironwood and Eucalyptus scheduled for removal along a powerline corridor in lower Mohiakea Gulch near McCarthy Flats. If bats present, discuss with regulatory agency possible mitigation measures to continue project or postpone removal of trees until pupping season is completed.

Survey

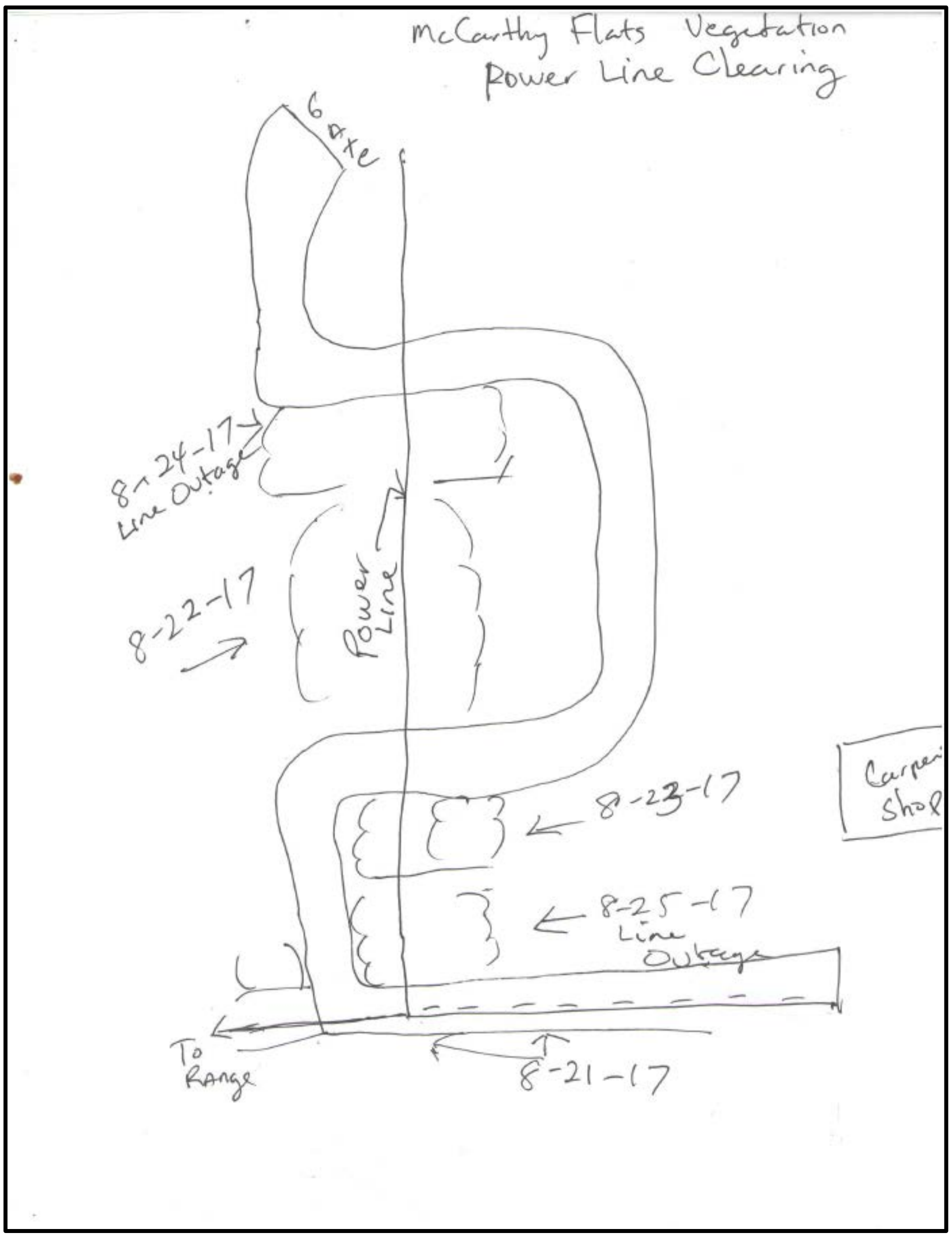


Figure 1. Sketch map provided by tree trimming company. The section slated for 8.24.17 contains trees > 15 feet tall.

Methods

Visual and acoustic surveys for bats were conducted on 24 August 2017, 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

Unfortunately, the section scheduled for clearing on August 24th was largely cut prior to the date communicated by the contractor lead. There were ~5 trees touching the powerlines that were not yet cut which were surveyed. Clear communication with contractors is essential in complying with the Garrison Policy. Visual thermal IR and acoustic surveys detected no bats in the trees remaining. 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.

