Spelling of Hawaiian Words

Hawaiian Words

English Spelling	Hawaiian Spelling
Amakihi	ʻAmakihi
Apapane	ʻApapane
Elepaio	ʻElepaio
Heiau	Heiau
Ii	ʻIʻi
Kahua	Kahua
Makai	Makai
Mauka	Mauka
Nui	Nui
Ohia	ʻŌhiʻa
Opeapea	ʻŌpeʻapeʻa

Hawaiian Place Names

Place Name	Hawaiian Spelling
Aiea	ʻAiea
Aihualama	ʻAihualama
Aimuu	ʻAimuʻu
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	Kaʻaikukui
Kaala	Kaʻala
Kaawa	Kaʻawa
Kaena	Kaʻena
Kahaluu	Kahaluʻu
Kahana	Kahana
Kahanahaiki	Kahanahāiki
Kaimuhole	Kaimuhole
Kaipapau	Kaipapaʻu*
Kaiwikoele	Kaiwikoʻele
Kalauao	Kalauao
Kaleleliki	Kaleleiki
Kalena	Kalena

Place Name	Hawaiian Spelling
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	Kawaihäpai
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	Kōloa*
Konahuanui	Kōnāhuanui

Place Name	Hawaiian Spelling
Koolau	Koʻolau
Kuaokala	Kuaokalā
Laie	Lāʻie
Lanai	Lānaʻi
Lanikai	Lanikai
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	Mokulēʻa
Molokai	Molokaʻi
Nanakuli	Nānākuli
Napepeiaoolelo	Nāpepeiaoʻōlelo*
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
Pokai Bay	Pōkaʻī Bay
Puaakanoa	Puaʻakanoa*
Pualii	Pualiʻi

Place Name	Hawaiian Spelling
Puhawai	Pūhāwai
Pukele	Pūkele
Pulee	Pūleʻe
Punapohaku	Punapōhaku
Puu Hapapa	Puʻu Hāpapa
Puu Kaaumakua	Puʻu Kaʻaumakua
Puu Kailio	Puʻu Kaʻīlio
Puu Kanehoa	Puʻu Kānehoa
Puu Kaua	Puʻu Kaua
Puu Kawiwi	Puʻu Kawiwi
Puu Kumakalii	Puʻu Kūmakaliʻi
Puu Keahiakahoe	Puʻu Keahiakahoe
Puu Pane	Puʻu Pane
Puukainapuaa	Puʻu Kaʻinapuaʻa
Puulu	Pūʻulu
Puuokona	Puʻu o Kona
Puu Pane	Puʻu Pane
Waahila	Waʻahila
Wahiawa	Wahiawā
Waialae Nui	Waiʻalae Nui
Waialua	Waialua
Waianae Kai	Waiʻanae Kai
Waiawa	Waiawa
Waieli	Waiʻeli
Waihee	Waiheʻe
Waikane	Waikāne
Wailupe	Wailupe
Waimalu	Waimalu
Waimano	Waimano
Waimea	Waimea
Wiliwilinui	Wiliwilinui

**Diacritical marks uncertain*

REFERENCES

Hawaii Natural Heritage Program (2001). *Welch's Hawaiian Land Snail Distribution Map*, based on the following papers:

> Welch, d'A. 1938. Distribution and variation of the Hawaiian tree snail *Achatinella mustelina* Mighels in the Waiane Mountain, Oahu. *Bernice P. Bishop Museum Bulletin.* 152: 1-164.
>
> Welch, d'A. 1942. Distribution and variation of the Hawaiian tree snail *Achatinella apexfulva* Dixon in the Koolau Range, Oahu. *Smithsonian Miscellaneous Collection.* 103(1): 1-236.

Ulukau, The Hawaiian Electronic Library. (n.d.). *Hawaiian Dictionaries* www.wehewehe.org

U.S. Geological Survey. (n.d.). *TopoView* for the island of Oahu https://ngmdb.usgs.gov/topoview/viewer/#10/21.4857/-158.0001

Tutorial: Operating the ANRPO Database

Overview

The Army Natural Resources Program Database on Oahu (ANRPO 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 2007-2019 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 ANRPO 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 20 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 ANRPO 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, 2022.

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 Army Natural Resources Program on Oahu.

Questions may be directed to:

Roy Kam
Natural Resources Database Programmer Specialist
Army Natural Resources Program on Oahu
Email: rkam@hawaii.edu

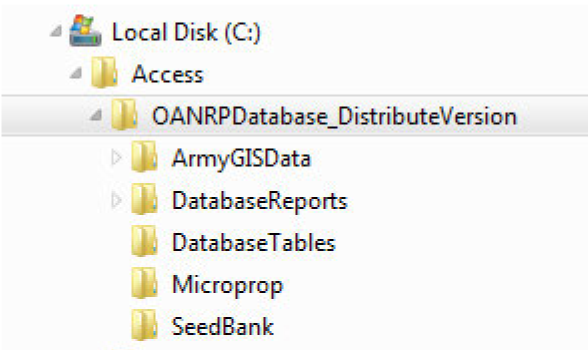
Linda Koch
Natural Resources GIS Specialist
Army Natural Resources Program on Oahu
Email: lkoch@hawaii.edu

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

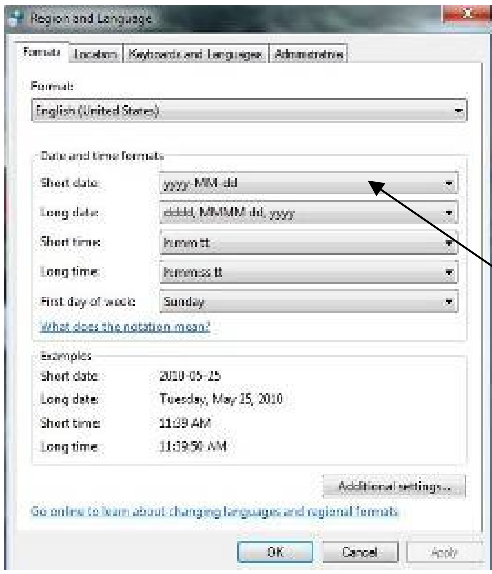
> Army SeedLab Database data. Contact Tim Chambers for more information.

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.



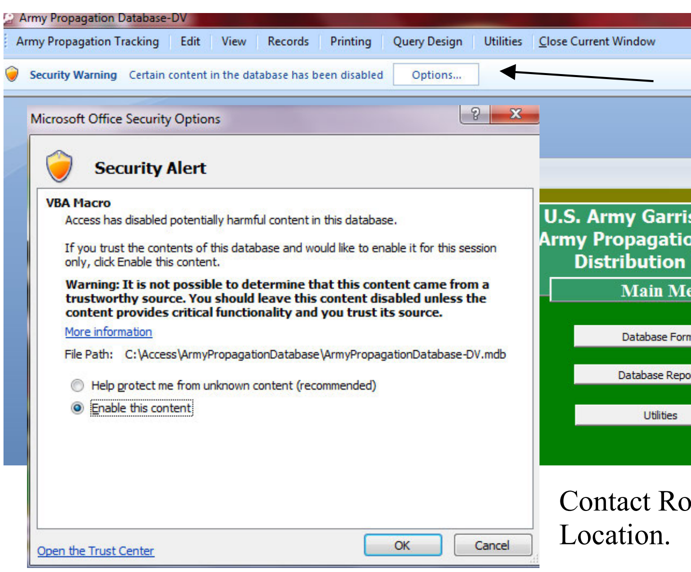
- Open Regional and Language Options by RIGHT clicking the **Start** button, clicking **Control Panel**, clicking **Clock, Language, and Region**, and then clicking **Region.** Under the Formats, change the **Short Date** to **yyyy-MM-dd.**

Change to yyyy-MM-dd

Security Warning

Security features in Microsoft Access 2007, 2010, 2013, 2016, 2019 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 2007-2019 database content must be enabled when the Security Warning appears.



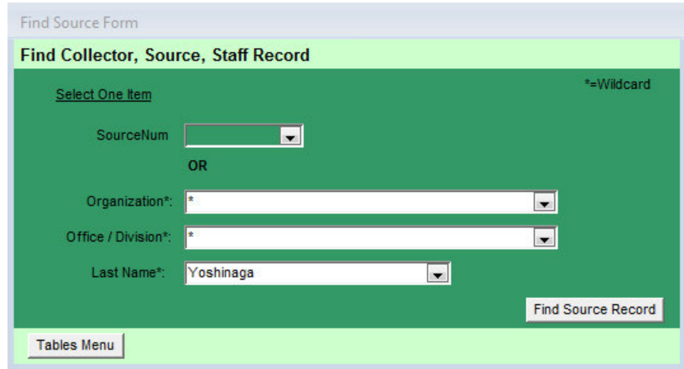
After opening the OANRPDatabase_DV.accdb file in Microsoft Access, click on Options when it appears at the top of your screen.

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.

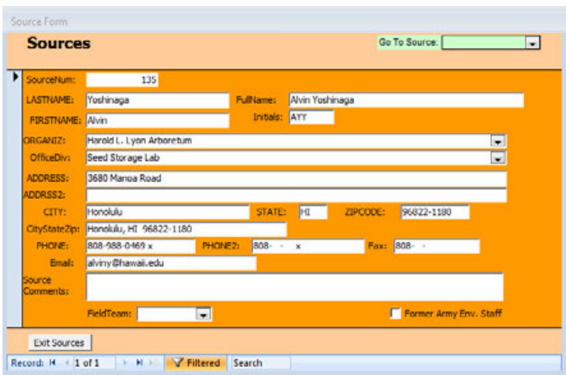
Enabling content will have to be done every time the database file is opened. You may avoid having this Security Warning appear if the Access subdirectory is added to the Trust Center Locations. Contact Roy Kam if you need to establish a Trust Center Location.

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.

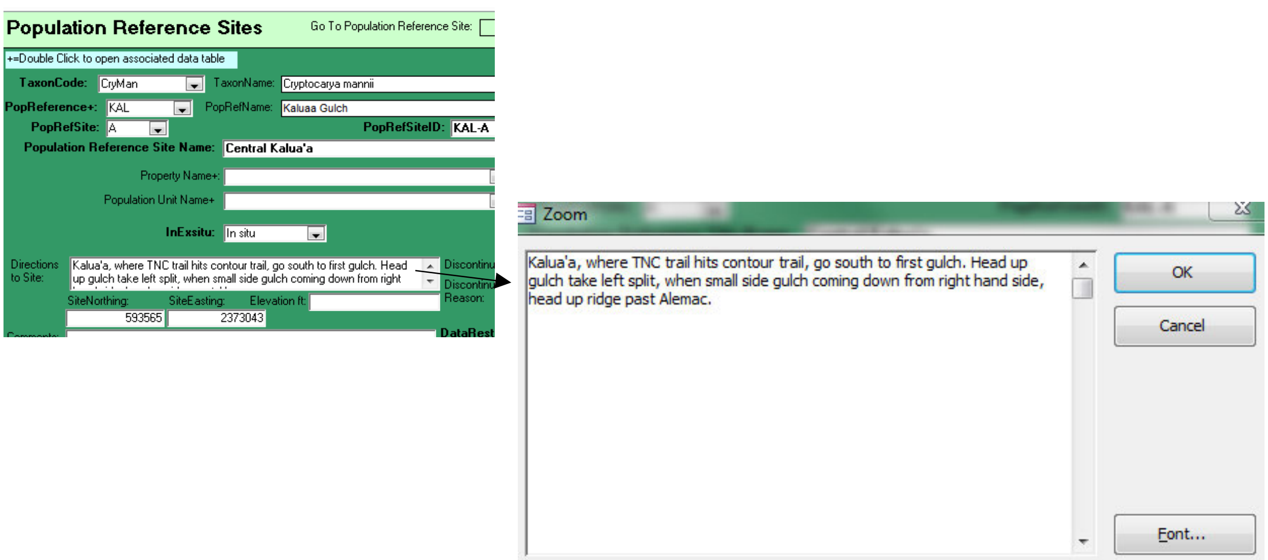


Using the * (asterisk), in a Find Form represents a wild card. Such as Organization *= Search for all Sources with any Organization. In this case, we will just search for the Last Name = Yoshinaga.



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.

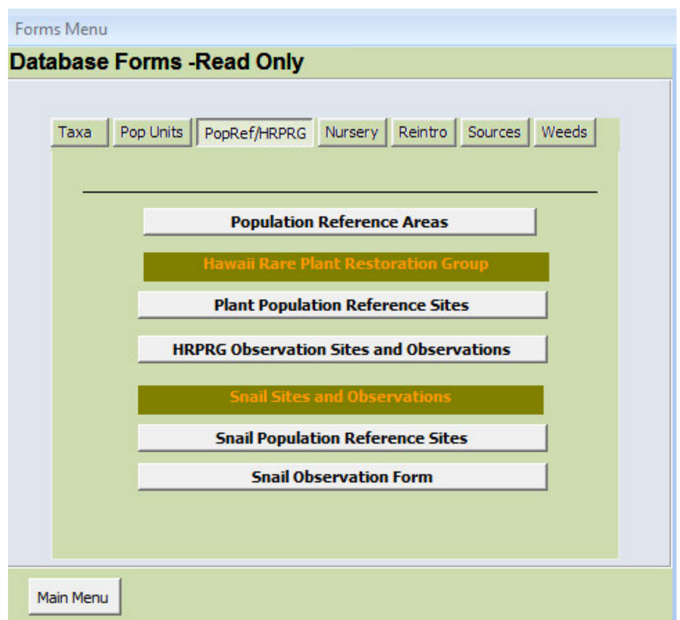
The database is broken up into 2 parts, Database Forms and Database Reports. We will primarily cover the Database reports. Database Forms are self-explanatory and is only for viewing purposes. The forms are provided for detailed review of individual observations. Only pertinent data fields will be discussed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

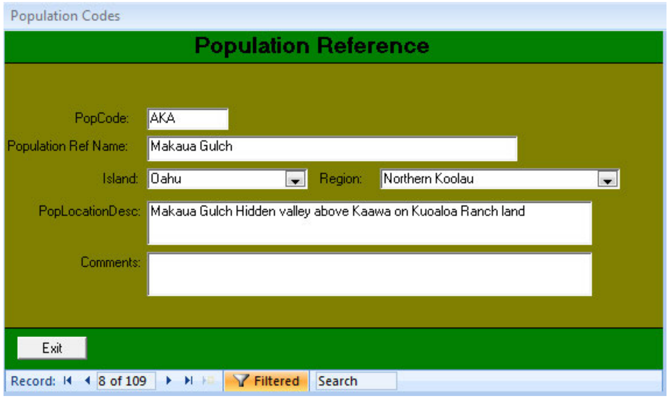
For the purpose of this tutorial, we will discuss forms of the PopRef/HRPRG tab with comprise of the Population Reference and Population Reference Sites. All other sections are supplemental and self-explanatory.



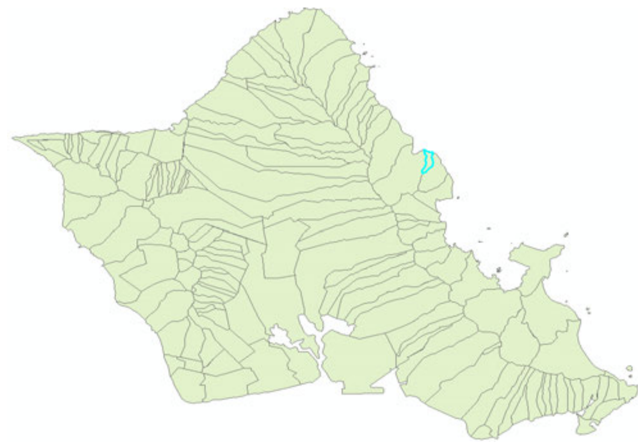
PopRef, Sites, and Observations

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.

