

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.

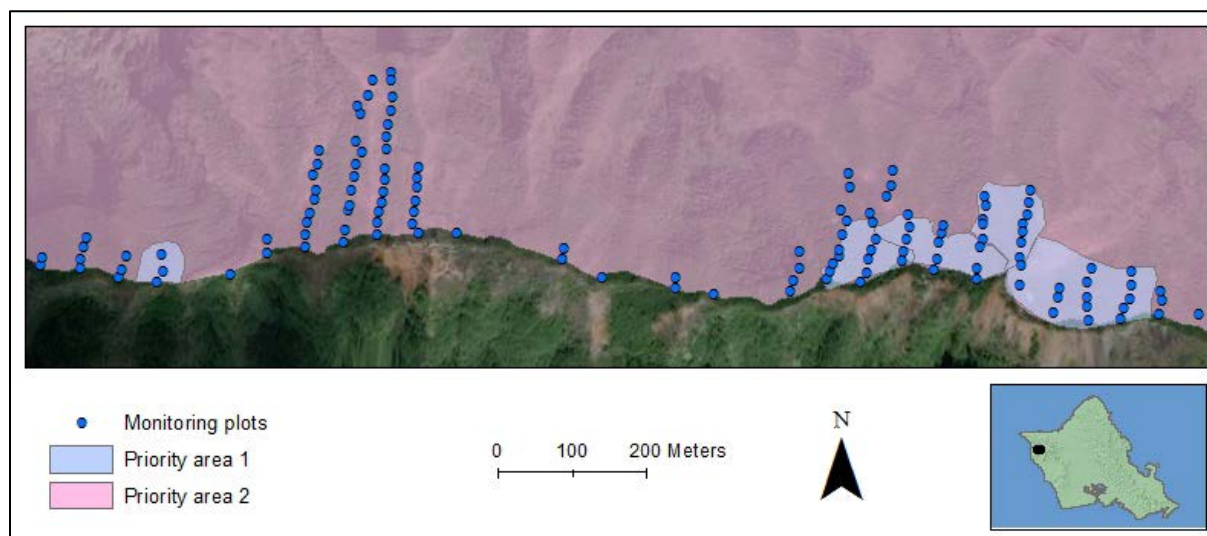


Figure 1. Ohikilolo Upper MU vegetation monitoring plot locations.

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 $\geq 10\%$ 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 $\geq 10\%$ 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	

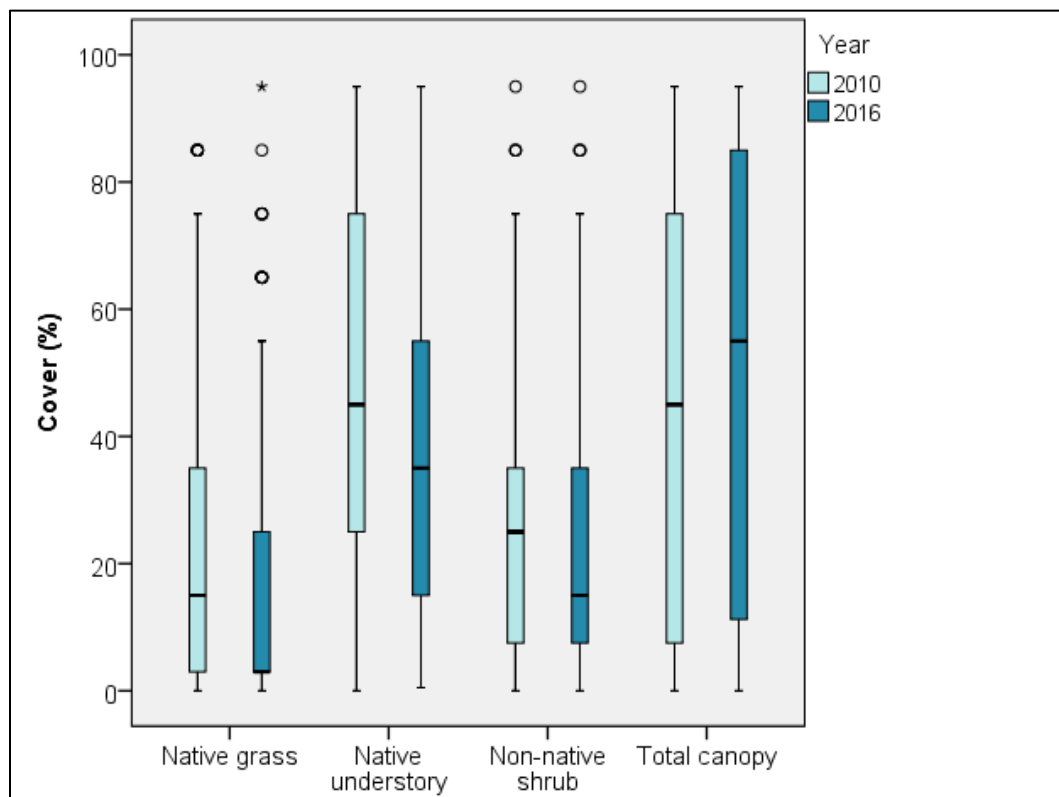


Figure 2. Boxplots for vegetation categories with significant change in percent cover that meet 10% standard for recognized change in cover between years 2010 and 2016 in Ohikilolo Upper MU, priority areas 1 and 2. [Note: The boxes depict 50% of the data values, and the horizontal line inside the box 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.]

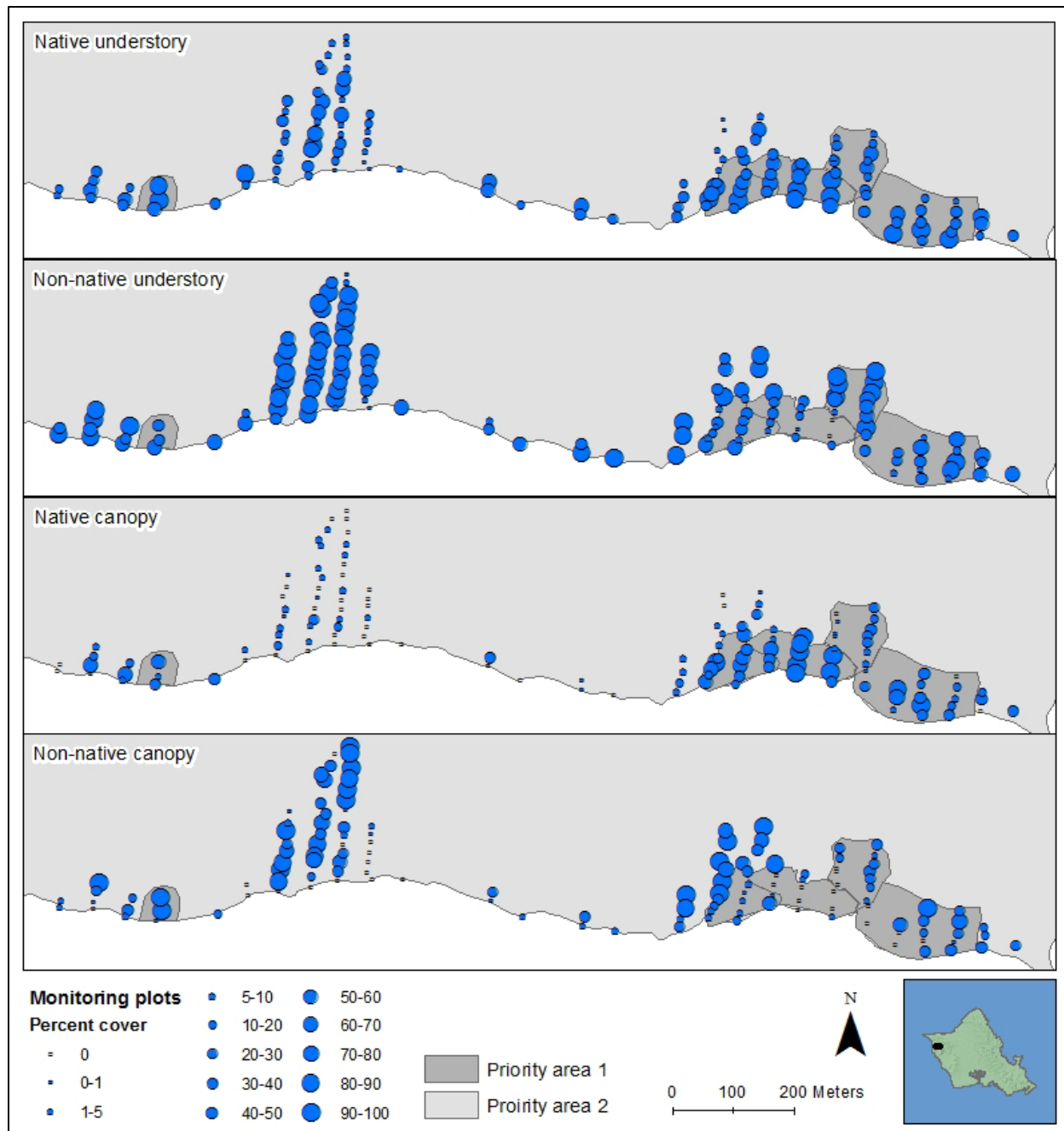


Figure 3. Locations of low to high percent cover of native and non-native understory and canopy vegetation among monitored plots at Ohikilolo Upper MU in priority areas 1 and 2 in 2016. Larger circles denote higher percent cover, while smaller circles represent lower cover.