Figure 2. Section scheduled for clearing on 8.24.17 that was largely completed before the survey.

Recommendations

Work with DPW and contractors to ensure follow through on plans for clearing. It is wasted effort on the part of the government when plans are not followed or communication fails.

Experimental Protocol for ContraPest Trial in Forest Areas

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6/15/17

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 Oahu Army Natural Resources Program (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 rat activity fluctuation 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 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 (*C. 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).

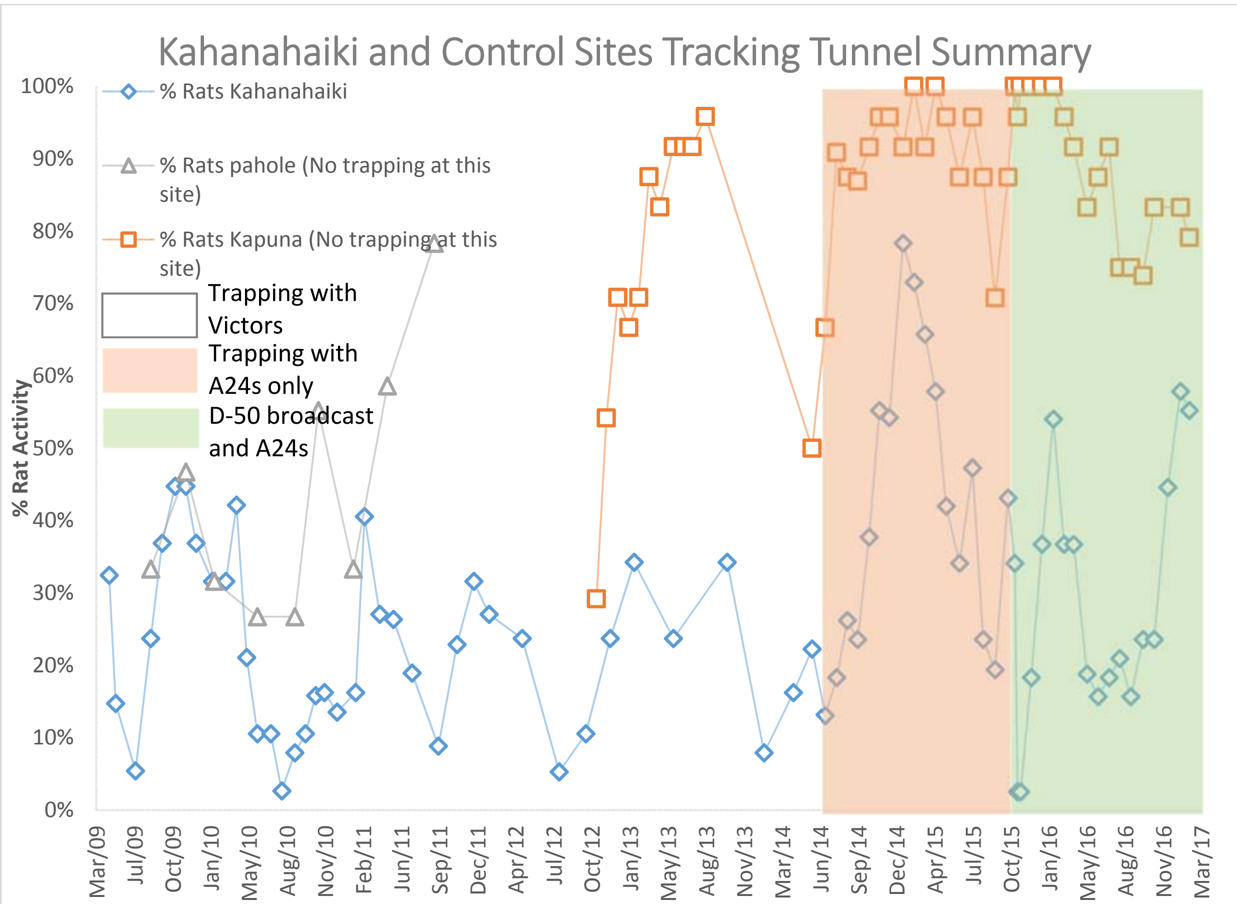

Figure 1. Percent rat activity (based on tracking tunnels) at Kahanahaiki (the rat-trapping site), and two nearby sites where no rat trapping occurred (Pahole and Kapuna). The shaded area from November 2015-Present is when A24 traps were continued after a two application hand broadcast of Diphacinone 50 in November of 2015; July 2014-October 2015 is when only A24 traps were deployed; and the non-shaded (May 2009-April 2014) was when only Victor snap-traps were used.