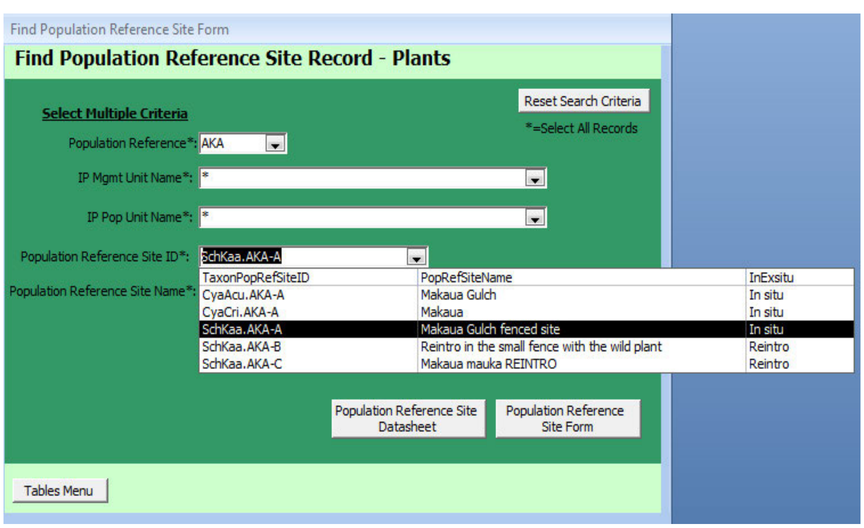


It should be noted that the Population Reference is not necessarily the name for any given population. It is only used as an identifier to compile different plant or animal populations within a given area. For example: Makaua on the Windward Koolau of Oahu (highlighted in blue). The GIS boundary is based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

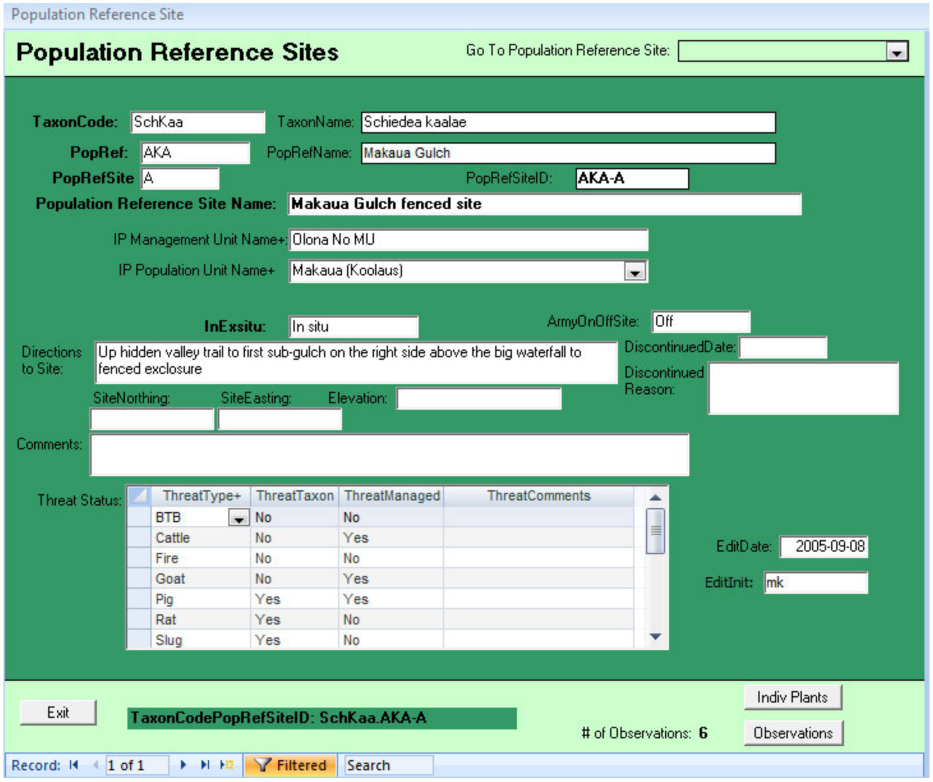
The Population Reference Site (PopRefSite) is the primary data table in establishing plant or animal population sites. The PopRefSite identifies the Population Name, whether it is In situ, Ex situ or Reintro, and provides directions to the site, etc. The PopRefSite is only site information; observation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



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.

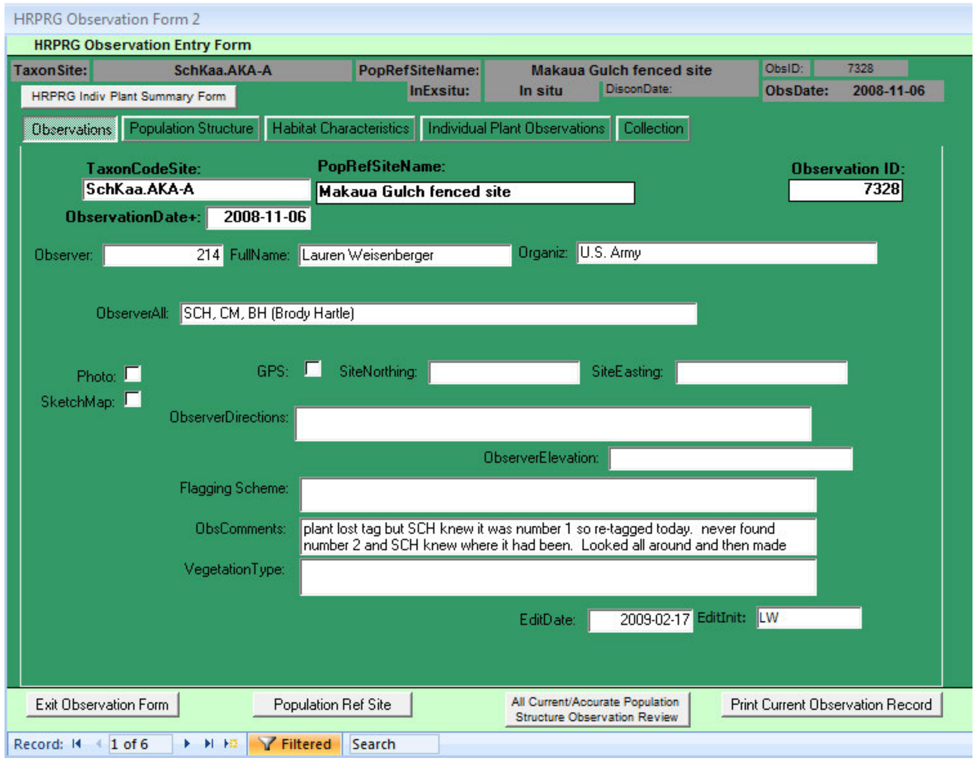
IP Population Unit Name (PopUnit): The PopUnit is used when several PopRefSites need to be tracked together. Such as a taxon with several sites throughout the Northern Waianae Mountains, Northern Waianae could be used as a PopUnit Name.

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

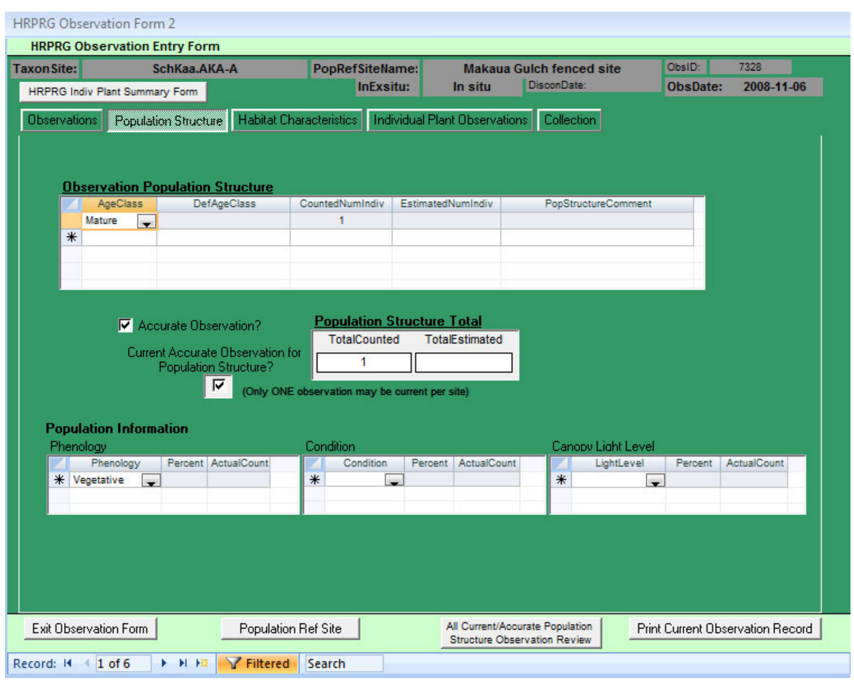


Clicking the Observations button on the bottom of the PopRefSite Form will open up the corresponding Observations.

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



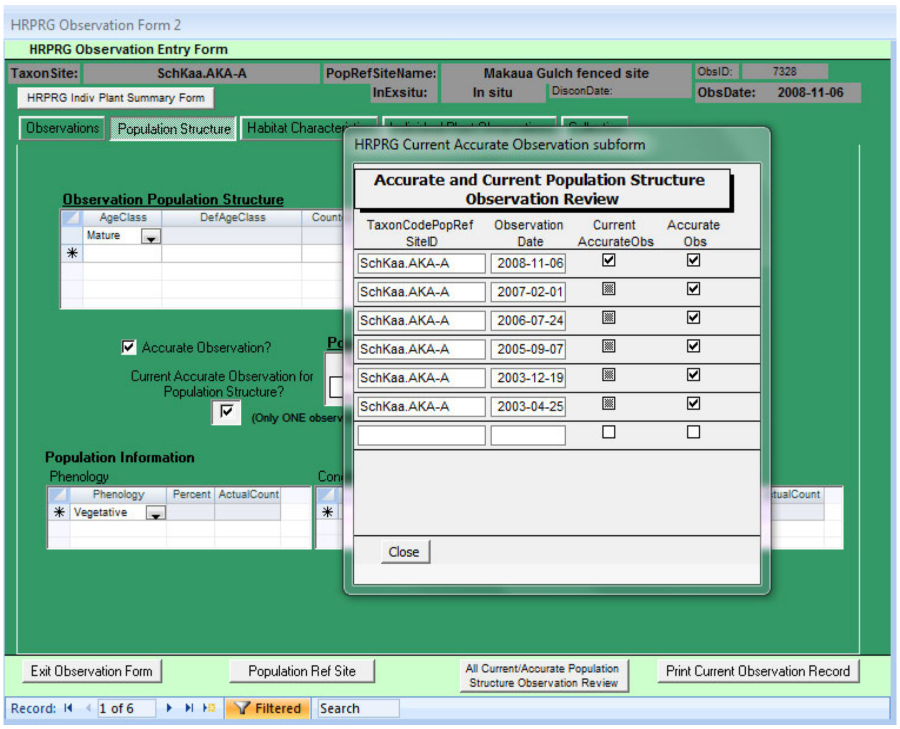
The Population Structure should are always entered for any observations, even if the number of plants observed are incomplete (not all plants observed).

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.

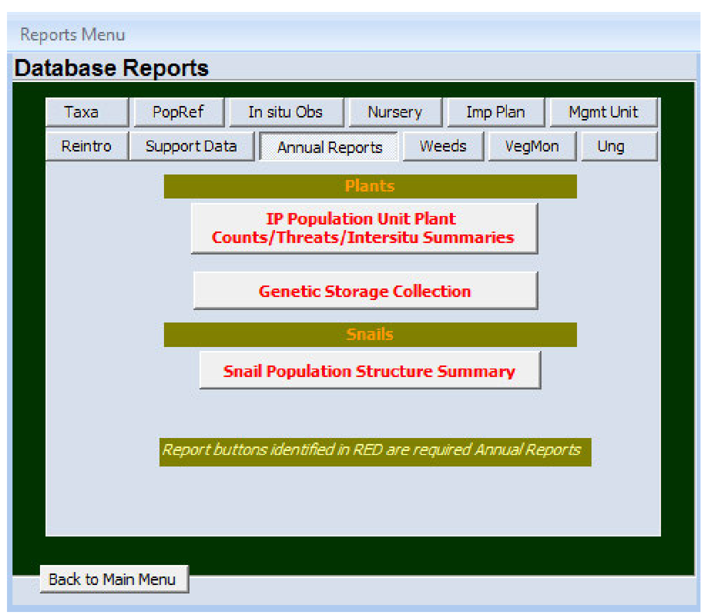
IV. Database Reports

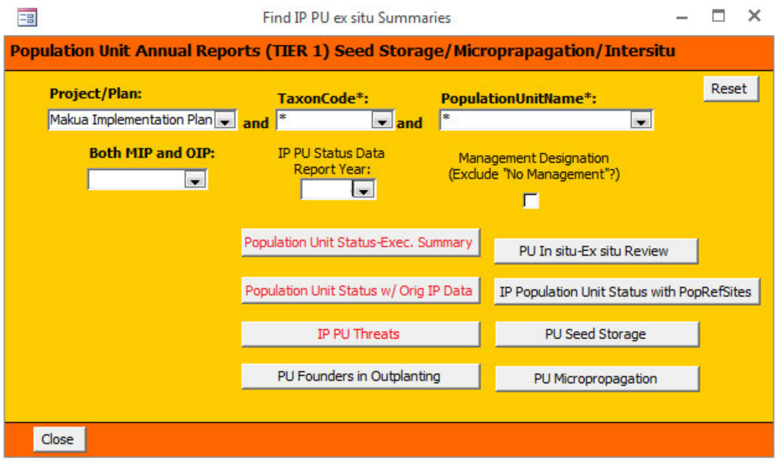
Starting from the Main Menu, click on the Database Reports button. The Database Reports menu provides reports for various sections of the database.

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 2021. Report Year is defined below under Total Mature, Immature and Seedling (Year).