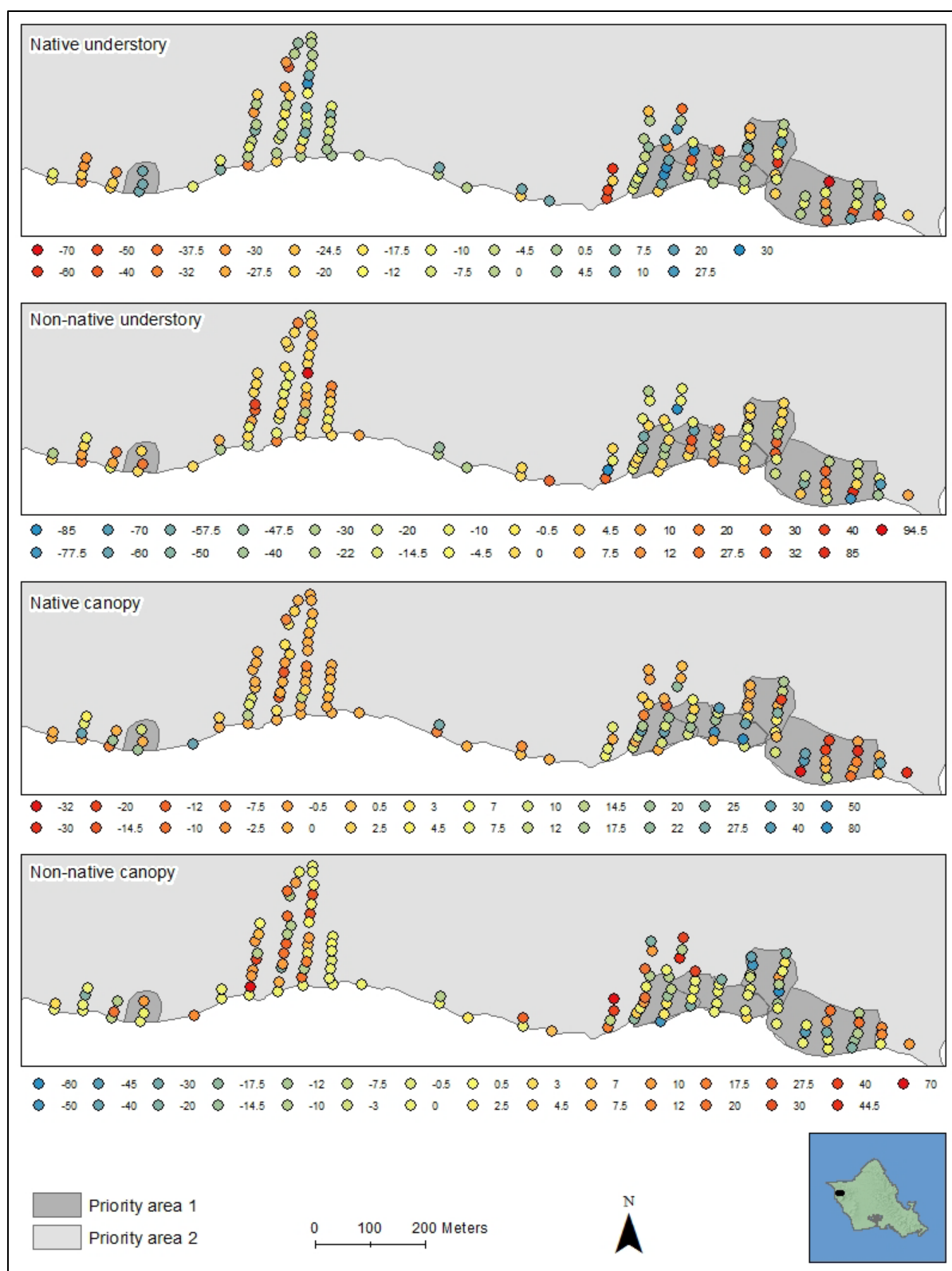


Figure 4. Locations of change in native and non-native percent cover for the understory and canopy vegetation in monitored plots in Ohikilolo Upper MU between 2010 and 2016. Color gradients are inverted for native and non-native vegetation, such that blue indicates beneficial change, red depicts worsening 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).