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 (*Mus 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, *Cyanea 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 management unit, 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 50x50meters 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 500ml 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 Management Unit 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 40th 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.

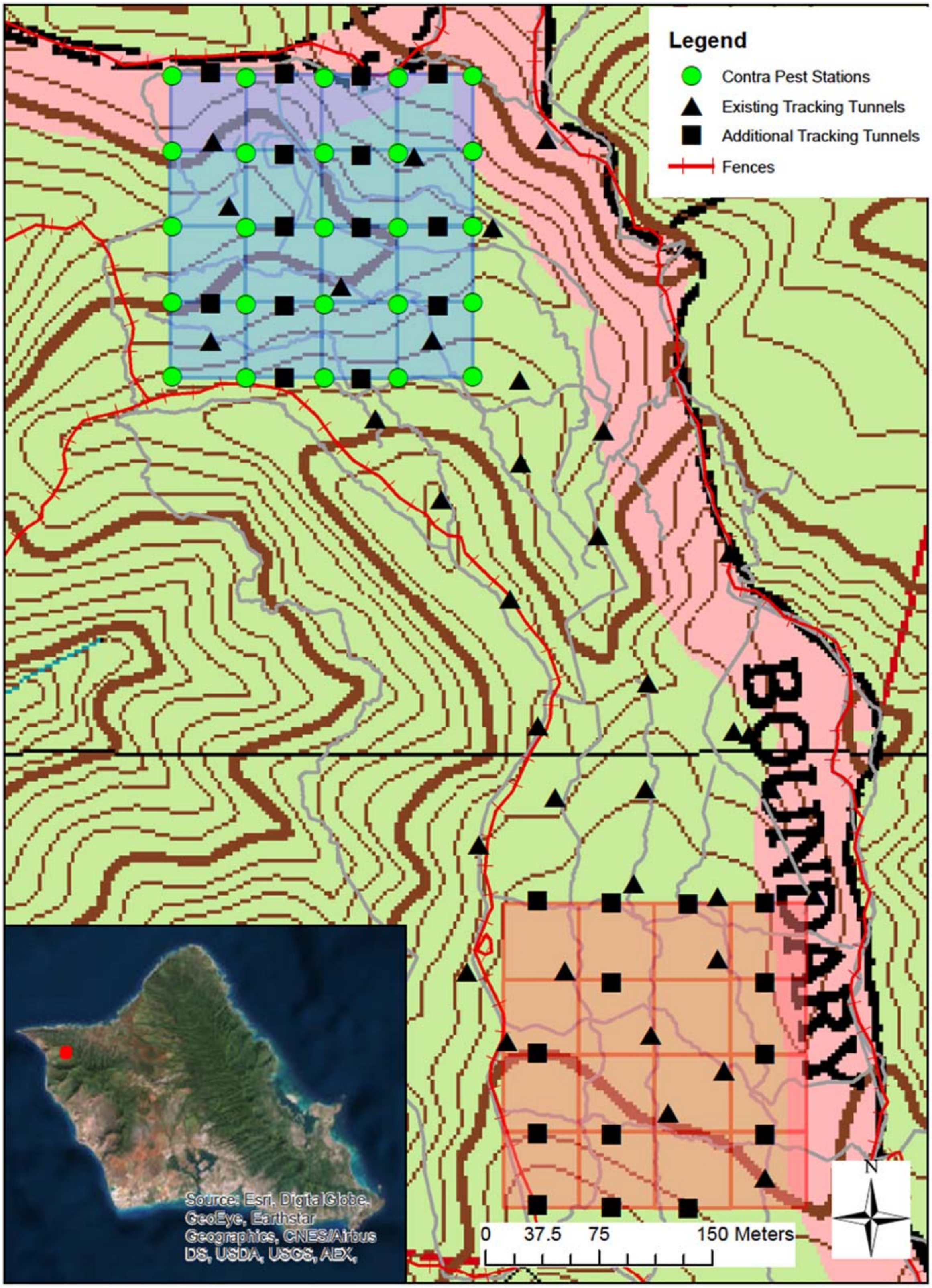

Figure 3. Kahanahaiki management unit study site showing control (red grid) and treatment site (blue grid).

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