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

= 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 ANRPO 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 ANRPO 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 ANRPO 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

= 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 ANRPO 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 ANRPO 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 ANRPO 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

= Threat to Taxon at Population Reference Site

No Shading = Absence of threat to Taxon at Population Reference Site

Yes=Threat is being controlled at PopRefSite

No=Threat is not being controlled at PopRefSite

Partial=Threat is being partially controlled at PopRefSite

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

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

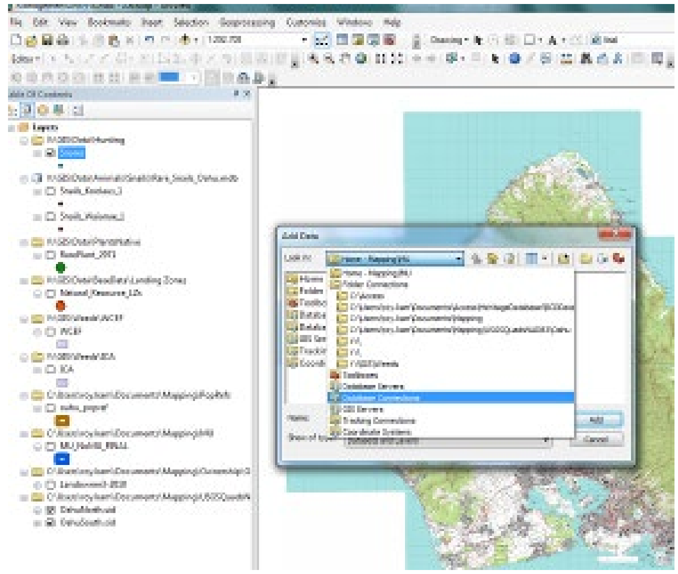
Population Reference Site: The first column lists the population reference code for each field site. This consists of a three-letter abbreviation for the gulch or area name. For example, MMR stands for Makua Military Reservation. Next, a letter code is applied in alphabetic order according to the order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

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

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

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

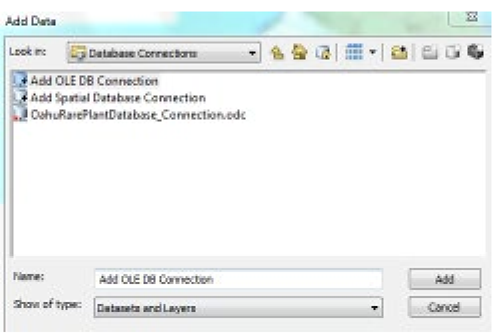
Linking Access Database Query into ArcGIS –Distribution Database Version



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

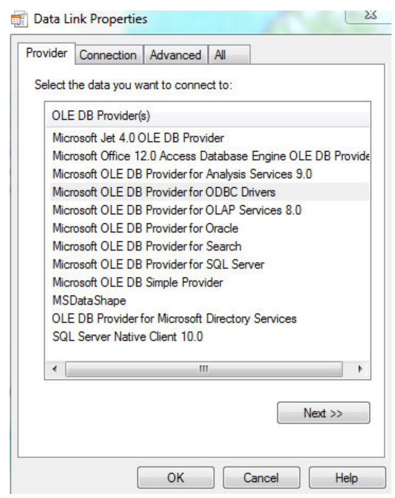
In your ArcGIS Project, make sure you have the Rare Plants or Rare Snails shapefile (or whatever shapefile you are linking) as one of your layers.

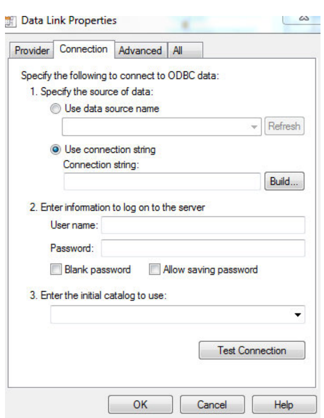
Click on the Add Button , and choose *Database Connections*. If you do not have Database Connections listed (versions ArcGIS 10.3 and up), you will need to add it before you start. Go to ArcCatalog>Customize (Tab)>Customize Mode>Under the Commands Tab, select ArcCatalog (left column) and on the right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



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

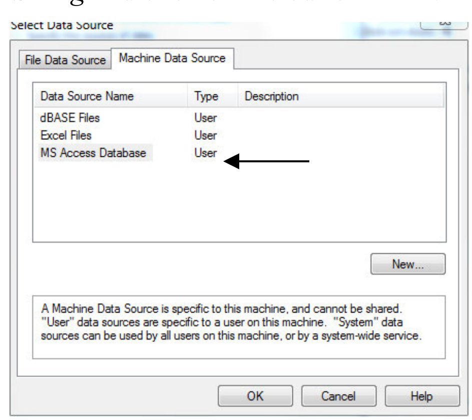
A Data Link Properties window will appear. Select *Microsoft OLE DB Provider for ODBC Drivers*.

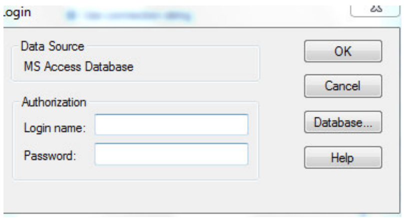




Then in the Data Link Properties window, select the *Connection tab*. Under the Connection Tab, select *Use Connection String* and click on the button *Build*.

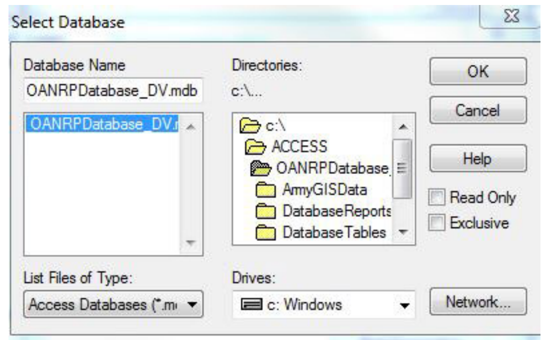
In the Select Data Source window, select the *Machine Data Source* tab, and select *MS Access Database then* click *OK*.





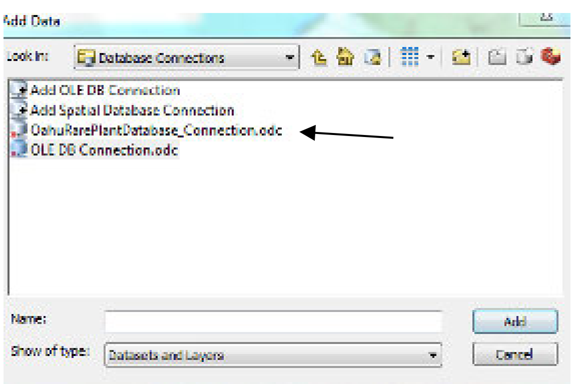
In the Login Window, Click on the *Database* button (leave Login Name and Password blank).

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

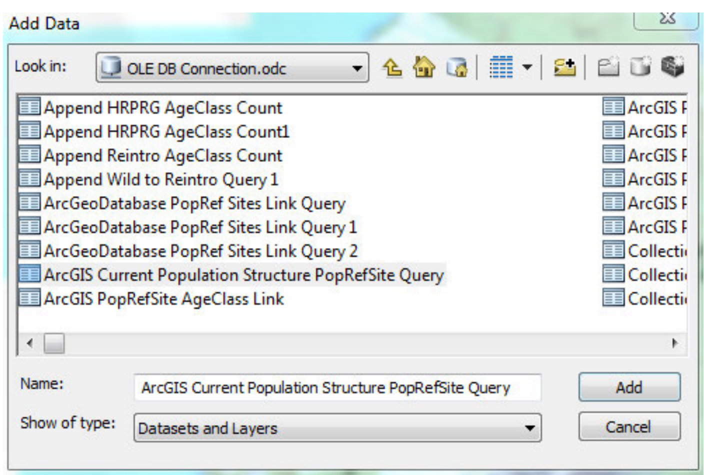


C:\Access\OANRPDatabase_DistributeVersion\ OANRPDatabase_DV.accdb

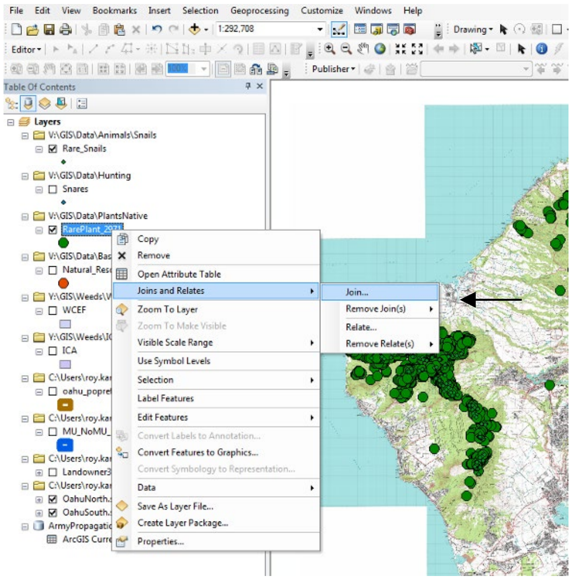
Click Ok to close the windows, until you are back at the Add Data window. You will now see a new OLE DB Connection.odc listed.



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

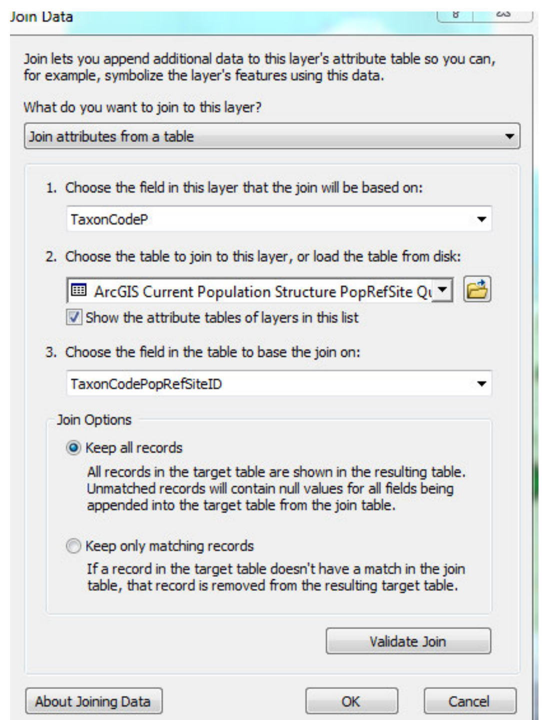


Browse through the list until you find *ArcGIS Current Population Structure PopRefSite Query*. This query in the Access Database lists all of the Rare Plants and Rare Snails with their current Population Structure and whether the site is In situ or Ex situ. Click Add. The query will now appear as a Layer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



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

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



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

← Rare Plants GIS Shapefile table data → Access Database data

RarePlants

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

→ Access Database data joined query →

RarePlants

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

Appendix ES-3: ANRPO Organization Chart, 2021-2022 Report Year

Includes all staff employed during the report year by their most recent position/job title.

OFFICE OF THE VICE PRESIDENT FOR RESEARCH AND INNOVATION

Vice President for Research & Innovation	Vassilis Syrmos
Administrative Officer	Tracie Nakagawa
VPRI Admin Officer	Melissa Arakawa

PROGRAM MANAGER

NATURAL RESOURCE FIELD PROGRAM

NRM Field/Operations Manager	Jobriath Rohrer
NR Field Supervisor	Kaia Kong
NR Field Team Leader	Wesley Shinsato
NRM Technician II	Cameron Young
NRM Technician I	Jenna Patague
NRM Technician I	Chayote Tomdasa
NRM Technician I	Samantha Shizuru
NRM Technician I	Alanna Miyashiro
NRM Technician I	Kauila Tengan
NR Field Supervisor	Chelsea Tamayo
NR Field Team Leader	Kupono Matsuoka
NRM Technician II	Nolan Caballero
NRM Technician II	Wesley Piena
NRM Technician I	Tazman Shim
NRM Technician I	Sara Van Gent
NRM Technician I	Andrew Gibbons
NRM Technician I	*vacant*
NR Field Supervisor	David Hoppe-Cruz
NR Field Team Leader	Keith Adams
NRM Technician II	Brenna Keefe
NRM Technician II	Katherine Cole
NRM Technician I	Aaron Pila
NRM Technician I	Krista Lizardi
NRM Technician I	Matthew Mancuso
NRM Technician I	*vacant*
VR Field Supervisor	Michael Bohling
VR Technician III	Ryan Colle
VR Technician I	Madison Daniel
VR Technician I	Nicole Gemmell
VR Technician I	Thomas McClain
VR Technician I	Nathaniel Garrett
VR Technician I	Mckenzie Brown
VR Technician I	Nada McClellan
Outreach/Volunteer Program Specialist	Kimberly Welch
Safety and Logistics Associate	George Schneller

ADMINISTRATIVE OPTERATIONS

Administrative Associate	Lillian Ostrander
Administrative Associate	Rachel Zinberg

PEST CONTROL PROGRAM

Pest Control Program Technician I	Glacel Lopez

Student Hires	Tressa Hoppe Liat Portner Nikki Preston Storey Welch
Americorps Intern/ Temp Hire	Jocelyn Dunn
Temp Hires	Francis Joy
Intermittent Hires	Daniel Tanji Chad Koide Daniel Adamski Jason Preble
Summer Interns 2022 & 2021	Kai Binney Makoa De Almeida Madelyne Harding Manowai Kobashigawa Brandon Najarian Mark Duffield Hoohila Kawelo Julia Kossakowski Glenn Meador Kalai Sim

NATURAL RESOURCE CONSERVATION PROGRAM

Natural Resource Conservation Manager	Jane Beachy
Animal Program Coordinator	Tyler Bogardus
Rare Snail Conservation Biologist	Deena Gary
Rare Insect Biologist	Karl Magnacca
Rare Insect Biologist	Tommy Russell
Rare Vertebrate Conservation Specialist	Philip Taylor
Invertebrate & Forest Invasive Species Biologist	Stephanie Joe
Small Vertebrate Pest Biologist	Troy Levinson
Conservation/Control Program Supervisor	Matthew Burt
Ungulate Biologist	Michael Gray
Cons/Control Technician	Jonah Dedrick
Rare Plant Program Coordinator	Tim Chambers
Propagule Conservation Program Biologist	Makanani Akiona
Propagule Conservation Technician	Elizabeth Conlon
Horticulture Supervisor	Chris Wong
Horticulture Technician III	Rebecca Geelhood
Horticulture Technician II	John Hintze
Horticulture Technician I	Santiago Flores
Vegetation Management Program Coordinator	Melissa Valdez
Native Plant Restoration Biologist	Chris Lum
Invasive Plant Biologist	Petelo Maosi
Monitoring Program Biologist	Michelle Akamine
Information Technology Systems Coordinator	Roy Kam
GIS Analyst and Programmer	Linda Koch
Biocontrol Research Technician	Rosalie Nelson
Biocontrol Research Technician	Sean Kirkpatrick

2022 SPECIES AT RISK ANALYSIS

Background

Identifying species on the trajectory for Federal listing under the Endangered Species Act is essential to maintaining Army readiness. These species are called 'Species at Risk' or 'SARs'. It is important for the Army to understand the presence, distribution and extent of SARs and incorporate natural resource management to benefit these taxa into the Integrated Natural Resources Management Plan (INRMP). Understanding the presence of SARs on installations also aids in anticipating how the Army, through implementation of beneficial management actions, can aid in precluding the need for these species to undergo federal listing.

The company NatureServe was contracted by the Department of Defense Legacy Program to identify which taxa qualify as SARs (Legacy Project 14-772, Feb 2015). NatureServe assigns global rankings to each taxon based on available distribution and occurrence data available. These global rankings can be found by searching by a taxon's full scientific name at http://explorer.natureserve.org/
Taxa that are not yet federally listed under the Endangered Species Act and are categorized as critically imperiled (G1/T1 or G2/T2) or are birds that are regarded as vulnerable (G3) or have an International Union for the Conservation of Nature (IUCN) status of Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Near Threatened (NT) are considered SARs.

Plants and Non-bird animals	• Not federally listed as endangered. AND • Categorized by Nature Serve as G1/T1 or G2/T2 AND/OR • Union for the Conservation of Nature (IUCN) status of Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Near Threatened (NT)
Birds	• Not federally listed as endangered. AND • Categorized by Nature Serve as G1, G2 or G3 AND/OR • Union for the Conservation of Nature (IUCN) status of Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Near Threatened (NT)

In 2021, the Army's Natural Resource Program at Pohakuloa conducted an analysis of plants and animals which qualify as Species at Risk (SARs). In 2022, the Army's Natural Resource Program on Oahu conducted a SAR analysis for taxa known from Army lands on Oahu. While, in general, the NatureServe global rankings for plants and birds are well updated, Hawaiian insects and snails are poorly addressed and very few taxa have been assigned a global ranking. This is likely a result of the lack of biological information available for these lesser studied groups. In order to complement the NatureServe database rankings, this analysis utilized other available resources to identify potential SARs for Oahu Army lands. These additional resources include Bishop Museum records, the State of Hawaii Department of Land and Natural Resources wildlife fact sheets (http://dlnr.hawaii.gov/wildlife/hswap/fact-sheets/), and expert opinions on taxa occurrence, distribution, and status . Results of this SAR analysis will be folded into the Army's INRMP revision along with further prioritization and management planning. The Army anticipates a full revision to the Oahu INRMP will be conducted in the 2023 calendar year.