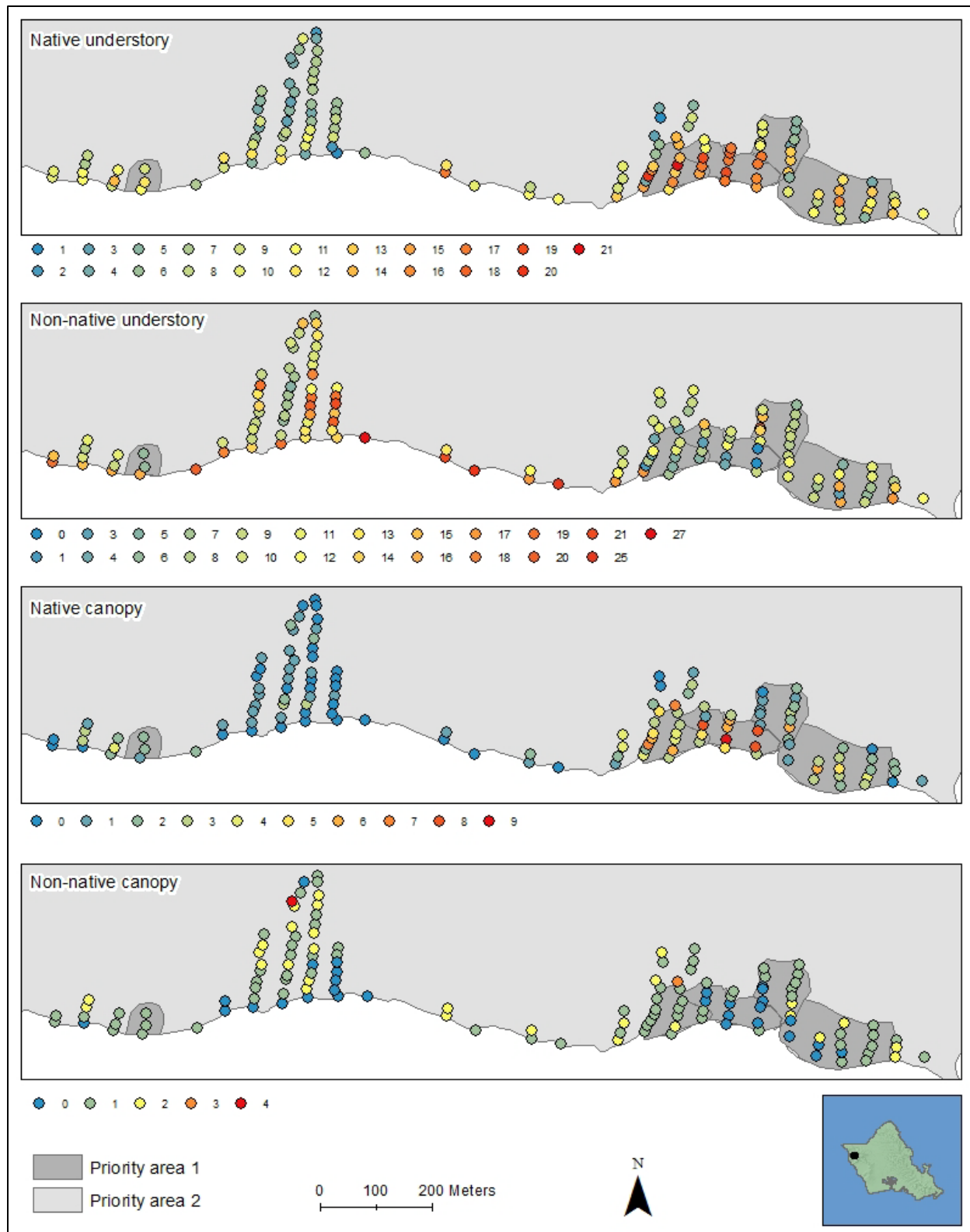


Figure 5. Locations of low to high species richness among plots in the native and non-native understory and canopy in Ohikilolo Upper MU in priority areas 1 and 2, 2016. Color gradients of blue to red indicate low to high values, respectively, of the number of species occurring in plots (i.e., blue indicates 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
<i>Arundina graminifolia</i>	0.8	<i>Adenophorus tenellus</i>	3.8
<i>Bidens alba</i>	0.8	<i>Cerastium fontanum</i>	1.5
<i>Boehmeria grandis</i>	0.8	<i>Cordyline fruticosa</i>	0.8
<i>Castilleja arvensis</i>	4.5	<i>Elaphoglossum alatum</i>	0.8
<i>Clidemia hirta</i>	6.0	<i>Elaphoglossum sp.</i>	0.8
<i>Cyperus brevifolius</i>	15.8	<i>Euphorbia multiformis</i>	0.8
<i>Desmodium sandwicense</i>	0.8	<i>Myrsine lanaiensis</i>	0.8
<i>Ehrharta stipoides</i>	0.8	<i>Perrottetia sandwicensis</i>	0.8
<i>Epidendrum x obrienianum</i>	1.5	<i>Pluchea carolinensis</i>	0.8
<i>Erechtites valerianifolia</i>	0.8	<i>Psydrax odorata</i>	0.8
<i>Euphorbia celastroides</i> var. <i>amplectens</i>	0.8	<i>Pteris irregularis</i>	0.8
<i>Kadua parvula</i>	0.8	<i>Rhynchospora sp.</i>	0.8
<i>Melicope kaalaensis</i>	0.8	<i>Sadleria pallida</i>	1.5
<i>Neraudia melastomifolia</i>	0.8	<i>Salvia occidentalis</i>	0.8
<i>Opuntia cochenillifera</i>	0.8	<i>Santalum album</i>	0.8
<i>Phaius tankervilleae</i>	0.8	<i>Smilax melastomifolia</i>	0.8
<i>Phyllanthus distichus</i>	0.8	<i>Syzygium cumini</i>	0.8
<i>Polystachya concreta</i>	1.5	<i>Trianthema portulacastrum</i>	0.8
<i>Pteris cretica</i>	1.5	<i>Zanthoxylum dipetalum</i> var. <i>dipetalum</i>	0.8
<i>Sadleria cyatheoides</i>	2.3		
<i>Santalum ellipticum</i>	0.8		
<i>Sida rhombifolia</i>	0.8		
<i>Spathodea campanulata</i>	0.8		
<i>Stapelia gigantea</i>	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			
<i>Blechnum appendiculatum</i> **	90.2	<i>Elaeocarpus bifidus</i>	10.5
<i>Carex meyenii</i>	88.0	<i>Emilia sonchifolia</i>	10.5
<i>Melinis minutiflora</i>	82.0	<i>Luzula hawaiiensis</i>	10.5
<i>Schinus terebinthifolius</i>	79.7	<i>Doryopteris decipiens</i>	9.8
<i>Stachytarpheta australis</i>	78.2	<i>Linum trigynum</i>	9.8
<i>Ageratina adenophora</i>	74.4	<i>Osteomeles anthyllidifolia</i>	9.8
<i>Ageratina riparia</i>	65.4	<i>Pritchardia kaalae</i>*	9.8
<i>Dodonaea viscosa</i>	60.2	<i>Psychotria mariniana</i>	9.8
<i>Pteridium aquilinum</i>	50.4	<i>Viola chamissoniana</i> subsp. <i>tracheliifolia</i>	9.8
<i>Metrosideros tremuloides</i>	48.9	<i>Antidesma platyphyllum</i>	9.0
<i>Metrosideros polymorpha</i>	47.4	<i>Chamaecrista nictitans</i>	9.0
<i>Kalanchoe pinnata</i>	43.6	<i>Dryopteris fusco-atra</i>	9.0
<i>Myrsine lessertiana</i>	42.1	<i>Dryopteris glabra</i>	9.0
<i>Cocculus orbiculatus</i>	39.1	<i>Pityrogramma austroamericana</i>	9.0
<i>Conyza bonariensis</i>	39.1	<i>Elaphoglossum paleaceum</i>	8.3
<i>Doodia kunthiana</i>	36.8	<i>Psychotria hathewayi</i>	8.3
<i>Lythrum maritimum</i>	36.8	<i>Paspalum conjugatum</i>	7.5
<i>Erigeron karvinskianus</i>	34.6	<i>Adiantum hispidulum</i>	6.8
<i>Sphenomeris chinensis</i>	33.8	<i>Clidemia hirta</i>	6.0
<i>Setaria parviflora</i>	30.8	<i>Kadua acuminata</i>	6.0
<i>Andropogon virginicus</i>	30.1	<i>Athyrium microphyllum</i>	5.3
<i>Centaurium erythraea</i>	29.3	<i>Lysimachia hillebrandii</i>	5.3
<i>Coprosma foliosa</i>	29.3	<i>Psidium cattleianum</i>	5.3
<i>Youngia japonica</i>	29.3	<i>Triumfetta semitriloba</i>	5.3
<i>Carex wahuensis</i>	28.6	<i>Acacia koa</i>	4.5
<i>Grevillea robusta</i> **	28.6	<i>Ageratum conyzoides</i>	4.5
<i>Lantana camara</i>	27.1	<i>Castilleja arvensis</i>	4.5
<i>Alyxia stellata</i>	25.6	<i>Deparia prolifera</i>	4.5
<i>Rubus rosifolius</i>	25.6	<i>Emilia fosbergii</i>	4.5
<i>Bidens torta</i>	23.3	<i>Kadua affinis</i>	4.5
<i>Gamochaeta purpurea</i>	23.3	<i>Melicope oahuensis</i>	4.5
<i>Lepisorus thunbergianus</i>	23.3	<i>Verbena litoralis</i>	4.5
<i>Selaginella arbuscula</i>	23.3	<i>Cuphea carthagenesis</i>	3.8
<i>Dryopteris sandwicensis</i>	22.6	<i>Dianella sandwicensis</i>	3.8
<i>Oxalis corniculata</i>	21.8	<i>Gahnia beecheyi</i>	3.8
<i>Eragrostis grandis</i>	20.3	<i>Paspalum scrobiculatum</i>	3.8
<i>Wikstroemia oahuensis</i> var. <i>oahuensis</i>	19.5	<i>Pipturis albidus</i>	3.8
<i>Lachnagrostis filiformis</i>	18.0	<i>Psidium guajava</i>	3.8
<i>Melinis repens</i>	18.0	<i>Diospyros sandwicensis</i>	3.0
<i>Nephrolepis exaltata</i> subsp. <i>hawaiiensis</i>	18.0	<i>Oplismenus hirtellus</i>	3.0
<i>Freycinetia arborea</i>	17.3	<i>Toona ciliata</i>	3.0
<i>Microlepis strigosa</i>	17.3	<i>Adiantum radianum</i>	2.3
<i>Festuca bromoides</i>	16.5	<i>Bidens pilosa</i>	2.3
<i>Cheilanthes viridis</i>	15.8	<i>Buddleja asiatica</i>	2.3
<i>Cyclosorus parasiticus</i>	15.8	<i>Cyclosorus dentatus</i>	2.3
<i>Cyperus brevifolius</i>	15.8	<i>Cyrtandra waianaeensis</i>	2.3
<i>Lysimachia arvensis</i>	12.8	<i>Dicranopteris linearis</i>	2.3
<i>Psilotum nudum</i>	12.0	<i>Nestegis sandwicensis</i>	2.3
<i>Cibotium chamissoi</i>	11.3	<i>Passiflora suberosa</i> **	2.3
<i>Sporobolus indicus</i>	11.3	<i>Sadleria cyatheoides</i>	2.3

Table 4, continued

Taxon	Freq.	Taxon	Freq.
Understory, cont.			
<i>Sonchus oleraceus</i>	2.3	<i>Ehrharta stipoides</i> **	0.8
<i>Araucaria columnaris</i> **	1.5	<i>Erechtites valerianifolia</i>	0.8
<i>Axonopus fissifolius</i> **	1.5	<i>Euphorbia celastroides</i> var. <i>amplectens</i>	0.8
<i>Chrysodracon forbesii</i>*	1.5	<i>Indigofera spicata</i>	0.8
<i>Cyclosorus cyatheoides</i>	1.5	<i>Kadua parvula</i>*	0.8
<i>Cyperus mindorensis</i>	1.5	<i>Leucaena leucocephala</i>	0.8
<i>Epidendrum x obrienianum</i>	1.5	<i>Melicope kaalaensis</i>	0.8
<i>Korthalsella complanata</i>	1.5	<i>Mesosphaerum pectinatum</i>	0.8
<i>Melicope makahae</i>*	1.5	<i>Neraudia melastomifolia</i>	0.8
<i>Planchonella sandwicensis</i>	1.5	<i>Opuntia cochenillifera</i>	0.8
<i>Platydesma cornuta</i> var. <i>decurrens</i>*	1.5	<i>Panicum nephelophilum</i>	0.8
<i>Plectranthus parviflorus</i>	1.5	<i>Peperomia membranacea</i>	0.8
<i>Polypodium pellucidum</i> var. <i>pellucidum</i>	1.5	<i>Phaius tankervilleae</i>	0.8
<i>Polystachya concreta</i>	1.5	<i>Phlebodium aureum</i>	0.8
<i>Pteris cretica</i>	1.5	<i>Phyllanthus distichus</i>	0.8
<i>Salvia coccinea</i>	1.5	<i>Santalum ellipticum</i>	0.8
<i>Scaevola gaudichaudiana</i>	1.5	<i>Sida rhombifolia</i>	0.8
<i>Artemisia australis</i>	0.8	<i>Spathodea campanulata</i>	0.8
<i>Arundina graminifolia</i>	0.8	<i>Stapelia gigantea</i>	0.8
<i>Asplenium caudatum</i>	0.8	<i>Syzygium sandwicense</i>	0.8
<i>Bidens alba</i>	0.8	<i>Tectaria gaudichaudii</i>	0.8
<i>Boehmeria grandis</i>	0.8	<i>Vaccinium reticulatum</i>	0.8
<i>Ctenitis latifrons</i>	0.8	<i>Waltheria indica</i>	0.8
<i>Desmodium sandwicense</i>	0.8	<i>Xylosma hawaiiense</i>	0.8
<i>Dubautia herbstobatae</i>*	0.8		
Canopy			
<i>Schinus terebinthifolius</i>	72.2	<i>Kadua affinis</i>	1.5
<i>Metrosideros tremuloides</i>	37.6	<i>Lantana camara</i>	1.5
<i>Metrosideros polymorpha</i>	33.1	<i>Melicope oahuensis</i>	1.5
<i>Dodonaea viscosa</i>	24.1	<i>Planchonella sandwicensis</i>	1.5
<i>Grevillea robusta</i> **	22.6	<i>Psidium cattleianum</i>	1.5
<i>Freycinetia arborea</i>	12.8	<i>Sadleria cyatheoides</i>	1.5
<i>Myrsine lessertiana</i>	12.0	<i>Syzygium sandwicense</i>	1.5
<i>Alyxia stellata</i>	9.8	<i>Bobea elatior</i>	0.8
<i>Cibotium chamissoi</i>	8.3	<i>Boehmeria grandis</i>	0.8
<i>Coprosma foliosa</i>	8.3	<i>Cyrtandra waianaeensis</i>	0.8
<i>Elaeocarpus bifidus</i>	8.3	<i>Korthalsella complanata</i>	0.8
<i>Acacia koa</i>	7.5	<i>Pipturis albidus</i>	0.8
<i>Lepisorus thunbergianus</i>	7.5	<i>Rubus rosifolius</i>	0.8
<i>Psychotria hathewayi</i>	6.0	<i>Santalum ellipticum</i>	0.8
<i>Psychotria mariniana</i>	4.5	<i>Scaevola gaudichaudiana</i>	0.8
<i>Antidesma platyphyllum</i>	3.8	<i>Stachytarpheta australis</i>	0.8
<i>Nestegis sandwicensis</i>	3.0	<i>Toona ciliata</i>	0.8
<i>Diospyros sandwicensis</i>	2.3	<i>Triumfetta semitriloba</i>	0.8
<i>Melinis minutiflora</i>	2.3	<i>Wikstroemia oahuensis</i> var. <i>oahuensis</i>	0.8
<i>Pritchardia kaalae</i>*	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				
<i>Ageratina riparia</i>	75.9	65.4	-10.5	0.022^a ↓
<i>Conyza bonariensis</i>	25.6	39.1	13.5	0.001^a ↑
<i>Cyperus spp.*</i>	6.0	17.3	11.3	0.001^b ↑
<i>Lepisorus thunbergianus</i>	7.5	23.3	15.8	<0.001^a ↑
<i>Rubus rosifolius</i>	12.8	25.6	12.8	<0.001^b ↑
<i>Youngia japonica</i>	10.5	29.3	18.8	<0.001^a ↑
Canopy				
<i>Dodonaea viscosa</i>	11.3	24.1	12.8	<0.001^b ↑

**Cyperus brevifolia* and/or *C. mindorensis*

^aAsymptotic significance

^bExact 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			
<i>Ageratina adenophora</i>	0.0	0.094	-1.674
<i>Ageratina riparia</i>	0.0	< 0.001 ↓	-6.324
<i>Alyxia stellata</i>	0.0	0.634	-0.476
<i>Andropogon virginicus</i>	0.0	0.109	-1.602
<i>Bidens torta</i>	0.0	0.348	-0.939
<i>Blechnum appendiculatum</i>	0.0	0.001 ↓	-3.319
<i>Carex meyenii</i>	-2.5	< 0.001 ↓	-5.476
<i>Carex wahuensis</i>	0.0	0.039 ↓	-2.059
<i>Centaurium erythraea</i>	0.0	0.834	-0.210
<i>Cocculus orbiculatus</i>	0.0	0.083	-1.732
<i>Conyza bonariensis</i>	0.0	0.001 ↑	-3.402
<i>Coprosma foliosa</i>	0.0	0.668	-0.428
<i>Dodonaea viscosa</i>	0.0	0.013 ↓	-2.490
<i>Doodia kunthiana</i>	0.0	0.090	-1.697
<i>Dryopteris sandwicensis</i>	0.0	0.629	-0.483
<i>Eragrostis grandis</i>	0.0	0.233	-1.193
<i>Erigeron karvinskianus</i>	0.0	0.036 ↑	-2.100
<i>Festuca bromoides</i>	0.0	0.050 ↓	-1.962
<i>Gamochaeta purpurea</i>	0.0	0.297	-1.043
<i>Grevillea robusta</i>	0.0	0.329	-0.976
<i>Kalanchoe pinnata</i>	0.0	0.600	-0.524
<i>Lantana camara</i>	0.0	0.045 ↓	-2.002
<i>Lepisorus thunbergianus</i>	0.0	< 0.001 ↑	-3.900
<i>Lythrum maritimum</i>	0.0	0.954	-0.058
<i>Melinis minutiflora</i>	0.0	0.146	-1.456
<i>Melinis repens</i>	0.0	0.113	-1.586
<i>Metrosideros polymorpha</i>	0.0	0.037 ↓	-2.080
<i>Metrosideros tremuloides</i>	0.0	0.328	-0.977
<i>Microlepia strigosa</i>	0.0	0.146	-1.453
<i>Myrsine lessertiana</i>	0.0	0.877	-0.550
<i>Oxalis corniculata</i>	0.0	0.127	-1.528
<i>Pteridium aquilinum</i>	0.0	< 0.001 ↓	-4.437
<i>Rubus rosifolius</i>	0.0	< 0.001 ↑	-4.716
<i>Schinus terebinthifolius</i>	0.0	< 0.001 ↓	-4.420
<i>Selaginella arbuscula</i>	0.0	0.035 ↑	-2.113
<i>Setaria parviflora</i>	0.0	< 0.001 ↓	-4.064
<i>Sphenomeris chinensis</i>	0.0	0.001 ↓	-3.447
<i>Stachytarpheta australis</i>	0.0	0.057↑	-1.906
<i>Youngia japonica</i>	0.0	< 0.001 ↑	-4.849
Canopy			
<i>Dodonaea viscosa</i>	0.0	< 0.001 ↑	-4.108
<i>Grevillea robusta</i>	0.0	0.015 ↑	-2.422
<i>Metrosideros polymorpha</i>	0.0	0.587	-0.544
<i>Metrosideros tremuloides</i>	0.0	0.022 ↑	-2.294
<i>Schinus terebinthifolius</i>	0.0	0.169	-1.374

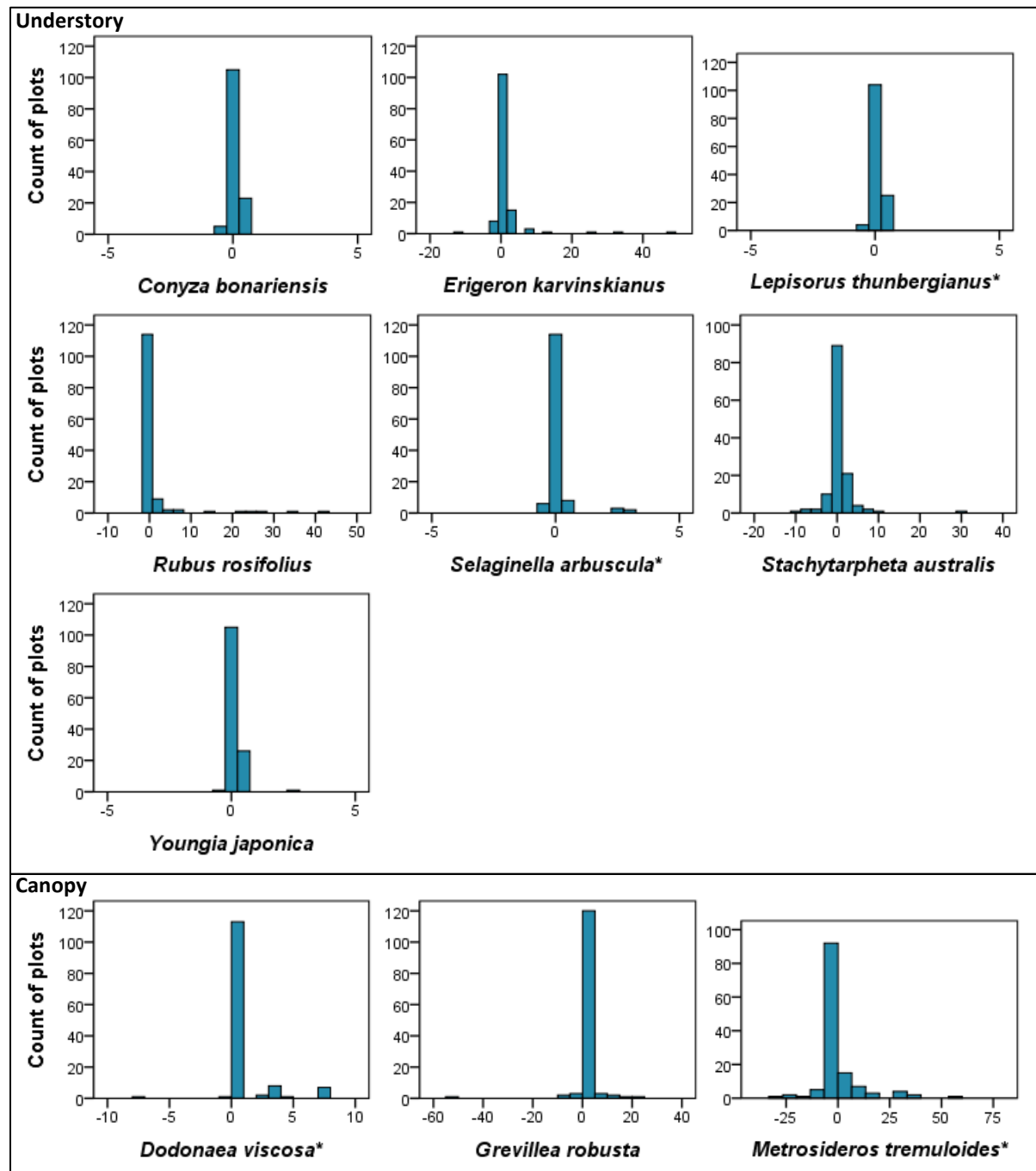


Figure 6. Histograms of percent cover change between 2010 and 2016 at Ohikilolo Upper MU in priority areas 1 and 2, for taxa with significant increases in cover in the understory and canopy. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change. *Native taxa.