Plants

To begin, Natural Resource Staff created a native plant species list for Army lands (see Appendix ES-X). Species presence information was pulled from the Army's rare plant tracking and vegetation monitoring databases. In addition, these lists were cross-checked with all available species lists from historical surveys conducted by the Hawaii Natural Heritage Program (now Hawaii Biodiversity and Mapping Program, HBMP) in the 1990s. Natural Heritage Program data is the primary source utilized by NatureServe to populate its database and assign rankings nationwide. Each native plant taxa found on Army lands was searched in the NatureServe explorer and the global ranking assigned was associated with that taxa. A spreadsheet was created which tracked each taxa, its federal status, NatureServe global ranking, IUCN ranking, distribution information, and notes. Taxa with federal status were filtered out of this spreadsheet and the remaining taxa were sorted for G1/T1 and/or G2/T2 ranks. This resulting list provided the plant SARs found on Army training lands. This spreadsheet also identifies the training areas where each taxon occurs, so that SAR lists per training area could be generated.

In summary, this analysis identified 97 plant SARs known on Oahu Army training lands. Thirteen are ranked G1 or T1 and two are ranked CR by the IUCN. By training range, there are 44 SAR plants found at Makua Military Reservation (MMR), 50 at Schofield Barracks West Range in the Waianae Mountains (SBW), 35 from Schofield Barracks East Range in the Koolau Mountains (SBE), 52 from the Kawailoa Training Area (KLOA), 5 from Dillingham Military Reservation (DMR), and 29 fromat Kahuku Training Area (KTA). Of these, IUCN ranks two taxa as CE, 13 as EN, 21 as VU and 5 as NT. The complete plant SAR list for Oahu is included in Table 1. Ten of these SARs are Oahu endemic taxa and six are single mountain range endemics.

Birds

For the SARS bird analysis, a complete species list of birds observed at Oahu Army Training Areas was generated. This list was populated with NatureServe and IUCN status. Those bird taxa that are not listed under the Endangered Species Act but are categorized as critically imperiled (G1/T1 or G2/T2) or are regarded as vulnerable (G3) or have an IUCN status of CR, EN, VU or NT are considered SARs. There are four birds that meet SAR criteria from Army lands on Oahu (Table 2); these are the Laysan Albatross, the Hawaiian Short-Eared Owl (Pueo), the Apapane and the Oahu Amakihi.

Invertebrates

For insects and snails, the only information available from NatureServe is for taxa that are federally listed. It appears that the listing packages for those taxa are used to draw information to support the NatureServe global ranking determination. It was also difficult to generate a comprehensive species list for insects and snails due to the high level of specialization amongst entomologists and difficulty in identifying these lesser known taxa, with certainty. In lieu of NatureServe information, the Army utilized species experts to make a first cut at SAR lists for these groups.

<u>Insects</u>

The Army Natural Resource Program's Entomologist, Dr. Karl Magnacca, generated a species list from all available resources including the Program's photodatabase. He then identified the taxa which he would consider SARs based on the following factors: low numbers, narrow distribution, narrow endemism, and population trends, if available. There is certainly some bias in the SAR determinations based on his expertise and familiarity with two particular groups of insects, *Drosophila* and *Sierola*. The insect spreadsheet identifies taxa observed by Army installation and is included in Table 3.

Snails

Similar limitations arose with the snail SAR analysis. We were unable to obtain a species list for native snails from Army lands, but were able to obtain a list of taxa considered SARs that have been observed on or near Army land from the Bishop Museum Malacology Department. This list is provided exactly as received from the Bishop Museum Malacology Department, see Table 4 . This list is lacking geo-locational information for now, but once received, the SAR analysis for snails will be updated by training area.

Table 1: ***PLANT Species at Risk (SARs)***

TaxonName	CommonName	Distribution	Nature Serve Rank	IUCN	MMR	SBW	SBE	KLOA	DMR	KTA
Adenophorus hymenophylloides		Endemic	G2			X	X	X		X
Adenophorus oahuensis		Endemic	G2				X	X		
Alphitonia ponderosa	Kauila	Endemic	G2	VU	X					
Anoectochilus sandvicensis			G3	VU						
Antidesma platyphyllum	Hame	Endemic		VU	X	X	X	X		X
Antidesma pulvinatum	Hame	Endemic	G2		X	X		X		
Arachniodes insularis		Endemic	G2					X		
Argemone glauca	Pua kala	Endemic	G2		X					
Asplenium kaulfussii	Kūau	Endemic	G2		X					
Bidens asymmetrica	Koʻokoʻolau	Endemic	G2				X			
Bidens cervicata	Koʻokoʻolau	Endemic	G2		X					
Bidens macrocarpa	Koʻokoʻolau	Endemic	G2				X	X		X
Bidens torta	Koʻokoʻolau	Endemic	G2		X	X			X	X
Bobea brevipes	ʻAkupa	Endemic	G2	EN	X	X		X		
Bobea elatior	ʻAhakea lau nui	Endemic		VU	X	X	X	X		X
Bobea sandwicensis	ʻAhakea	Endemic	G1	VU	X					
Bobea timonioides	ʻAhakea	Endemic	G1	EN				X		X
Capparis sandwichiana	Maiapilo	Endemic	G2	VU	X					
Charpentiera tomentosa	Pāpala	Endemic	G2		X	X		X		
Cheirodendron platyphyllum	Lapalapa	Endemic	G2			X	X	X		X
Cheirodendron trigynum	ʻŌlapa	Endemic		VU		X	X	X		
Clermontia oblongifolia	ʻŌhāwai	Endemic	G3	VU			X	X		
Clermontia persicifolia	ʻŌhāwai	Endemic	G2	LR/NT			X	X		
Coprosma foliosa	Pilo, hupilo	Endemic		VU	X	X		X		
Cyanea angustifolia	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	G2			X		X		
Cyanea membranacea	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	G2	CR		X				
Cyrtandra kalihii (kalichii in manual)	Haʻiwale, kanawao keʻokeʻo	Endemic	G2				X	X		
Dichanthelium cynodon		Endemic	G2					X		

TaxonName	CommonName	Distribution	Nature Serve Rank	IUCN	MMR	SBW	SBE	KLOA	DMR	KTA
Dichanthelium hillebrandianum		Endemic	G2					X		
Dichanthelium koolauense		Endemic	G2				X	X		
Diospyros hillebrandii	Lama	Endemic	G2	EN	X	X				X
Diospyros sandwicensis	Lama	Indigenous		VU	X	X	X	X		X
Dissochondrus biflorus		Endemic	G2			X				
Doodia lyonii	Lyon's hacksaw fern	Endemic	G1				X	X		
Dracaena halapepe	Halapepe	Endemic	G2	VU		X		X		X
Dryopteris mauiensis		Endemic	G2			X				
Dubautia sherffiana	Na‘ena‘e, hanupaoa, hina‘aikamalama, ne‘ine‘i	Endemic	G1		X	X				
Elaphoglossum pellucidum	Hoe-a-Māui	Endemic	G2				X	X		X
Erythrina sandwicensis	Wiliwili	Endemic	G2	VU	X				X	
Euphorbia clusiifolia	‘Akoko	Endemic	G3	EN			X	X		
Eurya sandwicensis	Ānini	Endemic	G2	VU		X		X		
Exocarpos gaudichaudii	Heau	Endemic	G1	EN			X	X		
Gahnia aspera subsp. globosa		Indigenous	G2		X					X
Geniostoma hosakanum	Kāmakahala	Endemic	G1	CR			X	X		
Geniostoma hymenopodum	Kāmakahala	Endemic	G2				X	X		
Geniostoma kaalae	Kāmakahala	Endemic	G1		X	X				
Gunnera petaloidea	‘Ape‘ape	Endemic	G2			X				
Gynochthodes trimera	Noni kuahiwi	Endemic	G2	LR/NT	X	X				
Hibiscus arnottianus subsp. arnottianus	Koki‘o ke‘oke‘o, pāmakani	Endemic	G4	EN	X	X	X	X		
Hibiscus kokio subsp. kokio	Koki‘o ‘ula‘ula, koki‘o, koki‘o ‘ula	Endemic	T1					X	X	
Kadua fosbergii	Manono	Endemic	G2				X	X		
Lindsaea repens var. macraeana		Endemic	T2					X		
Lobelia gaudichaudii		Endemic	G1				X	X		

TaxonName	CommonName	Distribution	Nature Serve Rank	IUCN	MMR	SBW	SBE	KLOA	DMR	KTA
Lobelia yuccoides	Pānaunau	Endemic	G2			X				
Lysimachia hillebrandii	Kolokolo kuahiwi, kolekole lehua, puahekili	Endemic	G1		X	X				
Melicope cinerea	Alani	Endemic	G1	EN		X				
Melicope elliptica	Alani	Endemic	G1		X	X				
Melicope hosakae	Alani	Endemic	G2				X	X		
Melicope kaalaensis	Alani	Endemic	G1	VU	X	X				
Melicope sandwicensis	Alani	Endemic	G2	EN	X	X	X	X		X
Melicope spathulata	Pilo kea	Endemic	G2			X	X	X		X
Melicope wawraeana	Alani	Endemic	G2	VU				X		
Metrosideros macropus	ʻŌhiʻa lehua	Endemic	G2				X	X		X
Metrosideros rugosa	ʻŌhiʻa lehua	Endemic	G2	EN			X	X		X
Metrosideros tremuloides	Lehua ʻāhihi, ʻāhihi, ʻāhihi lehua, ʻāhihi kū ma kua	Endemic		EN	X	X	X	X		
Myrsine degeneri	Kōlea	Endemic	G3	VU			X	X		
Neraudia melastomifolia	Maʻaloa, Maʻoloa, ʻOloa	Endemic	G2	VU	X	X				
Nestegis sandwicensis	Olopua	Endemic		VU	X	X		X		X
Nothocestrum longifolium	ʻAiea	Endemic	G2	LR/NT		X				
Ochrosia compta	Hōlei	Endemic	G2		X	X				X
Panicum beecheyi		Endemic	G2		X	X				
Pittosporum flocculosum	Hōʻawa, hāʻawa	Endemic	G2		X					X
Polyscias kavaiensis	ʻOheʻohe	Endemic	G2			X				
Polyscias sandwicensis	ʻOhe, ʻohe kukuluaeʻo, ʻoheokai, ʻohemakai	Endemic	G2	LR/NT	X				X	
Pritchardia bakeri	Loulu	Endemic	not rate	CR						X

TaxonName	CommonName	Distribution	Nature Serve Rank	IUCN	MMR	SBW	SBE	KLOA	DMR	KTA
Pritchardia martii	Loulu	Endemic	G2	EN			X	X		X
Psychotria fauriei	Kōpiko, ʻōpiko	Endemic	G2	EN			X	X		X
Psychotria kaduana	Kōpiko, ʻōpiko	Endemic	G2				X	X		
Rumex albescens	Huʻahuʻakō	Endemic	G2		X	X				
Santalum ellipticum	ʻIliahialoʻe, ʻiliahi, ʻaoa	Endemic	G2		X					
Santalum freycinetianum var. freycinetianum	ʻIliahi, ʻaoa	Endemic		EN	X	X		X		X
Sapindus oahuensis	Lonomea, āulu, kaulu	Endemic	G2	VU	X	X	X	X	X	X
Scaevola gaudichaudii	Naupaka kuahiwi, Ridgetop Naupaka	Endemic	G2		X					
Scaevola glabra	ʻOhe naupaka	Endemic	G2				X	X		X
Scaevola mollis	Naupaka kuahiwi	Endemic	G2			X	X	X		X
Schiedea ligustrina		Endemic	G2		X	X				
Schiedea mannii		Endemic	G2	VU	X	X				
Schiedea pentandra (pubescens var. purpurescens)		Endemic	G2			X				
Sideroxylon polynesicum	Keahi	Indigenous	G2	VU	X					X
Stenogyne kaalae subsp. kaalae		Endemic	G2		X	X		X		
Strongylodon ruber	Nuku ʻiʻiwi	Endemic	G2		X	X				
Viola chamissoniana subsp.	Pāmakani	Endemic	G2		X	X				
Viola kauaensis var. hosakae		Endemic	G2					X		
Wikstroemia uva-ursi var. uva-ursi	ʻĀkia, kauhi	Endemic	G2							X
Wollastonia tenuis	Nehe	Endemic	G2			X				
Zanthoxylum dipetalum var. dipetalum	Kāwaʻu, heaʻe	Endemic	G2			X				X
Zanthoxylum kauaense	Heaʻe, aʻe, Oʻahu prickly ash	Endemic	G2	LR/NT	X	X				

Table 2: ***BIRD Species at Risk (SARs)***

TaxonName	CommonName	Distribution	DMR	KTA	KLOA	MMR	SB	Oahu Endemic Y/N	Federal Status	NatureServe Ranking	IUCN	Proposed/ Candidate for Fed listing Y/N
Asio flammeus sandwichensis	Short-eared owl or Pueo	Endemic	–	–	–	Y	Y	N	N	T2	LC	N
Chlorodrepanis flava	Oahu Amakihi	Endemic	–	–	Y	Y	Y	Y	N	G3	VU	N
Himatione sanguinea	Apapane	Endemic	–	–	Y	Y	Y	N	N	G3	LC	N
Phoebastria immutabilis	Laysan Albatross	Indigenous	Y	–	–	–	–	N	N	G3	NT	N

Table 3: ***INSECT Species at Risk (SARs)***

TaxonName	Native	Status	Nature Serve Rank	IUCN	SBW	KLOA	SBE	MMR	KTA	SBS
Drosophila ambochila	endemic	SAR	None	None	x					x
Drosophila arcuata	endemic	SAR	None	None	x	x				x
Drosophila craddockae	endemic	SAR	None	None		x			x	
Drosophila deltaneuron	endemic	SAR	None	None	x	x				
Drosophila divaricata	endemic	SAR	None	None						x
Drosophila hexachaetae	endemic	SAR	None	None	x			x		
Drosophila neogrimshawi	endemic	SAR	None	None	x					
Drosophila nigribasis	endemic	SAR	None	None	x					
Drosophila oahuensis	endemic	SAR	None	None	x	x				
Drosophila pilimana	endemic	SAR	None	None	x					
Drosophila turbata	endemic	SAR	None	None	x	x		x		
Philodoria lysimachiella	endemic	SAR	None	None				x		
Plagithmysus haasi	endemic	SAR	None	None	x					
Rhyncogonus fordi	endemic	SAR	None	None				x		
Rhyncogonus fuscus	endemic	SAR	None	None				x		
Sierola arpactes	endemic	SAR	None	None	x					
Sierola balteata	endemic	SAR	None	None				x		
Sierola gracilis	endemic	SAR	None	None	x					
Sierola koebelei	endemic	SAR	None	None	x					
Sierola koloa	endemic	SAR	None	None	x			x		
Sierola kumumu	endemic	SAR	None	None				x		
Sierola lateralis	endemic	SAR	None	None	x					
Sierola leiocephala	endemic	SAR	None	None	x	x				
Sierola neoarmata	endemic	SAR	None	None	x					

TaxonName	Native	Status	Nature Serve Rank	IUCN	SBW	KLOA	SBE	MMR	KTA	SBS
Sierola nuku	endemic	SAR	None	None	x					
Sierola tumidoventris	endemic	SAR	None	None				x		