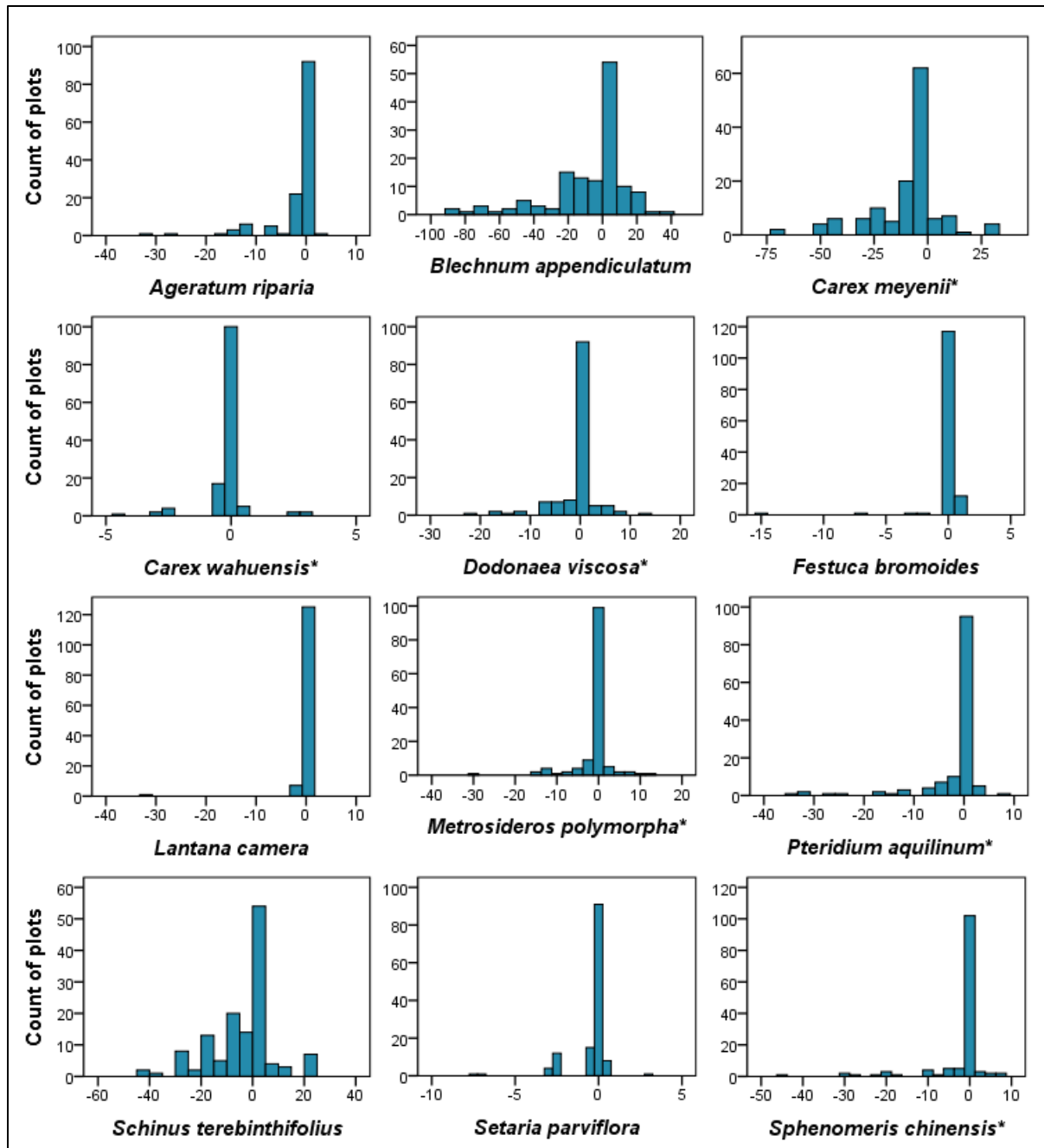


Figure 7. Histograms of percent cover change between 2010 and 2016 at Ohikilolo Upper MU in priority areas 1 and 2, for taxa with significant decreases in cover in the understory. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no 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
<i>Dodonaea viscosa</i>	47.4	<i>Coprosma foliosa</i>	2.3
<i>Schinus terebinthifolius</i>	46.6	<i>Kadua affinis</i>	2.3
<i>Myrsine lessertiana</i>	36.1	<i>Pipturis albidus</i>	2.3
<i>Metrosideros polymorpha</i>	30.8	<i>Toona ciliata</i>	2.3
<i>Metrosideros tremuloides</i>	28.6	<i>Acacia koa</i>	1.5
<i>Grevillea robusta</i> **	15.0	<i>Melicope oahuensis</i>	1.5
<i>Wikstroemia oahuensis</i>	10.5	<i>Psidium cattleianum</i>	1.5
<i>Pritchardia kaalae</i>*	7.5	<i>Freycinetia arborea</i>	0.8
<i>Psychotria mariniana</i>	6.0	<i>Leucaena leucocephala</i>	0.8
<i>Antidesma platyphyllum</i>	4.5	<i>Melicope makahae</i>*	0.8
<i>Psidium guajava</i>	3.8	<i>Syzygium sandwicense</i>	0.8
<i>Psychotria hathewayi</i>	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.

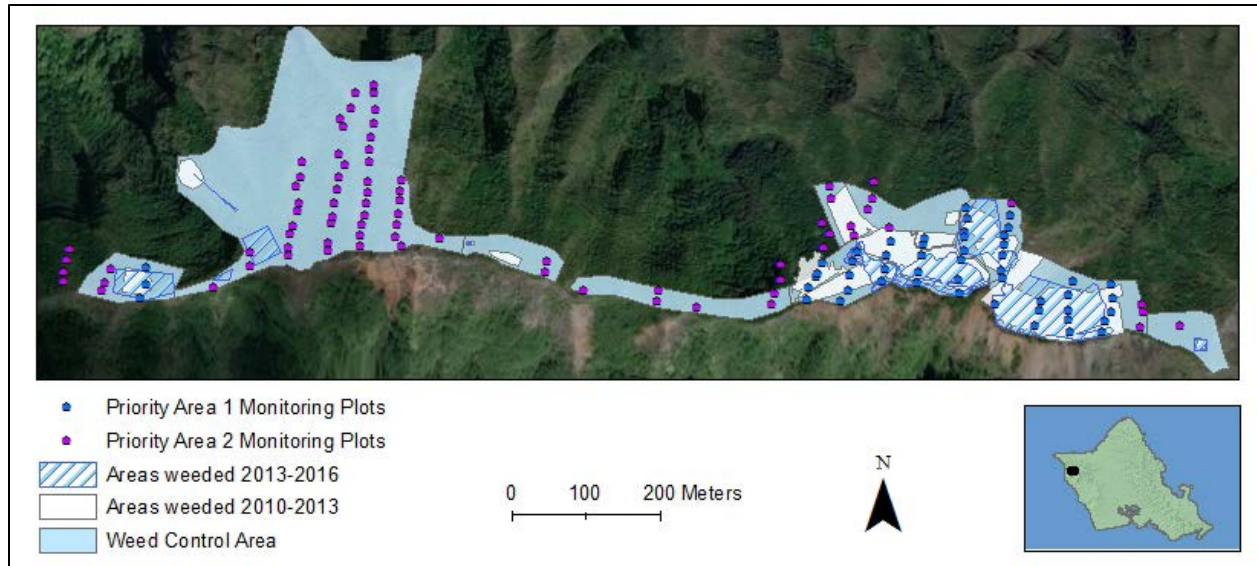


Figure 8. Locations of vegetation monitoring plots at Ohikilolo Upper MU in relation to weed control areas (WCA) and areas weeded between the 2010 to 2013 and 2013 to 2016 monitoring intervals, with plots color-coded by priority area.

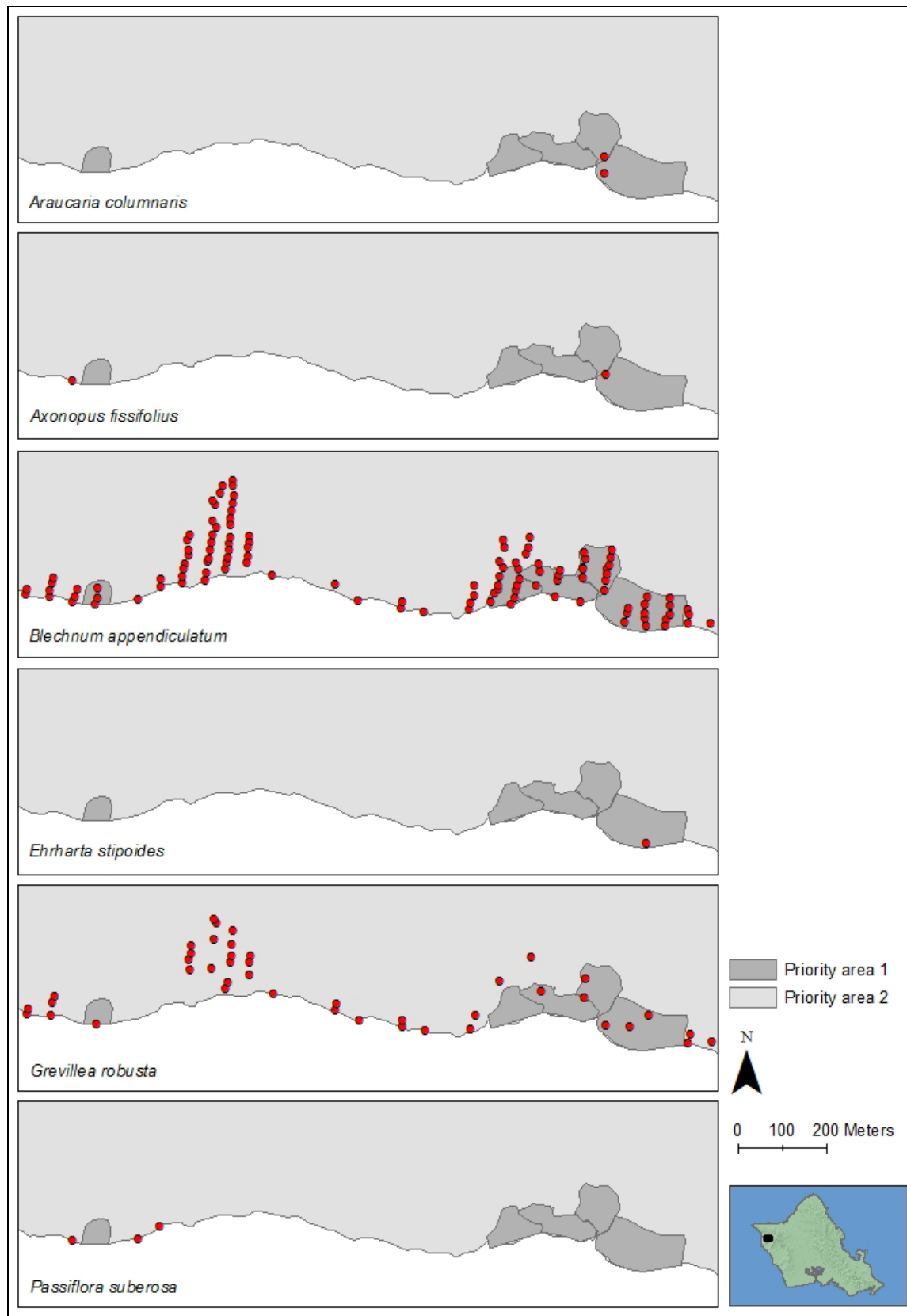


Figure 9. Locations of ERMUP target taxa in the understory and/or canopy among plots in Ohikilolo Upper MU in priority areas 1 and 2 in 2016.

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

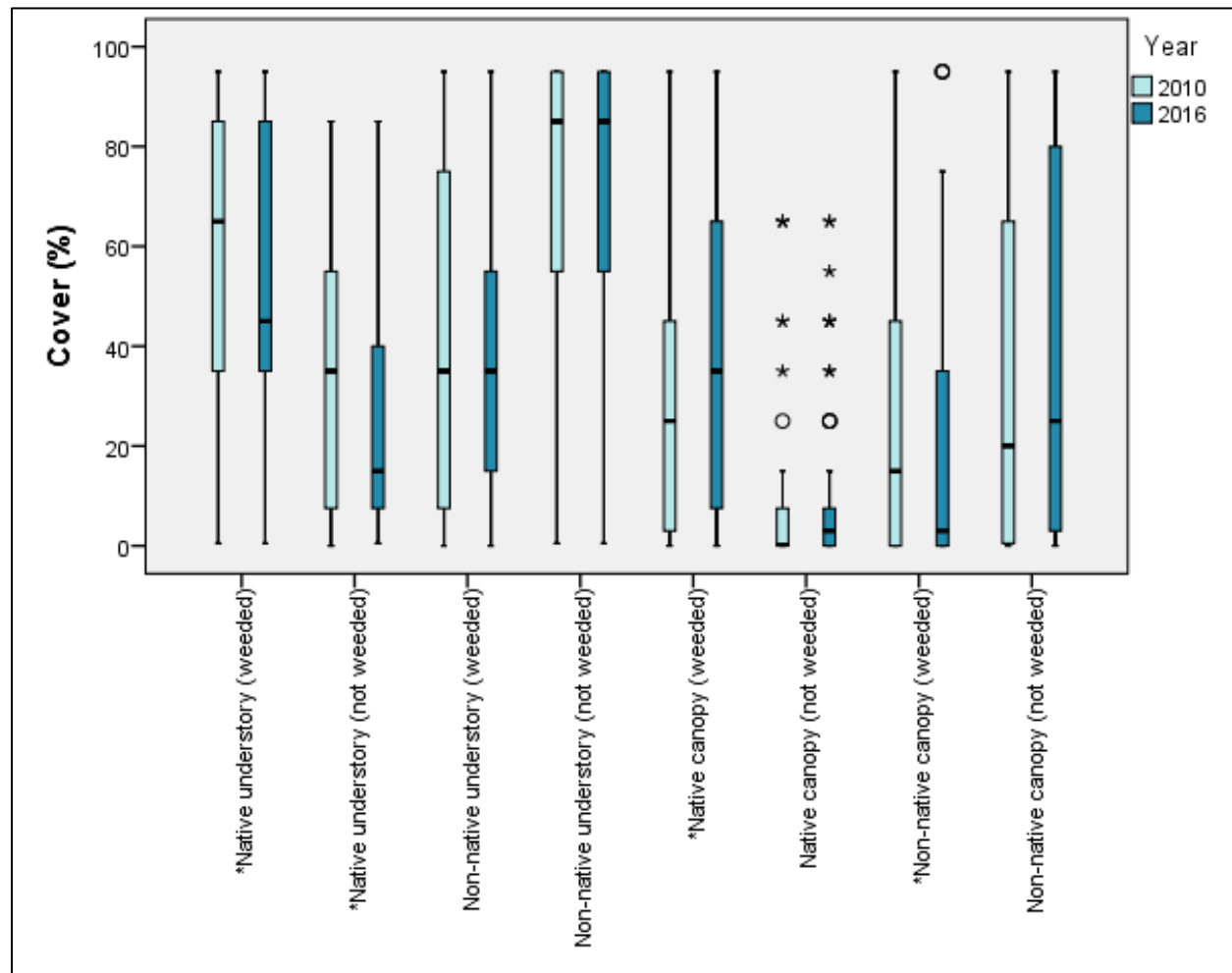


Figure 10. Boxplots of percent cover in plots within (n = 49) vs. outside (n = 84) weeded areas in 2010 and 2016 for native and non-native understory and canopy. *Significant change that meets the 10% standard for recognized change in cover between 2010 and 2016.

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 significant¹ 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%.

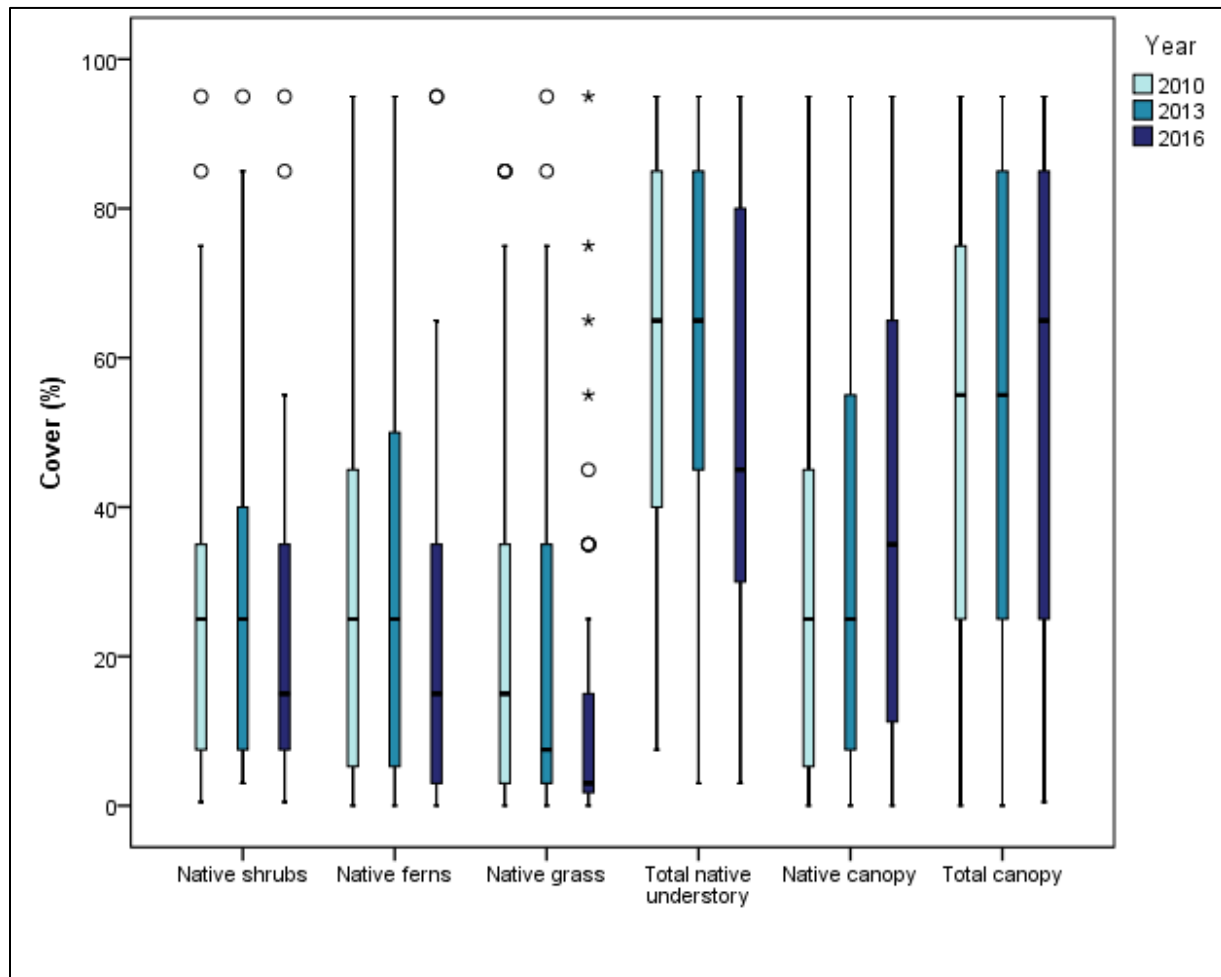


Figure 11. Boxplots for vegetation categories with significant change in percent cover that meet 10% standard for recognized change in cover between years 2010 and 2016 in Ohikilolo Upper MU, priority area 1.