Table 4: ***SNAIL Species at Risk (SARs)***

family	subfamily	genus	epithet	Notes
Achatinellidae	Auriculellinae	Auriculella	ambusta	
Achatinellidae	Auriculellinae	Auriculella	gagneorum	
Achatinellidae	Auriculellinae	Auriculella	malleata	
Achatinellidae	Auriculellinae	Auriculella	pulchra	
Achatinellidae	Auriculellinae	Auriculella	tenella	
Achatinellidae	Auriculellinae	Auriculella	turritella	
Achatinellidae	Pacificellinae	Lamellidea	polygnampta	
Achatinellidae	Pacificellinae	Pacificella	baldwini	
Achatinellidae	Tornatellidinae	Tornatellides	idae anisoplax	
Achatinellidae	Tornatellidinae	Tornatellides	oahuensis	
Achatinellidae	Tornatellidinae	Tornatellides	popouelensis	
Achatinellidae	Tornatellidinae	Tornatellides	sp. 16	
Achatinellidae	Tornatellidinae	Tornatellides	sp. 40 cf. macromphala	
Achatinellidae	Tornatellidinae	Tornatellides	sp. 60	
Achatinellidae	Tornatellidinae	Tornatellides	sp. 61 cf. idae var. anisoplax	
Achatinellidae	Tornatellidinae	Tornatellides	waianaensis	
Achatinellidae	Tornatellininae	Elasmias	fuscum obtusum	
Achatinellidae	Tornatellininae	Elasmias	sp. 04	
Amastridae	Amastrinae	Amastra	cylindrica	just listed all amastridae on Oahu
Amastridae	Amastrinae	Amastra	intermedia	just listed all amastridae on Oahu
Amastridae	Amastrinae	Amastra	micans	just listed all amastridae on Oahu
Amastridae	Amastrinae	Amastra	rubens	just listed all amastridae on Oahu
Amastridae	Amastrinae	Amastra	spirizona nigrolabris	just listed all amastridae on Oahu
Amastridae	Amastrinae	Amastra	spirizona spirizona	just listed all amastridae on Oahu
Amastridae	Amastrinae	Amastra	variegata	just listed all amastridae on Oahu
Amastridae	Amastrinae	Laminella	sanguinea	just listed all amastridae on Oahu
Amastridae	Leptachatininae	Leptachatina	cerealis	just listed all amastridae on Oahu
Amastridae	Leptachatininae	Leptachatina	crystallina	just listed all amastridae on Oahu
Amastridae	Leptachatininae	Leptachatina	gummea	just listed all amastridae on Oahu
Amastridae	Leptachatininae	Leptachatina	persubtilis	just listed all amastridae on Oahu
Amastridae	Leptachatininae	Leptachatina	popouwelensis	just listed all amastridae on Oahu
Amastridae	Leptachatininae	Leptachatina	sp. 01	just listed all amastridae on Oahu
Endodontidae		Cookeconcha	cf. contorta	
Endodontidae		Cookeconcha	hystricella	
Euconulidae		Hiona	megodonta	
Euconulidae		Kaala	subrutila	
Euconulidae		Philonesia	oahuensis	
Euconulidae		Philonesia	palawai	
Euconulidae		Philonesia	sp. 02	
Euconulidae		Philonesia	sp. 05	
Euconulidae		Philonesia	sp. 06	
Euconulidae		Philonesia	sp. 13	
Euconulidae		Philonesia	sp. 16	
Helicinidae		Pleuropoma	oahuensis	
Helicinidae		Pleuropoma	oahuensis ferruginea	
Helicinidae		Pleuropoma	oahuensis gemina	
Helicinidae		Pleuropoma	sandwichiensis	
Punctidae		Punctum	sp. 03	
Succineidae		Succinea	cinnamomea	
Succineidae		Succinea	sp. 03	
Vertiginidae		Nesopupa	sp. 08	
Vertiginidae		Pronesopupa	sp. 01	

SPECIES LISTS FOR OAHU ARMY TRAINING LANDS

The full native plant, native and introduced bird and native and introduced insect species lists which were compiled in order to conduct this SAR analysis are included in their entirety here in the following appendices. This resource will be continually updated and maintained digitally. Updated species lists will be published every three years as an appendix to the UH annual report. Please note that the insect species list includes a level of uncertainty regarding identification to species and the list is published showing this.

Plants Species List for Oahu Army Training Lands

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Abutilon incanum	Maʻo, hoary abutilon	Indigenous				X					
Abutilon sandwicense	Greenflower indian mallow, koʻolua maʻomaʻo	Endemic	E	G1	CR	X					
Acacia koa	Koa	Endemic			LC	X	X	X	X		X
Adenophorus abietinus		Endemic						X	X		
Adenophorus haalilioanus		Endemic							X		
Adenophorus hymenophylloides		Endemic		G2			X	X	X		X
Adenophorus oahuensis		Endemic		G2				X	X		
Adenophorus pinnatifidus		Endemic					X	X	X		X
Adenophorus tamariscinus	Wahine noho mauna	Endemic					X	X	X		X
Adenophorus tenellus	Kolokolo, mahinalua	Endemic				X	X	X	X		X
Adenophorus tripinnatifidus	Wahine noho mauna	Endemic						X	X		
Adenostemma viscosum	Kāmanamana	Indigenous			LC		X				
Adiantum capillus-veneris	ʻIwaʻiwa	Indigenous			LC	X					
Alectryon macrococcus var. macrococcus	Māhoe	Endemic	E	G1	CR	X	X				
Alphitonia ponderosa	Kauila	Endemic		G2	VU	X					
Alyxia stellata	Maile	Indigenous				X	X	X	X		X
Amauropelta globulifera	Palapalai a Kamapuaʻa	Endemic						X	X		
Anoectochilus sandvicensis				G3	VU						
Antidesma platyphyllum	Hame	Endemic			VU	X	X	X	X		X
Antidesma pulvinatum	Hame	Endemic		G2		X	X		X		
Arachniodes insularis		Endemic		G2					X		
Argemone glauca	Pua kala	Endemic		G2		X					
Artemisia australis	ʻĀhinahina	Endemic				X	X				
Asplenium acuminatum	Lola	Endemic				X	X				
Asplenium adiantum-nigrum	ʻIwaʻiwa	Indigenous									

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Asplenium caudatum	ʻAlae	Indigenous				X	X				
Asplenium contiguum		Endemic				X	X	X	X		
Asplenium dielfalcatum		Endemic	E	G2	CR	X	X				
Asplenium kaulfussii	Kūau	Endemic		G2		X					
Asplenium lobulatum	ʻAnaliʻi	Indigenous					X	X	X		
Asplenium macraei	ʻIwaʻiwa lau liʻi	Endemic				X	X				
Asplenium nidus	ʻĒkaha, bird's-nest ferns	Indigenous				X	X	X	X		X
Asplenium normale		Indigenous					X		X		
Astelia menziesiana	Paʻiniu	Endemic				X	X		X		
Athyrium microphyllum	ʻĀkōlea	Endemic				X	X	X	X		
Bacopa monnieri	ʻAeʻae	Endemic			LC						
Bidens amplectens	Koʻokoʻolau	Endemic	E	G1	VU	X					
Bidens asymmetrica	Koʻokoʻolau	Endemic		G2				X			
Bidens cervicata	Koʻokoʻolau	Endemic		G2		X					
Bidens macrocarpa	Koʻokoʻolau	Endemic		G2				X	X		X
Bidens torta	Koʻokoʻolau	Endemic		G2		X	X			X	X
Bobea brevipes	ʻAkupa	Endemic		G2	EN	X	X		X		
Bobea elatior	ʻAhakea lau nui	Endemic			VU	X	X	X	X		X
Bobea sandwicensis	ʻAhakea	Endemic		G1	VU	X					
Bobea timonioides	ʻAhakea	Endemic		G1	EN				X		X
Boehmeria grandis	Hawaiʻi false-nettle	Endemic				X	X	X	X		
Boerhavia repens	Alena	Indigenous				X					
Bonamia menziesii		Endemic	E	G1	CR	X					
Callistopteris baldwinii		Indigenous						X	X		
Canavalia galeata	ʻĀwikiwiki	Endemic		G3		X	X				
Capparis sandwichiana	Maiapilo	Endemic		G2	VU	X					
Carex alligata		Endemic					X	X	X		
Carex meyenii	Kāluhāluhā	Indigenous				X	X		X		X
Carex wahuensis	Kāluhāluhā	Endemic				X	X	X	X		X

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Cenchrus agrimonioides var. agrimonioides	Kāmanomano	Endemic	E	G1	EN	X					
Ceodes brunoniana	Pāpala kēpau	Indigenous				X	X				
Ceodes umbellifera	Pāpala kēpau	Indigenous				X	X		X		X
Charpentiera obovata	Pāpala	Endemic				X	X				
Charpentiera tomentosa	Pāpala	Endemic		G2		X	X		X		
Cheirodendron platyphyllum	Lapalapa	Endemic		G2			X	X	X		X
Cheirodendron trigynum	ʻŌlapa	Endemic			VU		X	X	X		
Chenopodium oahuense	ʻĀweoweo, ʻāheahea, ʻahea, ʻāhewahewa, alaweo	Endemic								X	
Cibotium chamissoi	Hāpuʻu, treefern	Endemic				X	X	X	X		X
Cibotium glaucum	Hāpuʻu, treefern	Endemic					X	X	X		X
Cibotium menziesii	Hāpuʻu ʻiʻi	Endemic				X	X	X	X		X
Cibotium x heleniae	Hāpuʻu	Endemic						X	X		
Claoxylon sandwicense	Poʻolā, laukea	Endemic		G2		X	X				
Clermontia kakeana	ʻŌhāwai	Endemic					X	X	X		
Clermontia oblongifolia	ʻŌhāwai	Endemic		G3	VU			X	X		
Clermontia persicifolia	ʻŌhāwai	Endemic		G2	LR/NT			X	X		
Cocculus orbiculatus	Huehue, hueʻie	Indigenous				X	X				X
Coleus australis	ʻAlaʻala wai nui wahine, ʻAlaʻala wai nui pua kī	Indigenous				X	X	X	X	X	X
Coniogramme pilosa	Loʻulu	Endemic				X	X				
Coprosma foliosa	Pilo, hupilo	Endemic			VU	X	X		X		
Coprosma longifolia	Pilo, hupilo	Endemic				X	X	X	X		
Coprosma ochracea	Pilo, hupilo	Endemic					X				
Cordia subcordata	Kou	Indigenous			LC						
Crepidomanes draytonianum		Endemic		G3					X		X
Crepidomanes parvulum		Indigenous					X	X	X		X

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Ctenitis latifrons		Endemic				X					
Ctenitis squamigera	Pauoa	Endemic	E	G1	CR	X					
Cyanea acuminata	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G2	CR		X		X		
Cyanea angustifolia	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic		G2			X		X		
Cyanea calycina	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G1	CR		X	X	X		
Cyanea crispa	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G1	CR				X		
Cyanea grimesiana subsp. obatae	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G1	CR		X				
Cyanea humboldtiana	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G1	CR				X		
Cyanea koolauensis	Hāhā	Endemic	E	G1	EN			X	X		X
Cyanea lanceolata	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G1				X	X		
Cyanea membranacea	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic		G2	CR		X				
Cyanea st.-johnii	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G1	CR				X		
Cyanea superba subsp. superba	Hāhā	Endemic	E	G1	EX	X					
Cyclosorus interruptus	Neke	Indigenous						X	X		
Cyperus hillebrandii var. hillebrandii		Endemic				X					
Cyperus hypochlorus var. hypochlorus	Ahuʻawa	Endemic				X					
Cyperus phleoides		Endemic									
Cyperus polystachyos		Indigenous				X	X				
Cyperus sandwicensis		Endemic							X		

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Cyrtandra cordifolia	Haʻiwale, kanawao keʻokeʻo	Endemic		G3					X		
Cyrtandra dentata	Haʻiwale, kanawao keʻokeʻo	Endemic	E	G1	CR	X			X		
Cyrtandra garnotiana	Haʻiwale, kanawao keʻokeʻo	Endemic				X	X				
Cyrtandra grandiflora	Haʻiwale, kanawao keʻokeʻo	Endemic		G3			X				
Cyrtandra hawaiensis	Haʻiwale, kanawao keʻokeʻo	Endemic					X	X	X		
Cyrtandra kalihii	Haʻiwale, kanawao keʻokeʻo	Endemic		G2				X	X		
Cyrtandra lessoniana	Haʻiwale, kanawao keʻokeʻo	Endemic		G3			X				
Cyrtandra paludosa	Haʻiwale, kanawao keʻokeʻo	Endemic						X	X		
Cyrtandra propinqua	Haʻiwale, kanawao keʻokeʻo	Endemic		G3					X		
Cyrtandra subumbellata	Haʻiwale, kanawao keʻokeʻo	Endemic	E	G1	CR			X			
Cyrtandra viridiflora	Haʻiwale, kanawao keʻokeʻo	Endemic	E	G1	CR				X		
Cyrtandra waianaeensis	Haʻiwale, kanawao keʻokeʻo	Endemic		G3		X	X				
Cyrtomium caryotideum	Kāʻapeʻape, ʻāhina kuahiwi	Indigenous		G5		X	X				
Delissea waianaeensis		Endemic	E	G1	CR	X	X				
Deparia fenzliana		Endemic					X				
Deparia marginalis		Endemic				X			X		
Deparia prolifera		Endemic				X			X		X
Dianella sandwicensis	ʻUkiʻuki	Indigenous				X	X	X	X		X

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Dichanthelium cynodon		Endemic		G2					X		
Dichanthelium hillebrandianum		Endemic		G2					X		
Dichanthelium koolauense		Endemic		G2				X	X		
Dicranopteris linearis	Uluhe, unuhe	Indigenous			LC	X	X	X	X		X
Diospyros hillebrandii	Lama	Endemic		G2	EN	X	X				X
Diospyros sandwicensis	Lama	Indigenous			VU	X	X	X	X		X
Diplazium arnottii	Pohole, hōʻiʻo	Endemic						X	X		
Diplazium sandwichianum	Pohole, hōʻiʻo	Endemic				X	X	X	X		X
Diplopterygium pinnatum	Uluhe lau nui	Indigenous					X	X	X		X
Dissochondrus biflorus		Endemic		G2			X				
Dodonaea viscosa	ʻAʻaliʻi	Indigenous				X	X	X	X	X	X
Doodia kunthiana	ʻŌkupukupulauliʻi	Endemic				X	X	X	X		X
Doodia lyonii	Lyon's hacksaw fern	Endemic		G1				X	X		
Doryopteris decipiens	Kumuniu	Endemic				X					
Doryopteris decora	Kumuniu	Endemic				X	X			X	
Dracaena forbesii	Halapepe	Endemic	E	G1	EN	X	X				
Dracaena halapepe	Halapepe	Endemic		G2	VU		X		X		X
Dryopteris fuscoatra	ʻIʻi	Endemic				X	X				
Dryopteris glabra	Kīlau	Endemic				X	X		X		
Dryopteris mauiensis		Endemic		G2			X				
Dryopteris rubiginosa		Endemic					X				
Dryopteris sandwicensis		Endemic		G3		X	X				
Dryopteris unidentata	ʻAkole	Endemic				X	X				
Dubautia herbstobatae	Naʻenaʻe, hanupaoa, hinaʻaikamalama, neʻineʻi	Endemic	E	G1	CR	X					
Dubautia laxa	Naʻenaʻe, hanupaoa, hinaʻaikamalama, neʻineʻi	Endemic					X	X	X		