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
<i>Castilleja arvensis</i>	2.0	<i>Adenophorus tenellus</i>	3.9	-
<i>Cyperus brevifolius</i>	3.9	<i>Artemisia australis</i>	-	2.0
<i>Dianella sandwicensis</i>	3.9	<i>Asclepias physocarpa</i>	-	2.0
<i>Ehrharta stipoides</i>	2.0	<i>Asplenium caudatum</i>	7.8	3.9
<i>Epidendrum x obrienianum</i>	2.0	<i>Cerastium fontanum</i>	2.0	-
<i>Lysimachia arvensis</i>	2.0	<i>Cyrtomium caryotideum</i>	-	2.0
<i>Neraudia melastomifolia</i>	2.0	<i>Elaphoglossum alatum</i>	2.0	-
<i>Spathodea campanulata</i>	2.0	<i>Elaphoglossum sp.</i>	2.0	-
		<i>Emilia fosbergii</i>	2.0	2.0
		<i>Erechtites valerianifolia</i>	-	2.0
		<i>Melicope makahae</i>	2.0	-
		<i>Mesosphaerum pectinatum</i>	2.0	-
		<i>Nephrolepis cordifolia</i>	-	2.0
		<i>Paspalum scrobiculatum</i>	3.9	-
		<i>Pteris irregularis</i>	2.0	-
		<i>Rhynchospora sp.</i>	2.0	-
		<i>Sadleria pallida</i>	2.0	2.0
		<i>Santalum album</i>	2.0	-
		<i>Zanthoxylum dipetalum var. dipetalum</i>	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. *decurrans*) 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			
<i>Carex meyenii</i>	88.2	<i>Kadua acuminata</i>	11.8
<i>Blechnum appendiculatum</i> **	84.3	<i>Melicope oahuensis</i>	11.8
<i>Stachytarpheta australis</i>	76.5	<i>Triumfetta semitriloba</i>	11.8
<i>Melinis minutiflora</i>	68.6	<i>Acacia koa</i>	9.8
<i>Myrsine lessertiana</i>	64.7	<i>Centaurium erythraea</i>	9.8
<i>Doodia kunthiana</i>	62.7	<i>Cheilanthes viridis</i>	9.8
<i>Schinus terebinthifolius</i>	60.8	<i>Clidemia hirta</i>	9.8
<i>Coprosma foliosa</i>	56.9	<i>Cuphea carthagenesis</i>	9.8
<i>Dodonaea viscosa</i>	56.9	<i>Eragrostis grandis</i>	9.8
<i>Metrosideros polymorpha</i>	54.9	<i>Gahnia beecheyi</i>	9.8
<i>Rubus rosifolius</i>	54.9	<i>Bidens torta</i>	7.8
<i>Ageratina adenophora</i>	51.0	<i>Festuca bromoides</i>	7.8
<i>Alyxia stellata</i>	51.0	<i>Kadua affinis</i>	7.8
<i>Kalanchoe pinnata</i>	47.1	<i>Oxalis corniculata</i>	7.8
<i>Metrosideros tremuloides</i>	47.1	<i>Ageratum conyzoides</i>	5.9
<i>Sphenomeris chinensis</i>	47.1	<i>Cyrtandra waianaeensis</i>	5.9
<i>Wikstroemia oahuensis</i> var. <i>oahuensis</i>	45.1	<i>Dicranopteris linearis</i>	5.9
<i>Cocculus orbiculatus</i>	43.1	<i>Doryopteris decipiens</i>	5.9
<i>Ageratina riparia</i>	39.2	<i>Lachnagrostis filiformis</i>	5.9
<i>Erigeron karvinskianus</i>	39.2	<i>Lysimachia hillebrandii</i>	5.9
<i>Freycinetia arborea</i>	39.2	<i>Melinis repens</i>	5.9
<i>Pteridium aquilinum</i>	39.2	<i>Pipturis albidus</i>	5.9
<i>Nephrolepis exaltata</i> subsp. <i>hawaiiensis</i>	37.3	<i>Araucaria columnaris</i> **	3.9
<i>Youngia japonica</i>	35.3	<i>Cyclosorus cyatheoides</i>	3.9
<i>Dryopteris sandwicensis</i>	29.4	<i>Cyclosorus dentatus</i>	3.9
<i>Cibotium chamissoi</i>	27.5	<i>Cyperus brevifolius</i>	3.9
<i>Conyza bonariensis</i>	27.5	<i>Dianella sandwicensis</i>	3.9
<i>Elaeocarpus bifidus</i>	25.5	<i>Korthalsella complanata</i>	3.9
<i>Pritchardia kaalae</i> *	25.5	<i>Nestegis sandwicensis</i>	3.9
<i>Selaginella arbuscula</i>	25.5	<i>Oplismenus hirtellus</i>	3.9
<i>Antidesma platyphyllum</i>	23.5	<i>Platydesma cornuta</i> var. <i>decurrens</i> *	3.9
<i>Cyclosorus parasiticus</i>	23.5	<i>Psidium cattleianum</i>	3.9
<i>Dryopteris fusco-atra</i>	23.5	<i>Psilotum nudum</i>	3.9
<i>Lantana camara</i>	23.5	<i>Sadleria cyatheoides</i>	3.9
<i>Lepisorus thunbergianus</i>	23.5	<i>Scaevola gaudichaudiana</i>	3.9
<i>Psychotria mariniana</i>	23.5	<i>Sporobolus indicus</i>	3.9
<i>Lythrum maritimum</i>	21.6	<i>Adiantum hispidulum</i>	2.0
<i>Microlepia strigosa</i>	21.6	<i>Axonopus fissifolius</i> **	2.0
<i>Setaria parviflora</i>	21.6	<i>Bidens pilosa</i>	2.0
<i>Carex wahuensis</i>	17.6	<i>Buddleja asiatica</i>	2.0
<i>Dryopteris glabra</i>	17.6	<i>Castilleja arvensis</i>	2.0
<i>Paspalum conjugatum</i>	17.6	<i>Chamaecrista nictitans</i>	2.0
<i>Viola chamissoniana</i> subsp. <i>trachelifolia</i>	17.6	<i>Ctenitis latifrons</i>	2.0
<i>Andropogon virginicus</i>	15.7	<i>Cyperus mindorensis</i>	2.0
<i>Gamochaeta purpurea</i>	15.7	<i>Diospyros sandwicensis</i>	2.0
<i>Psychotria hathewayi</i>	15.7	<i>Ehrharta stipoides</i> **	2.0
<i>Athyrium microphyllum</i>	11.8	<i>Emilia sonchifolia</i>	2.0
<i>Deparia prolifera</i>	11.8	<i>Epidendrum x obrienianum</i>	2.0
<i>Elaphoglossum paleaceum</i>	11.8	<i>Linum trigynum</i>	2.0
<i>Grevillea robusta</i> **	11.8	<i>Luzula hawaiiensis</i>	2.0

Table 12, continued

Taxon	Freq.	Taxon	Freq.
Understory, cont.			
<i>Lysimachia arvensis</i>	2.0	<i>Plectranthus parviflorus</i>	2.0
<i>Melicope kaalaensis</i>	2.0	<i>Polypodium pellucidum</i> var. <i>pellucidum</i>	2.0
<i>Neraudia melastomifolia</i>	2.0	<i>Sonchus oleraceus</i>	2.0
<i>Opuntia cochenillifera</i>	2.0	<i>Spathodea campanulata</i>	2.0
<i>Osteomeles anthyllidifolia</i>	2.0	<i>Syzygium sandwicense</i>	2.0
<i>Panicum nephelophilum</i>	2.0	<i>Tectaria gaudichaudii</i>	2.0
<i>Peperomia membranacea</i>	2.0	<i>Toona ciliata</i>	2.0
<i>Phaius tankervilleae</i>	2.0	<i>Vaccinium reticulatum</i>	2.0
<i>Phyllanthus distichus</i>	2.0	<i>Verbena litoralis</i>	2.0
<i>Pityrogramma austroamericana</i>	2.0	<i>Xylosma hawaiiense</i>	2.0
<i>Planchonella sandwicensis</i>	2.0		
Canopy			
<i>Schinus terebinthifolius</i>	68.6	<i>Pritchardia kaalae</i>*	5.9
<i>Metrosideros polymorpha</i>	54.9	<i>Grevillea robusta</i> **	3.9
<i>Metrosideros tremuloides</i>	39.2	<i>Kadua affinis</i>	3.9
<i>Dodonaea viscosa</i>	35.3	<i>Melicope oahuensis</i>	3.9
<i>Freyinetia arborea</i>	29.4	<i>Syzygium sandwicense</i>	3.9
<i>Elaeocarpus bifidus</i>	21.6	<i>Bobea elatior</i>	2.0
<i>Alyxia stellata</i>	19.6	<i>Cyrtandra waianaeensis</i>	2.0
<i>Cibotium chamissoi</i>	19.6	<i>Korthalsella complanata</i>	2.0
<i>Acacia koa</i>	17.6	<i>Melinis minutiflora</i>	2.0
<i>Myrsine lessertiana</i>	17.6	<i>Planchonella sandwicensis</i>	2.0
<i>Coprosma foliosa</i>	13.7	<i>Rubus rosifolius</i>	2.0
<i>Psychotria mariniana</i>	11.8	<i>Sadleria cyatheoides</i>	2.0
<i>Antidesma platyphyllum</i>	7.8	<i>Scaevola gaudichaudiana</i>	2.0
<i>Lepisorus thunbergianus</i>	7.8	<i>Stachytarpheta australis</i>	2.0
<i>Psychotria hathewayi</i>	7.8	<i>Toona ciliata</i>	2.0
<i>Nestegis sandwicensis</i>	5.9	<i>Wikstroemia oahuensis</i> var. <i>oahuensis</i>	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
<i>Coprosma foliosa</i>	41.2	45.1	56.9	15.7	2010-2016 2013-2016	0.039↑ 0.031↑
<i>Dryopteris fusco-atra</i>	11.8	25.5	23.5	11.8	2010-2013 2010-2016	0.039↑ 0.031↑
<i>Festuca bromoides</i>	21.6	0.0	7.8	-13.7	2010-2013 2010-2016	0.001↓ 0.039↓
<i>Rubus rosifolius</i>	31.4	33.3	54.9	23.5	2010-2016 2013-2016	0.002↑ 0.001↑
<i>Schinus terebinthifolius</i>	76.5	66.7	60.8	-15.7	2010-2016	0.039↓
<i>Setaria parviflora</i>	37.3	43.1	21.6	-15.7	2010-2016 2013-2016	0.039↓ 0.003↓
<i>Wikstroemia oahuensis</i>	29.4	41.2	45.1	15.7	2010-2013 2010-2016	0.07↑ 0.008↑
<i>Youngia japonica</i>	15.7	15.7	35.3	19.6	2010-2016 2013-2016	0.006↑ 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					
<i>Ageratina adenophora</i>	0.023↓	7.507	NA		
<i>Ageratina riparia</i>	0.048↓	6.081	NA		
<i>Blechnum appendiculatum</i>	0.003↓	11.450	2013-2016↓	0.012	-3.0
<i>Carex meyenii</i>	<0.001↓	31.985	2010-2016↓ 2013-2016↓	<0.001 <0.001	-2.5 -2.5
<i>Doodia kunthiana</i>	0.022↓	7.622	NA		
<i>Festuca bromoides</i>	<0.001↓	16.270	NA		
<i>Lantana camara</i>	0.049↓	6.030	NA		
<i>Pritchardia kaalae</i>	0.018↑	8.000	NA		
<i>Psychotria mariniana</i>	0.006↑	10.383	NA		
<i>Rubus rosifolius</i>	<0.001↑	35.685	2010-2016↑ 2013-2016↑	0.002 0.002	0.0 0.0
<i>Schinus terebinthifolius</i>	0.033↓	6.819	NA		
<i>Selaginella arbuscula</i>	0.036↑	6.650	NA		
<i>Setaria parviflora</i>	<0.001↓	18.581	NA		
<i>Sphenomeris chinensis</i>	0.025↓	7.367	NA		
<i>Youngia japonica</i>	<0.001↑	16.133	NA		
Canopy					
<i>Dodonaea viscosa</i>	<0.001↑	17.200	NA		
<i>Freycinetia arborea</i>	0.034↑	6.778	NA		

*from Friedman's test

**from post-hoc pairwise comparisons with Bonferroni adjustment

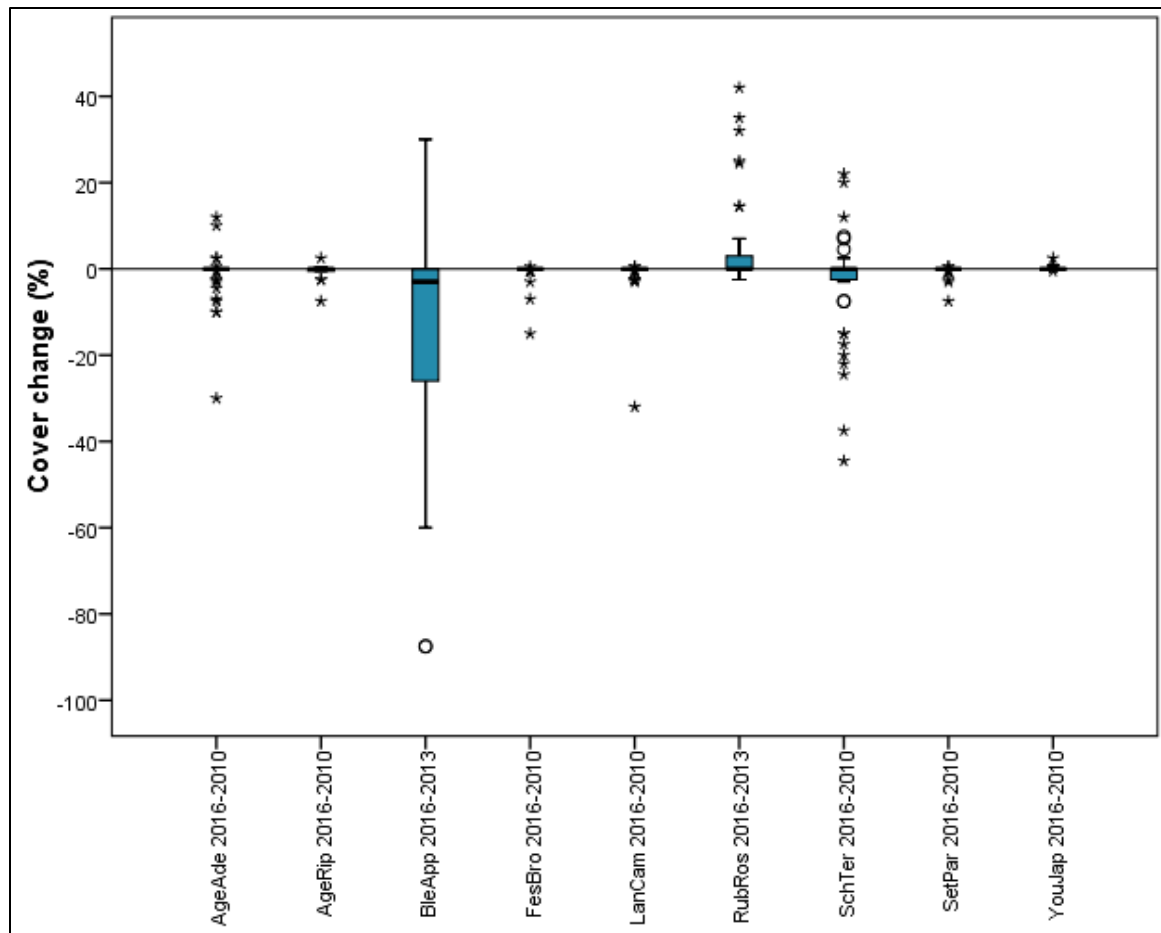


Figure 12. Boxplots of percent cover change between 2010 and 2016 in priority area 1, for understory non-native species with significant changes in cover. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover.

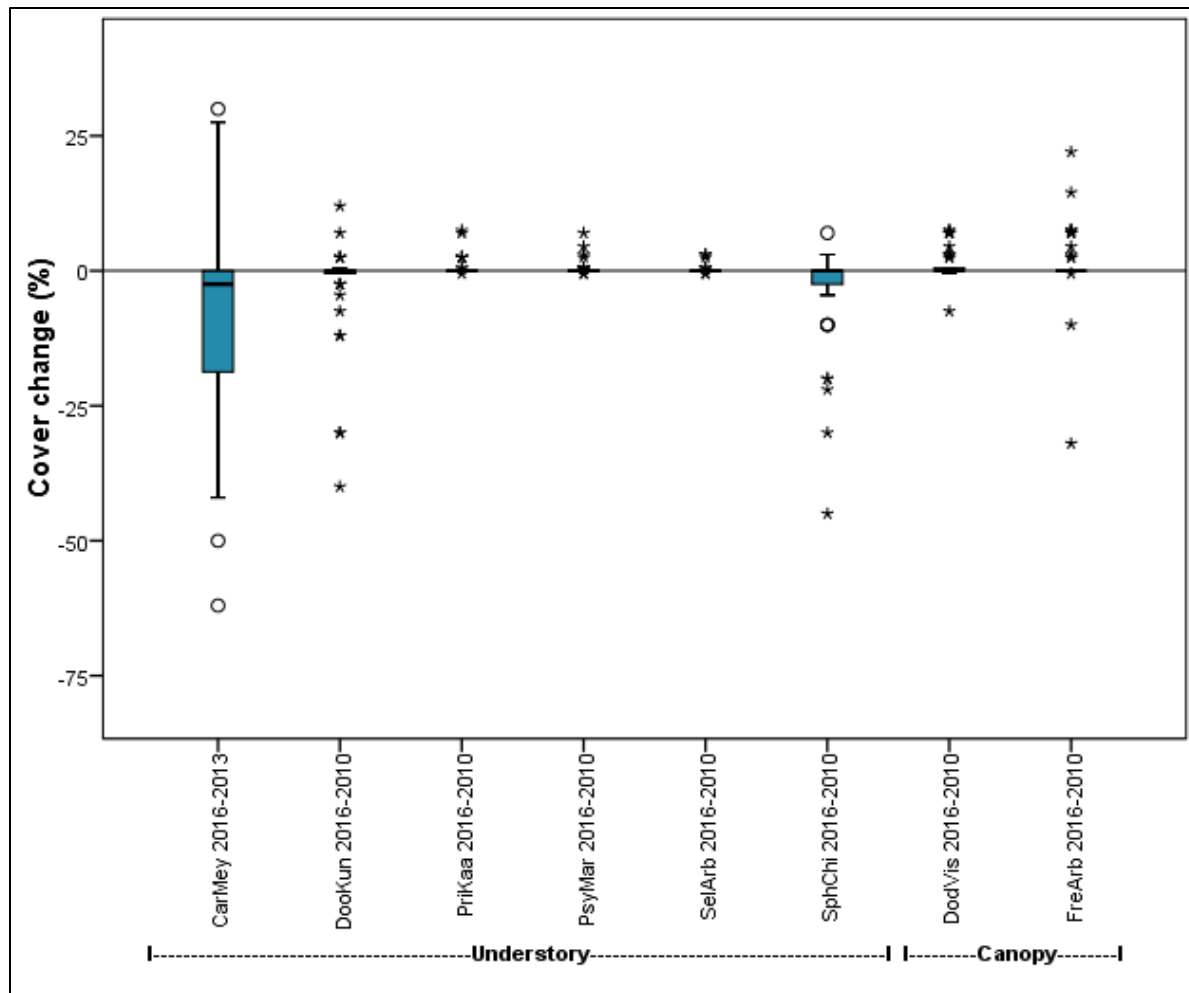


Figure 13. Boxplots of percent cover change between 2010 and 2016 in priority area 1, for native species with significant changes in cover. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover.

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
<i>Myrsine lessertiana</i>	58.8	<i>Psychotria hathewayi</i>	7.8
<i>Dodonaea viscosa</i>	41.2	<i>Kadua affinis</i>	5.9
<i>Metrosideros polymorpha</i>	33.3	<i>Acacia koa</i>	3.9
<i>Schinus terebinthifolius</i>	31.4	<i>Melicope oahuensis</i>	3.9
<i>Wikstroemia oahuensis</i>	23.5	<i>Pipturis albidus</i>	3.9
<i>Metrosideros tremuloides</i>	19.6	<i>Freycinetia arborea</i>	2.0
<i>Pritchardia kaalae</i> *	19.6	<i>Psidium cattleianum</i>	2.0
<i>Psychotria mariniana</i>	15.7	<i>Scaevola gaudichaudiana</i>	2.0
<i>Antidesma platyphyllum</i>	11.8	<i>Syzygium sandwicense</i>	2.0
<i>Grevillea robusta</i> **	7.8	<i>Toona ciliata</i>	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

- o 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**
 - o Decrease in native shrubs, ferns, grass/sedge, and total native understory
 - o Increase in native and total canopy
- **Richness**
 - o Increase in native canopy richness
- **Frequency**
 - o Increased for non-native understory species:
 - *R. rosifolius* (2013 to 2016)
- **Species cover**
 - o Increased for non-native species:
 - *R. rosifolius* (2013 to 2016)
 - o 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.

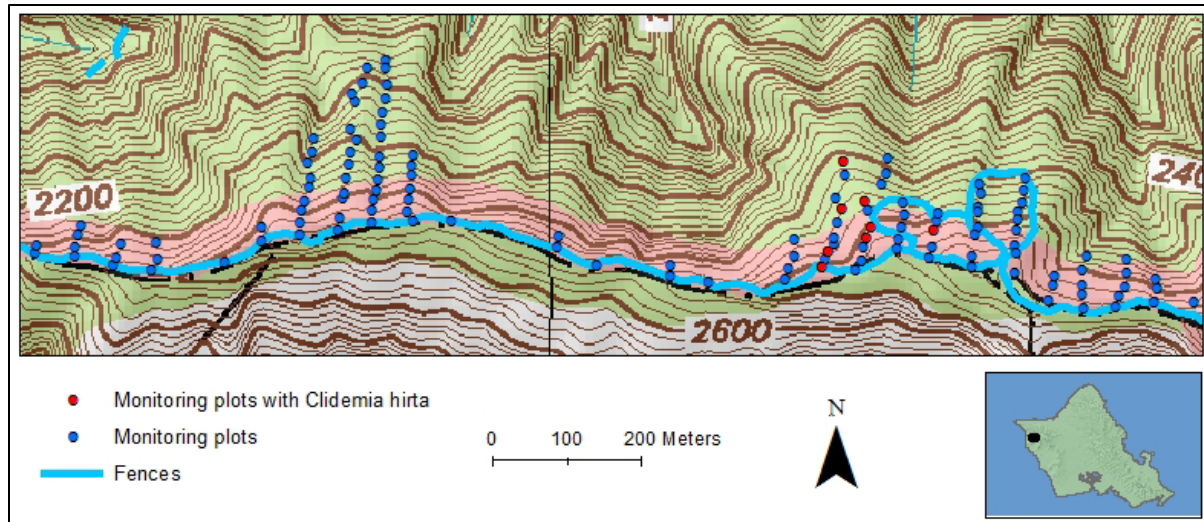


Figure 14. Locations of *Clidemia hirta* found during monitoring of Ohikilolo Upper MU in 2016.

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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