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Dubautia plantaginea	Naʻenaʻe, hanupaoa, hinaʻaikamalama, neʻineʻi	Endemic				X	X		X		
Dubautia sherffiana	Naʻenaʻe, hanupaoa, hinaʻaikamalama, neʻineʻi	Endemic		G1		X	X				
Elaeocarpus bifidus	Kalia	Endemic				X	X	X	X		X
Elaphoglossum aemulum		Endemic				X	X				
Elaphoglossum alatum		Endemic				X	X		X		
Elaphoglossum crassifolium		Endemic				X	X	X	X		X
Elaphoglossum fauriei		Endemic						X	X		
Elaphoglossum paleaceum	ʻĒkaha	Indigenous				X	X	X	X		X
Elaphoglossum pellucidum	Hoe-a-Māui	Endemic		G2				X	X		X
Elaphoglossum wawrae	Island tonguefern	Endemic					X				
Eleocharis obtusa	Spikerush	Indigenous						X	X		
Eragrostis grandis	Lovegrass	Endemic				X	X				
Eragrostis variabilis	ʻEmoloa, kāwelu	Endemic				X	X				
Erythrina sandwicensis	Wiliwili	Endemic		G2	VU	X				X	
Eugenia koolauensis	Nīoi	Endemic	E	G1	CR						X
Eugenia reinwardtiana	Nīoi	Indigenous		G5		X					
Euphorbia celastroides var. amplectens	ʻAkoko	Endemic				X	X				
Euphorbia celastroides var. kaenana	ʻAkoko	Endemic	E	T1		X					
Euphorbia clusiifolia	ʻAkoko	Endemic		G3	EN			X	X		
Euphorbia haeleeleana	ʻAkoko	Endemic	E	G1	EN	X					
Euphorbia multiformis	ʻAkoko	Endemic				X	X				
Euphorbia rockii	ʻAkoko, Rock's broomspurge	Endemic	E	G1	CR			X	X		
Eurya sandwicensis	Ānini	Endemic		G2	VU		X		X		
Exocarpos gaudichaudii	Heau	Endemic		G1	EN			X	X		

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Fimbristylis dichotoma		Indigenous						X	X		
Flueggea neowawraea	Mēhamehame	Endemic	E	G1	CR	X	X				
Freycinetia arborea	ʻIeʻie	Indigenous				X	X	X	X		X
Gahnia aspera subsp. globosa		Indigenous		G2		X					X
Gahnia beecheyi		Endemic				X	X	X	X		X
Gardenia mannii	Nānū, nāʻū	Endemic	E	G1	CR		X	X	X		X
Geniostoma cyrtandrae	Kāmakahala	Endemic	E				X				
Geniostoma hosakanum	Kāmakahala	Endemic		G1	CR			X	X		
Geniostoma hymenopodum	Kāmakahala	Endemic		G2				X	X		
Geniostoma kaalae	Kāmakahala	Endemic		G1		X	X				
Geniostoma tinifolium	Kāmakahala	Endemic					X				
Geniostoma waiolani	Kāmakahala	Endemic					X		X		
Gunnera petaloidea	ʻApeʻape	Endemic		G2			X				
Gynochthodes trimera	Noni kuahiwi	Endemic		G2	LR/NT	X	X				
Haplopteris elongata		Indigenous						X	X		
Hesperomannia oahuensis		Endemic	E	G1	CR		X				
Hesperomannia swezeyi		Endemic	E	G1	CR			X	X		
Heterpogon contortus	Pili	Indigenous				X					
Hibiscus arnottianus subsp. arnottianus	Kokiʻo keʻokeʻo, pāmakani	Endemic		G4	EN	X	X	X	X		
Hibiscus brackenridgei subsp. mokuleianus	Maʻo hau hele	Endemic	E	G1	CR	X					
Hibiscus kokio subsp. kokio	Kokiʻo ʻulaʻula, kokiʻo, kokiʻo ʻula	Endemic		T1					X	X	
Hoiokula sandwicensis	Hōʻiʻo kula	Endemic				X	X	X	X		
Huperzia serrata		Indigenous						X	X		X

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Hydrangea arguta	Kanawao, kupuwao, piohiʻa, akiahala, pūʻaha nui	Endemic				X	X	X	X		X
Hymenasplenium excisum		Indigenous				X	X		X		
Hymenasplenium unilaterale	Pāmoho	Indigenous							X		
Hymenophyllum recurvum		Endemic				X	X	X	X		X
Hypolepis hawaiiensis	Olua	Endemic					X		X		
Ilex anomala	Kāwaʻu	Indigenous				X	X	X	X		X
Ipomoea indica	Koali ʻawa	Indigenous				X	X				
Isachne distichophylla	ʻOhe	Endemic						X	X		
Isachne pallens		Endemic					X	X	X		
Isodendrion laurifolium	Aupaka	Endemic	E	G1	CR			X			
Joinvillea ascendens subsp. ascendens	ʻOhe	Endemic	E	G5T1			X	X	X		
Kadua acuminata	Au, pilo, manono	Endemic				X	X	X	X		
Kadua affinis	Manono	Endemic				X	X	X	X		X
Kadua centranthoides	Manono	Endemic					X	X	X		
Kadua cordata	Kopa, manono	Endemic				X	X				
Kadua degeneri subsp. degeneri	Manono	Endemic	E	G1	CR	X					
Kadua fluviatilis	Kamapuaʻa, pilo, manono	Endemic	E	G1					X		
Kadua fosbergii	Manono	Endemic		G2				X	X		
Kadua parvula	Manono	Endemic	E	G1	CR	X					
Korthalsella complanata	Hulumoa	Indigenous				X	X	X	X		X
Korthalsella cylindrica	Hulumoa	Endemic				X	X	X	X		X
Korthalsella degeneri	Hulumoa, kaumahana	Endemic	E	G1		X					
Korthalsella platycaula	Hulumoa, kaumahana	Endemic				X					

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Lachnagrostis filiformis	Heʻupueo	Indigenous				X	X				
Lepidium arbuscula	`Ānaunau, kūnānā, naunau	Endemic	E	G1	CR	X	X				
Lepisorus thunbergianus	Pākahakaha, ʻēkaha ʻākōlea	Indigenous				X	X	X	X	X	X
Leptecophylla tameiameiae	Pūkiawe, ʻaʻaliʻi mahu, kānehoa, maiele, pūpūkiawe, kāwaʻu	Indigenous				X	X	X	X	X	X
Lindsaea repens var. macraeana		Endemic		T2					X		
Lobelia gaudichaudii		Endemic		G1				X	X		
Lobelia hypoleuca	ʻŌpelu, liua, moʻowahie, kuhiʻaikamoʻowahie	Endemic		G3			X	X	X		
Lobelia koolauensis	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G1	CR			X			
Lobelia niihauensis	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G2	EN	X	X				
Lobelia oahuensis	ʻŌhā, hāhā, ʻōhā wai, ʻōhāhā	Endemic	E	G1	CR	X	X				
Lobelia yuccoides	Pānaunau	Endemic		G2			X				
Luzula hawaiiensis		Endemic		G4T2		X	X				
Lycopodium venustulum		Indigenous					X	X	X		
Lysimachia hillebrandii	Kolokolo kuahiwi, kolekole lehua, puahekili	Endemic		G1		X	X				
Lysimachia remyi		Endemic		G3		X					
Lythrum maritimum	Pūkāmole, loosestrife	Indigenous				X	X				
Machaerina angustifolia	ʻUki	Indigenous				X	X	X	X		X
Machaerina mariscoides	ʻAhaniu, ʻuki	Indigenous				X	X	X	X		X

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Marrattia douglasii	Pala, kapuaʻi lio	Endemic				X	X	X	X		
Melicope christophersenii	Alani	Endemic	E	G1	EN		X				
Melicope cinerea	Alani	Endemic		G1	EN		X				
Melicope clusiifolia	Alani	Endemic				X	X	X	X		X
Melicope cornuta var. cornuta		Endemic	E	G2T1				X	X		
Melicope cornuta var. decurrens		Endemic	E	G2T1		X	X				
Melicope elliptica	Alani	Endemic		G1		X	X				
Melicope hiiakae	Alani	Endemic	E	G1	EN				X		
Melicope hosakae	Alani	Endemic		G2				X	X		
Melicope kaalaensis	Alani	Endemic		G1	VU	X	X				
Melicope lydgatei	Alani	Endemic	E	G1	CR				X		
Melicope makahae	Alani	Endemic	E	G1	EN	X					
Melicope oahuensis	Alani	Endemic				X	X	X	X		X
Melicope peduncularis	Alani	Endemic				X	X		X		X
Melicope rotundifolia	Alani	Endemic		G3					X		
Melicope sandwicensis	Alani	Endemic		G2	EN	X	X	X	X		X
Melicope spathulata	Pilo kea	Endemic		G2			X	X	X		X
Melicope wawraeana	Alani	Endemic		G2	VU				X		
Menisciopsis boydiae	Kupukupu makaliʻi	Endemic	E	G1	EN				X		
Menisciopsis cyatheoides	Kikawaiō	Endemic				X	X	X	X		
Metrosideros macropus	ʻŌhiʻa lehua	Endemic		G2				X	X		X
Metrosideros polymorpha var. glaberrima	ʻŌhiʻa lehua	Endemic				X	X	X	X		X
Metrosideros polymorpha var. incana	ʻŌhiʻa lehua	Endemic				X	X		X		X
Metrosideros polymorpha var. polymorpha	ʻŌhiʻa lehua	Endemic				X	X	X	X		X
Metrosideros polymorpha var. pumila	ʻŌhiʻa lehua	Endemic							X		X
Metrosideros rugosa	ʻŌhiʻa lehua	Endemic		G2	EN			X	X		X

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Metrosideros tremuloides	Lehua ʻāhihi, ʻāhihi, ʻāhihi lehua, ʻāhihi kū ma kua	Endemic			EN	X	X	X	X		
Microlepia speluncae		Indigenous				X	X				
Microlepia strigosa var. strigosa	Palapalai	Indigenous				X	X	X	X	X	X
Microlepia strigosa var. mauiensis	Palapalai	Endemic	E	G2		X					
Microsorum spectrum	Peahi, Lauaʻe	Endemic		G3					X		
Myoporum sandwicense	Naio, bastard sandalwood	Indigenous				X	X			X	X
Myrsine degeneri	Kōlea	Endemic		G3	VU			X	X		
Myrsine fosbergii	Kōlea	Endemic	E	G1	VU			X	X		
Myrsine juddii	Kōlea	Endemic	E	G1	CR				X		
Myrsine lanaiensis	Kōlea	Endemic				X	X				
Myrsine lessertiana	Kōlea lau nui	Endemic				X	X	X	X		
Myrsine pukooensis	Kōlea, Molokaʻi colicwood	Endemic		G3					X		
Myrsine sandwicensis	Kōlea lau liʻi	Endemic					X	X	X		
Nephrolepis cordifolia		Indigenous					X	X	X		X
Nephrolepis exaltata subsp. hawaiiensis	Niʻaniʻau, kupukupu, ʻōkupukupu	Endemic				X	X	X	X		X
Neraudia angulata var. angulata	Maʻaloa, Maʻoloa, ʻOloa	Endemic	E	G1T1	CR	X					
Neraudia angulata var. dentata	Maʻaloa, Maʻoloa, ʻOloa	Endemic	E	G1T1	CR	X					
Neraudia melastomifolia	Maʻaloa, Maʻoloa, ʻOloa	Endemic		G2	VU	X	X				

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Nertera granadensis	Mākole	Indigenous					X	X	X		X
Nestegis sandwicensis	Olopua	Endemic			VU	X	X		X		X
Nothocestrum latifolium	ʻAiea	Endemic	E	G1	EN		X				
Nothocestrum longifolium	ʻAiea	Endemic		G2	LR/NT		X				
Nototrichium humile	Kuluʻi	Endemic	E	G2	EN	X					
Ochrosia compta	Hōlei	Endemic		G2		X	X				X
Odontosoria chinensis	Palaʻā, palapalaʻā, pāʻū o Palaʻe	Indigenous				X	X	X	X		X
Ophioderma pendula	Puapuamoa	Indigenous						X	X		X
Oreobolus furcatus		Endemic							X		
Oreogrammitis hookeri		Indigenous						X	X		X
Osteomeles anthyllidifolia	ʻŪlei, eluehe	Indigenous				X	X	X	X		X
Palhinhaea cernua	Wāwaeʻiole	Indigenous				X	X	X	X		X
Pandanus tectorius	Hala	Indigenous						X	X		X
Panicum beecheyi		Endemic		G2		X	X				
Panicum nephelophilum	Konakona	Endemic				X	X				
Paratrophis pendulina	Aʻiaʻi	Indigenous				X	X				X
Paspalum scrobiculatum	Rice grass	Indigenous				X	X	X	X		X
Peperomia cookiana	ʻAlaʻala wai nui, ʻawalauaKāne	Endemic					X				
Peperomia ellipticibacca	ʻAlaʻala wai nui, ʻawalauaKāne	Endemic		G3				X	X		
Peperomia latifolia	ʻAlaʻala wai nui, ʻawalauaKāne	Endemic				X	X	X	X		
Peperomia leptostachya	ʻAlaʻala wai nui, ʻawalauaKāne	Indigenous				X	X			X	
Peperomia macraeana	ʻAlaʻala wai nui, ʻawalauaKāne	Endemic					X	X	X		
Peperomia membranacea	ʻAlaʻala wai nui, ʻawalauaKāne	Endemic				X	X	X	X		

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Peperomia oahuensis	ʻAlaʻala wai nui, ʻawalauaKāne	Endemic		G3				X			
Peperomia sandwicensis	ʻAlaʻala wai nui, ʻawalauaKāne	Endemic				X	X				
Peperomia tetraphylla	ʻAlaʻala wai nui, ʻawalauaKāne	Endemic				X	X	X	X		
Perrottetia sandwicensis	Olomea, waimea, puaʻa olomea	Endemic				X	X	X	X		X
Phlegmariurus filiformis								X	X		
Phlegmariurus nutans		Endemic	E					X	X		
Phlegmariurus phyllantha		Indigenous				X	X	X	X		X
Phyllanthus distichus	Pāmakani mahu	Endemic				X	X				
Phyllostegia glabra	Ulihi	Endemic		G3			X		X		
Phyllostegia grandiflora	Kāpana	Endemic					X	X	X		X
Phyllostegia hirsuta		Endemic	E	G1	CR		X	X	X		
Phyllostegia lantanoides	Kāpana	Endemic		G3			X	X	X		
Phyllostegia mollis		Endemic	E	G1	CR		X				
Pilea peploides		Indigenous				X	X				
Pipturus albidus	Māmaki	Endemic				X	X	X	X		X
Pittosporum confertiflorum	Hōʻawa, hāʻawa	Endemic					X	X	X		X
Pittosporum flocculosum	Hōʻawa, hāʻawa	Endemic		G2		X					X
Pittosporum glabrum	Hōʻawa, hāʻawa	Endemic				X	X	X	X		X
Planchonella sandwicensis	ʻĀlaʻa, āulu, kaulu	Endemic				X	X	X	X	X	X
Plantago pachyphylla		Endemic						X	X		
Plantago princeps var. princeps	Ale	Endemic	E	G1T1		X	X				
Plumbago zeylanica	ʻIlieʻe, hilieʻe, ʻiliheʻe, lauhihi	Indigenous				X				X	X
Polypodium pellucidum	ʻAe	Endemic				X	X		X		
Polyscias gymnocarpa	ʻOheʻohe	Endemic	E	G1	CR			X			
Polyscias kavaiensis	ʻOheʻohe	Endemic		G2			X				
Polyscias oahuensis	ʻOhe mauka	Endemic		G3		X	X	X	X		X

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Polyscias sandwicensis	ʻOhe, ʻohe kukuluaeʻo, ʻoheokai, ʻohemakai	Endemic		G2	LR/NT	X				X	
Pritchardia bakeri	Loulu	Endemic		not rated	CR						X
Pritchardia kaalae	Loulu	Endemic	E	G1		X	X				
Pritchardia martii	Loulu	Endemic		G2	EN			X	X		X
Pseudognaphalium sandwicensium var. sandwicensium	ʻEnaʻena, pūheu	Endemic	E	G3T1		X					
Pseudophegopteris keraudreniana	False beach fern	Endemic		G3		X			X		X
Psilotum complanatum	Moa, moa nahele, pipi	Indigenous					X	X	X		X
Psilotum nudum	Moa, moa nahele, pipi	Indigenous				X	X	X	X		X
Psychotria fauriei	Kōpiko, ʻōpiko	Endemic		G2	EN			X	X		X
Psychotria hathewayi	Kōpiko, ʻōpiko	Endemic				X	X				
Psychotria hexandra var. oahuensis	Kōpiko, ʻōpiko	Endemic	E	G4T1	CR						
Psychotria kaduana	Kōpiko, ʻōpiko	Endemic		G2				X	X		
Psychotria mariniana	Kōpiko, ʻōpiko	Endemic				X	X	X	X		X
Psydrax odorata	Alaheʻe, ʻōheʻe, walaheʻe	Indigenous			LC	X	X	X	X	X	X
Pteralyxia macrocarpa	Kaulu	Endemic	E	G1	VU	X	X				X
Pteridium aquilinum subsp. decompositum	Kīlau, Bracken	Endemic				X	X	X	X		X
Pteris cretica	ʻŌali, ʻowali, ʻōwali	Indigenous				X					
Pteris irregularis	Mānā, ʻāhewa, ʻiwa puakea	Endemic				X					
Pteris lidgatei		Endemic	E	G1	CR			X	X		
Pteris terminalis	Waimakanui	Indigenous				X	X				

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Rauvolfia sandwicensis	Hao	Endemic				X	X		X	X	X
Reholttumia hudsoniana	Laukahi	Endemic				X	X		X		
Rhynchospora chinensis subsp. spiciformis	Kuolohia	Indigenous						X	X		
Rhynchospora rugosa subsp. lavarum	Kuolohia	Indigenous						X	X		X
Rhynchospora sclerioides	Kuolohia	Indigenous				X		X	X		X
Rockia sandwicensis	Pāpala kēpau, āulu	Endemic				X	X		X		X
Rumex albescens	Huʻahuʻakō	Endemic		G2		X	X				
Sadleria cyatheoides	ʻAmaʻu, maʻu	Endemic				X	X	X	X		X
Sadleria pallida	ʻAmaʻu, maʻu	Endemic					X	X	X		X
Sadleria souleyetiana	ʻAmaʻu, maʻu	Endemic					X	X	X		X
Sadleria squarrosa	ʻAmaʻu, maʻu	Endemic					X	X	X		X
Sanicula mariversa	Waiʻanae Range blacksnakeroot	Endemic	E	G1	CR	X					
Sanicula purpurea	Purple-Flowered Sanicle	Endemic	E	G1	CR			X	X		
Santalum ellipticum	ʻIliahialoʻe, ʻiliahi, ʻaoa	Endemic		G2		X					
Santalum freycinetianum var. freycinetianum	ʻIliahi, ʻaoa	Endemic			EN	X	X		X		X
Sapindus oahuensis	Lonomea, āulu, kaulu	Endemic		G2	VU	X	X	X	X	X	X
Scaevola gaudichaudiana	Naupaka kuahiwi, mountain naupaka	Endemic				X	X	X	X		X
Scaevola gaudichaudii	Naupaka kuahiwi, Ridgetop Naupaka	Endemic		G2		X					
Scaevola glabra	ʻOhe naupaka	Endemic		G2				X	X		X
Scaevola mollis	Naupaka kuahiwi	Endemic		G2			X	X	X		X
Scaevola taccada	Naupaka kahakai, huahekili, aupaka	Indigenous				X					

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Schiedea hookeri		Endemic	E	G1	CR	X	X				
Schiedea kaalae		Endemic	E	G1	CR		X				
Schiedea kealiae		Endemic	E	G1	CR	X				X	
Schiedea ligustrina		Endemic		G2		X	X				
Schiedea mannii		Endemic		G2	VU	X	X				
Schiedea nuttallii	Valley schiedea	Endemic	E	G1	CR	X					
Schiedea obovata		Endemic	E	G1	CR	X					
Schiedea pentandra (pubescens var. purpurescens)		Endemic		G2			X				
Schiedea trinervis		Endemic	E		CR		X				
Schizaea robusta		Endemic						X	X		X
Selaginella arbuscula	Lepelepeamoa	Endemic				X	X	X	X		X
Senna gaudichaudii	Kolomona, kalamona	Indigenous				X					
Sicyos lanceoloideus	ʻĀnunu	Endemic	E	G1	submitted		X				
Sicyos pachycarpus	Kūpala, ʻānunu	Endemic				X				X	
Sida fallax	ʻIlima	Indigenous				X	X	X	X	X	X
Sideroxylon polynesicum	Keahi	Indigenous		G2	VU	X					X
Silene lanceolata		Endemic	E	G1		X					
Smilax melastomifolia	Hoi kuahiwi, akaʻawa, uhi, ulehihi	Endemic				X	X	X	X		X
Solanum americanum	Pōpolo, ʻolohua, glossy nightshade	Indigenous				X	X	X	X	X	X
Sophora chrysophylla	Māmane	Endemic				X	X				
Spermolepis hawaiiensis		Endemic	E	G2		X					
Sphaerocionium lanceolatum		Endemic					X	X	X		X
Sphaerocionium obtusum		Endemic					X	X	X		X
Stenogrammitis saffordii	Kihe	Endemic					X	X	X		X
Stenogyne kaalae subsp. kaalae		Endemic		G2		X	X		X		
Stenogyne kaalae subsp. sherffii		Endemic	E						X		

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Stenogyne kanehoana		Endemic	E	GH	CR		X				
Sticherus owhyhensis	Uluhe, unuhe	Endemic					X	X	X		
Strongylodon ruber	Nuku ʻiʻiwi	Endemic		G2		X	X				
Syzygium sandwicense	ʻŌhiʻa ʻai	Endemic				X	X	X	X		X
Tectaria gaudichaudii	ʻIwaʻiwa lau nui	Endemic				X	X	X	X		X
Tetramolopium filiforme		Endemic	E	G1		X	X				
Tetramolopium lepidotum subsp. lepidotum		Endemic	E	G1	CR		X				
Thespesia populnea	Milo	Indigenous				X					
Touchardia latifolia	Olonā	Endemic		G3			X	X	X		
Trematolobelia kaalae							X				
Trematolobelia macrostachys	Koliʻi	Endemic					X	X	X		X
Urera glabra	Ōpuhe	Endemic				X	X				
Urera kaalae	Ōpuhe	Endemic	E	G1	CR		X				
Vaccinium calycinum	ʻŌhelo	Endemic					X		X		X
Vaccinium dentatum	ʻŌhelo	Endemic				X	X	X	X		
Vaccinium reticulatum	ʻŌhelo	Endemic							X		
Vandenboschia cyrtotheca		Endemic				X		X	X		
Vandenboschia davallioides		Endemic				X		X	X		
Viola chamissoniana subsp. chamissoniana	ʻOlopū, pāmakani	Endemic	E	T1	CR	X	X				
Viola chamissoniana subsp. tracheliifolia	Pāmakani	Endemic		G2		X	X				
Viola kauaensis var. hosakae		Endemic		G2					X		
Viola oahuensis	Oʻahu violet	Endemic	E	G1				X	X		
Waltheria indica	ʻUhaloa, ʻalaʻala pū loa, halaʻuhaloa, kanakaloa	Indigenous				X	X	X	X	X	X
Wikstroemia oahuensis var. oahuensis	ʻĀkia, kauhi	Endemic				X	X	X	X		X
Wikstroemia uva-ursi	ʻĀkia, kauhi	Endemic		G2							X

TaxonName	CommonName	Distribution	FedStat	Nature Serve Rank	IUCN	MMR	SB	SBE	KLOA	DMR	KTA
Wollastonia tenuifolia	Nehe	Endemic	E	G1	CR	X					
Wollastonia tenuis	Nehe	Endemic		G2			X				
Xylosma hawaiiense	Maua, aʻe	Endemic				X	X	X	X		X
Zanthoxylum dipetalum var. dipetalum	Kāwaʻu, heaʻe	Endemic		G2			X				X
Zanthoxylum kauaense	Heaʻe, aʻe, Oʻahu prickly ash	Endemic		G2	LR/NT	X	X				
Zanthoxylum oahuense	Heaʻe, aʻe, Oʻahu prickly ash	Endemic	E	G1	VU			X	X		

Insect Species List for Oahu Army Training Lands

Name	Native	Status	SBW	KLOA	SBE	MMR	KTA	SBS
Acrostica apicalis	adventive			x				
Aedes japonicus	adventive			x		x		
Allograpta obliqua	adventive		x					
Aloha dubautiae	endemic			x				
Aloha myoporicola	endemic		x					
Aloha nr. ipomoeae	endemic			x				
Aloha swezeyi	endemic			x				
Anax strenuus	endemic		x	x		x		
Anchastus swezeyi	endemic			x				
Anoplolepis gracilipes	adventive		x	x	x		x	x
Apetasimus nr. debbiae	endemic			x				
Apis mellifera	purposeful		x	x	x	x	x	x
Araneus emmae	endemic					x		
Araneus kapiolaniae	endemic					x		
Atrichopogon jacobsoni	adventive			x				
Bactrocera dorsalis	adventive							
Banza parvula	endemic					x		
Banza unica	endemic					x		
Batrachedrodes sp.	endemic					x		
Bembidion blackburni	endemic		x	x	x			
Bembidion ignicola	endemic		x	x	x			
Bembidion spurcum	endemic		x	x				
Blackburnia audax	endemic		x					
Blackburnia barda	endemic			x	x			
Blackburnia caliginosa	endemic			x	x			
Blackburnia corrusca	endemic		x	x	x			
Blackburnia cuneipennis	endemic		x	x	x			
Blackburnia epicurus	endemic		x	x	x			
Blackburnia fordi	endemic			x	x			
Blackburnia fossipennis	endemic			x	x		x	
Blackburnia fractistriata	endemic			x	x			
Blackburnia fraterna	endemic		x	x	x		x	
Blackburnia fugitiva	endemic			x	x			
Blackburnia hihia	endemic		x					
Blackburnia hilaris	endemic		x					
Blackburnia huhula	endemic		x					
Blackburnia insignis	endemic		x	x				
Blackburnia kamehameha	endemic			x	x			
Blackburnia meticulosa	endemic		x	x				
Blackburnia metromenoides	endemic		x					

Name	Native	Status	SBW	KLOA	SBE	MMR	KTA	SBS
Blackburnia micans	endemic		x	x	x			
Blackburnia muscicola	endemic		x	x	x			
Blackburnia mutabilis	endemic			x	x		x	
Blackburnia mystica	endemic		x					
Blackburnia optata	endemic			x	x			
Blackburnia palmae	endemic		x	x	x		x	
Blackburnia paludicola	endemic		x					
Blackburnia perpolita	endemic			x	x			
Blackburnia proterva	endemic			x	x			
Blackburnia tantalus	endemic		x	x				
Blackburnia tibialis	endemic		x					
Brachymyrmex obscurior	adventive		x					
Caccodes oceaniae	adventive					x		
Camponotus variegatus	adventive						x	
Campsicnemus williamsi	endemic			x				
Cardiocondyla emeryi	adventive							
Cephalops juvator	endemic			x				
Chalybion bengalense	adventive		x					
Coleotichus blackburniae	endemic		x					
Colobopyga pritchardiae	endemic			x				
Conoderus exsul	adventive			x				
Corythucha gossypii	adventive		x					
Corythucha morrilli	adventive		x					
Cossoninae?	adventive?			x				
Cyclosa simplicicauda	endemic					x		
Dasyhelea hawaiiensis	endemic			x				
Dicranomyia kauaiensis	endemic			x				
Dicranomyia nigropolita	endemic			x				
Dicranomyia stygipennis	endemic			x				
Dicranomyia swezeyi	endemic			x				
Dictyophorodelphax mirabilis	endemic							
Dolichopus exsul	endemic			x				
Drosophila ambochila	endemic	SAR	x					x
Drosophila arcuata	endemic	SAR	x	x				x
Drosophila brevitarsus	endemic			x				
Drosophila craddockae	endemic	SAR		x			x	
Drosophila crucigera	endemic		x	x		x	x	x
Drosophila deltaneuron	endemic	SAR	x	x				
Drosophila divaricata	endemic	SAR						x

Name	Native	Status	SBW	KLOA	SBE	MMR	KTA	SBS
Drosophila floricola	adventive			x			x	
Drosophila gradata	endemic		x					
Drosophila hexachaetae	endemic	SAR	x			x		
Drosophila immigrans	adventive		x	x	x	x	x	x
Drosophila inedita	endemic		x					x
Drosophila montgomeryi	endemic	E	x					x
Drosophila neogrimshawi	endemic	SAR	x					
Drosophila nigribasis	endemic	SAR	x					
Drosophila oahuensis	endemic	SAR	x	x				
Drosophila obatai	endemic	E	x					
Drosophila pilimana	endemic	SAR	x					
Drosophila punalua	endemic		x	x		x	x	x
Drosophila simulans	adventive		x	x				
Drosophila substenoptera	endemic	E	x	x				
Drosophila turbata	endemic	SAR	x	x		x		
Drosophila velata	endemic		x					
Ecphylopsis nigra	endemic					x		
Elaterinae cf. sericus	adventive			x				
Elliptera sp.	adventive			x				
Empoasca solana	adventive		x					
Enicospilus orbitalis	endemic			x				
Eopenthes arduus?	endemic			x				
Erioptera bicornifer	adventive			x				
Eudocima fullonia	adventive		x					
Eupelmus sp.	endemic		x					
Eupelmus? cf. xestias	endemic?			x				
Eupetinus	endemic			x				
Eurynogaster clavaticauda	endemic			x				
Eurynogaster s.l.	endemic			x				
Euwallacea fornicatus	adventive		x					x
Forcipomyia (Forcipomyia)	adventive			x				
Forcipomyia hardyi	endemic			x				
Goniozus nr. hubbardi	adventive					x		
Haematoloecha rubescens	adventive			x				
Hawaiiandra puncticeps	endemic		x					
Hercinothrips femoralis	adventive		x					
Heteropoda venatoria	adventive		x					
Hevaheva nr. monticola	endemic		x					
Hevaheva perkinsi	endemic		x	x				

Name	Native	Status	SBW	KLOA	SBE	MMR	KTA	SBS
Hyalopeplus pellucidus	endemic			x				
Hylaeus kuakea	endemic	E						x
Hyles callida	endemic					x		
Hyposmocoma spp.	endemic					x		
Hyposmocoma trimaculata	endemic							
Hypothenemus sp.	adventive					x		
Icerya purchasi	adventive		x					
Iolania sp.	endemic			x				
Kallitaxila granulata	adventive		x					
Klambothrips myopori	adventive		x					
Kuwayama gracilis	endemic			x				
Kuwayama nr. nigricapitata	endemic			x				
Lagocheirus undatus	adventive							
Leialoha naniicola	endemic			x				
Leialoha oahuensis	endemic			x				
Leialoha ohiae	endemic			x				
Leialoha sp.	endemic			x				
Leptogenys falcigera	adventive		x				x	
Leptogryllus fusconotatus	endemic				x			
Leptogryllus kaala	endemic					x		
Lestodiplosis fimicola	endemic			x				
Limnoxenus nesiticus	endemic			x				
Limnoxenus semicylindricus	endemic		x	x				
Lius poseidon	purposeful			x				
Macarya abydata	adventive					x		
Macropsinae	adventive			x				
Mecaphesa sp.	endemic					x		
Mecyclothorax acherontius	endemic						x	
Mecyclothorax carteri	endemic		x					
Mecyclothorax euryoides	endemic		x					
Mecyclothorax invictus	endemic		x					
Mecyclothorax lemur	endemic		x					
Mecyclothorax pelops	endemic			x	x			
Mecyclothorax ramsdalei	endemic		x					
Mecyclothorax satyrus	endemic			x	x			
Megalagrion hawaiiense	endemic					x		
Megalagrion koelense	endemic		x	x	x			
Megalagrion nigrohamatum nigrolineatum	endemic	E		x				
Megalagrion oahuense	endemic			x	x			

Name	Native	Status	SBW	KLOA	SBE	MMR	KTA	SBS
Megatrioza kauaiensis	endemic			x				
Megatrioza palmicola	endemic			x				
Melormenis basalis	adventive		x					
Metacolpodes buchanani	adventive			x				
Meteorus laphygmae	purposeful			x				
Micromus angularis	endemic			x				
Micromus brunnescens?	endemic			x				
Micromus ombrias?	endemic			x				
Micromus sp.	endemic			x				
Microvelia vagans	endemic			x				
Myrmarachne nigella	adventive		x					
Nabis kaohinani	endemic			x				
Nabis kerasphoros purpureus	endemic			x				
Nabis kerasphoros s.s.	endemic			x				
Nabis lusciosus	endemic			x				
Nabis sp. nr. lusciosus	endemic			x				
Nabis subrufus	endemic			x				
Nanixipha nahoa	adventive			x				
Neomachilis insularis insularis	endemic			x				
Nesogonia blackburni	endemic		x					
Nesophrosyne sp. 246	endemic		x					
Nesophrosyne sp. 343	endemic		x					
Nesorestias sp.	endemic		x					
Nesosydne sp.	endemic		x					
Nesothoe elaeocarpi	endemic			x				
Nesothoe eugeniae	endemic			x				
Nesothoe perkinsi	endemic			x				
Nesotocus giffardi	endemic		x					
Niesthrea louisianica	adventive		x					
Nudilla spp.	endemic		x	x	x	x		
Nysius sp.	endemic					x		
Oceanides nimbatus	endemic			x				
Ochetellus glaber	adventive		x	x	x	x	x	x
Oliarus acaciae?	endemic			x				
Oliarus haleakalae	endemic			x				
Oliarus kaiulani	endemic			x				
Oliarus kaonohi	endemic			x				
Oliarus kaumuahona	endemic			x				
Oliarus neomorai	endemic			x				
Oliarus neotarai	endemic			x				

Name	Native	Status	SBW	KLOA	SBE	MMR	KTA	SBS
Oliarus nr. myoporicola	endemic			x				
Oliarus pele beta	endemic			x				
Oliarus sp.	endemic		x					
Oliarus tantalus	endemic			x				
Oligota?	endemic?			x				
Omiodes blackburni	endemic					x		
Oodemas aenescens kahanae	endemic			x				
Oodemas breviscapum	endemic		x					
Ophiusa disjugens	adventive							
Opius humilis?	purposeful			x				
Opogona sacchari	adventive		x					
Opuna sp.	endemic			x				
Orthotylus diospyropsis	endemic		x					
Paratrechina bourbonica	adventive		x				x	
Pariaconus oahuensis	endemic			x				
Pariaconus ohiacola	endemic			x				
Pheidole fervens	adventive							
Pheidole megacephala	adventive		x			x	x	x
Philodoria lysimachiella	endemic	SAR				x		
Philodoria naenaeiella	endemic		x					
Philodoria pipturicola	endemic		x					
Philodoria splendida	endemic		x			x		
Placosternus crinicornis	adventive							
Plagiolepis alluaudi	adventive		x					x
Plagithmysus haasi	endemic	SAR	x					
Polynema sp.	endemic			x				
Prognathogryllus makai	endemic					x		
Protaetia fusca	adventive		x					
Proterhinus spp.	endemic		x	x	x	x	x	x
Pseudeucoila hygrophila?	endemic			x				
Pseudodiranchis naias?	endemic			x				
Pseudosmittia sp. A	adventive?			x				
Pterolophia bigibbera	adventive		x					
Rhantus sp.	endemic			x				
Rhodesiella scutellata	adventive		x					
Rhyncogonus fordi	endemic	SAR				x		
Rhyncogonus fuscus	endemic	SAR				x		
Saldula exulans	endemic		x	x				
Saldula longicornis	endemic			x				

Name	Native	Status	SBW	KLOA	SBE	MMR	KTA	SBS
Scaptomyza (Elmomyza)	endemic			x				
Scaptomyza (Exalloscaptomyza)?	endemic			x				
Scaptomyza inflata	endemic		x					
Scaptomyza palata	endemic					x		
Scatella hawaiiensis	endemic		x					
Scotorythra epixantha	endemic		x			x		
Scotorythra rara	endemic		x			x		
Sierola alba	endemic		x			x		
Sierola armata	endemic		x					
Sierola arpactes	endemic	SAR	x					
Sierola aspera	endemic		x	x				
Sierola balteata	endemic	SAR				x		
Sierola beardsleyi	endemic		x					
Sierola brevicornis	endemic		x					
Sierola bridwelli	endemic		x					
Sierola brunnea	endemic		x	x		x		
Sierola canuta	endemic		x					
Sierola celeris	endemic		x			x		
Sierola danimalis	endemic					x		
Sierola femoralis	endemic			x				
Sierola gracilariae	endemic		x					
Sierola gracilis	endemic	SAR	x					
Sierola heterochroma	endemic		x			x		
Sierola hirsuta	endemic		x			x		
Sierola kahuku	endemic						x	
Sierola koebelei	endemic	SAR	x					
Sierola koloa	endemic	SAR	x			x		
Sierola komohana	endemic		x			x		
Sierola kumumu	endemic	SAR				x		
Sierola lanihuliana	endemic			x				
Sierola lateralis	endemic	SAR	x					
Sierola leiocephala	endemic	SAR	x	x				
Sierola malino	endemic			x				
Sierola neoarmata	endemic	SAR	x					
Sierola nitens	endemic		x					
Sierola nuku	endemic	SAR	x					
Sierola oahuensis	endemic		x			x		
Sierola olena	endemic		x					

Name	Native	Status	SBW	KLOA	SBE	MMR	KTA	SBS
Sierola olympiana	endemic		x					
Sierola peleana	endemic			x		x		
Sierola rufignatha	endemic		x					
Sierola suttoniae	endemic		x			x		
Sierola tenuis	endemic					x		
Sierola timberlakei	endemic		x			x		
Sierola tumidoventris	endemic	SAR				x		
Sierola uhiwai	endemic		x					
Sierola waianaeana	endemic						x	
Sierola weawea	endemic		x					
Sierola welau	endemic		x					
Sipyloidea sipylus	adventive							
Solenopsis geminata	adventive							
Solenopsis papuana	adventive		x	x	x	x	x	x
Sphenophorus cariosus	adventive						x	
Syagrius fulvitarsis	adventive		x					
Tachypompilus analis	adventive		x					
Technomyrmex albipes	adventive		x				x	
Tetragnatha quasimodo	endemic					x		
Tetramorium simillimum	adventive							
Thaumastocoris peregrinus	adventive		x					
Thelyphassa apicata	adventive			x				
Theridion grallator	endemic		x					
Tmolus echion	adventive							
Trichomyia hawaiiensis	endemic			x				
Triclistus?	adventive			x				
Trupanea crassipes	endemic			x				
Uroplata girardi	purposeful					x		
Vanessa tameamea	endemic		x	x				x
Vulgichneumon diminutus	adventive			x				
Xyleborus affinis	adventive			x				
Xylosandrus compactus	adventive		x					
Zaprionus indianus	adventive		x			x		x
Zelus renardii	adventive		x					

Bird Species List for Oahu Army Training Lands

TaxonName	CommonName	Distribution	DMR	KTA	KLOA	MMR	SB	Oahu Endemic Y/N	Federal Status	NatureServe Ranking	IUCN	Proposed/ Candidate for Fed listing Y/N
Acridotheres tristis	Common Myna	Introduced	Y	Y	–	Y	Y	N		G5	LC	N
Amandava amandava	Red Avadavat	Introduced	Y	–	–	–	–	N		G5	LC	N
Amazona viridigenalis	Red-crowned Parrot	Introduced	–	–	–	–	Y	N		G5	LC	N
Anas platyrhynchos	Mallard	Introduced	Y	–	–	–	–	N		G5	LC	N
Arenaria interpres	Ruddy Turnstone	Indigenous	–	–	–	–	–	N		G5	LC	N
Asio flammeus sandwichensis	Short-eared owl or Pueo	Endemic	–	–	–	Y	Y	N	N	T2	LC	N
Bubulcus ibis	Cattle Egret	Introduced	Y	Y	–	–	Y	N		G5	LC	N
Cardinalis cardinalis	Northern Cardinal	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N
Chasiempis ibidis	Oahu elepaio	Endemic	–	–	Y	Y	Y	Y	E	G1	EN	N
Chlorodrepanis flava	Oahu Amakihi	Endemic	–	–	Y	Y	Y	Y	N	G3	VU	N
Columba livia	Rock Pigeon	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N
Copsychus malabaricus	White-rumped Shama	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N
Drepanis coccinea	Iiwi	Endemic	–	–	–	–	Y	N	T	G4	VU	N
Estrilda astrild	Common Waxbill	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N
Francolinus francolinus	Black Francolin	Introduced	–	–	–	Y	Y	N		G5	LC	N
Francolinus pondicerianus	Gray Francolin	Introduced	–	–	–	–	Y	N		G5	LC	N
Fulica alai	Hawaiian coot or Alae Keokeo	Endemic	Y	–	–	–	–	N	E	G3	VU	N
Gallinula galeata sandvicensis	Hawaiian gallinule or Alae Ula	Endemic	Y	–	–	–	–	N	E	T2	LC	N
Geopelia striata	Zebra Dove	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N

TaxonName	CommonName	Distribution	DMR	KTA	KLOA	MMR	SB	Oahu Endemic Y/N	Federal Status	NatureServe Ranking	IUCN	Proposed/ Candidate for Fed listing Y/N
Haemorhous mexicanus	House Finch	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N
Himantopus mexicanus knudseni	Hawaiian Stilt or Aeo	Endemic	Y	–	–	–	Y	N	E	T2	LC	N
Himatione sanguinea	Apapane	Endemic	–	–	Y	Y	Y	N	N	G3	LC	N
Horornis diphone	Japanese Bush-Warbler	Introduced	–	Y	Y	–	Y	N		G5	LC	N
Leiothrix lutea	Red-billed Leiothrix	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N
Lophura leucomelanos	Kalij Pheasant	Introduced	–	–	–	Y	Y	N		G5	LC	N
Mareca penelope	Eurasian Wigeon	Indigenous	Y	–	–	–	–	N		G5	LC	N
Nycticorax nycticorax	Black-crowned Night-Heron	Indigenous	–	–	–	–	–	N		G5	LC	N
Paroaria coronata	Red-crested Cardinal	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N
Pavo cristatus	Indian Peafowl	Introduced	Y	–	–	Y	Y	N		G5	LC	N
Phaethon lepturus	White-tailed tropicbird	Indigenous	–	–	–	Y	–	N		G5	LC	N
Phoebastria immutabilis	Laysan Albatross	Indigenous	Y	–	–	–	–	N	N	G3	NT	N
Pluvialis fulva	Pacific Golden-Plover	Indigenous	Y	Y	Y	Y	Y	N		G5	LC	N
Psittacula krameri	Rose-ringed Parakeet	Introduced	–	–	–	–	Y	N		G5	LC	N
Pternistis erckelii	Erckel's Francolin	Introduced	–	–	–	Y	Y	N		G5	LC	N
Puffinus newelli	Newell's Shearwater	Endemic	–	–	–	–	Y	N	E	G2	CR	N
Pycnonotus cafer	Red-vented Bulbul	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N

TaxonName	CommonName	Distribution	DMR	KTA	KLOA	MMR	SB	Oahu Endemic Y/N	Federal Status	NatureServe Ranking	IUCN	Proposed/ Candidate for Fed listing Y/N
Pycnonotus jocosus	Red-whiskered Bulbul	Introduced	–	Y	Y	Y	Y	N		G5	LC	N
Sicalis flaveola	Saffron Finch	Introduced	–	–	–	–	Y	N		G5	LC	N
Streptopelia chinensis	Spotted Dove	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N
Zosterops japonicus	Warbling White-eye	Introduced	Y	Y	Y	Y	Y	N		G5	LC	N

MEMORANDUM FOR RECORD

Schofield Barracks West Range Fire June 2-July 14, 2022

1. OVERVIEW: The fire at Schofield Barracks burned a total of 22.7 acres, 14.8 acres of which is designated critical habitat for the Oahu Elepaio (map at Enclosure 1). This exceeded the Army's 3.7 acre per year allowance for the loss of Elepaio critical habitat. The fire also impacted two occupied elepaio territories. The Army Wildland Fire Program (Army Fire) coordinated fire-fighting actions and resources which included Aviation Brigade helicopters. The fire was deemed extinguished on July 14, 2022. The fire primarily burned non-native forest dominated by *Eucalyptus* on the dividing ridge between north and south Pulee gulch. (See illustrative photos in Enclosure 2). ANRPO did not support with a contract helicopter due to the perceived risk to resources and the adequacy of response from Army Aviation assets. Also, as this fire was burning in heavy *Eucalyptus* fuels under tall canopy, the contract company's 100 gallon water bucket would have provided little effect on the fire.

2. GROUND SURVEYS. During ground surveys conducted on July 19, 2022, Natural Resource Staff walked the fire perimeter in order to accurately map the area burned and to assess impacts to listed species, critical habitat and other native taxa. While the fire mainly burned *Eucalyptus* forest, native trees, shrubs and ferns were also present in the burn footprint including, *Metrosideros polymorpha*, *Psydrax odoratum*, *Acacia koa*, *Dodonaea viscosa* and *Odontosoria chinesis*. Please find enclosed a full list of plants and animals impacted in this fire (Enclosure 3).

Special survey effort focused on determining whether federally listed Oahu elepaio birds were directly affected by the fire. One team of biologists surveyed along the north and south Pulee stream corridors to assess whether previously documented elepaio territories were affected. The second team paid close attention to elepaio presence while mapping the burn perimeter. On the burn edge in south Pulee, the fire burned strawberry guava (*Psidium cattleianum*) forest within the territory utilized by a breeding pair and two first-year hatchling elepaio. Take as defined under the ESA means "to harrasss, harm, pursue, hunt, shoot, wound or kill" and applies to federally listed wildlife. Although the elepaio were observed alive during the survey, the fire burned strawberry guava forest, which is favored habitat of Oahu elepaio. The two hatch-year birds were observed at the very margin of this unburned strawberry guava forest. Thus, it is the Army's determination that these four elepaio were harmed and thus 'taken' by the fire within this south Pulee territory. In addition, the margins of an elepaio territory in north Pulee were burned. Again, trees along this margin included strawberry guava. During the survey, this territory was occupied by one breeding pair of elepaio. Using the same analysis as above, the Army has concluded that this pair of elepaio were also 'taken' by the fire. Based on these survey results, the Army has taken 6 elepaio birds by harming them through burning portions of two occupied territories. This exceeds the one pair per year incidental take allowance from the Oahu BO. It should be noted that in Enclosure 1, the territory polygons don't overlap with the fire polygon. This is because the territories represent the core area used by the elepaio occupying it, but during post-fire surveys, birds were observed using areas outside of this core territory. Also, fledglings eventually disperse out of the territory entirely, into surrounding areas

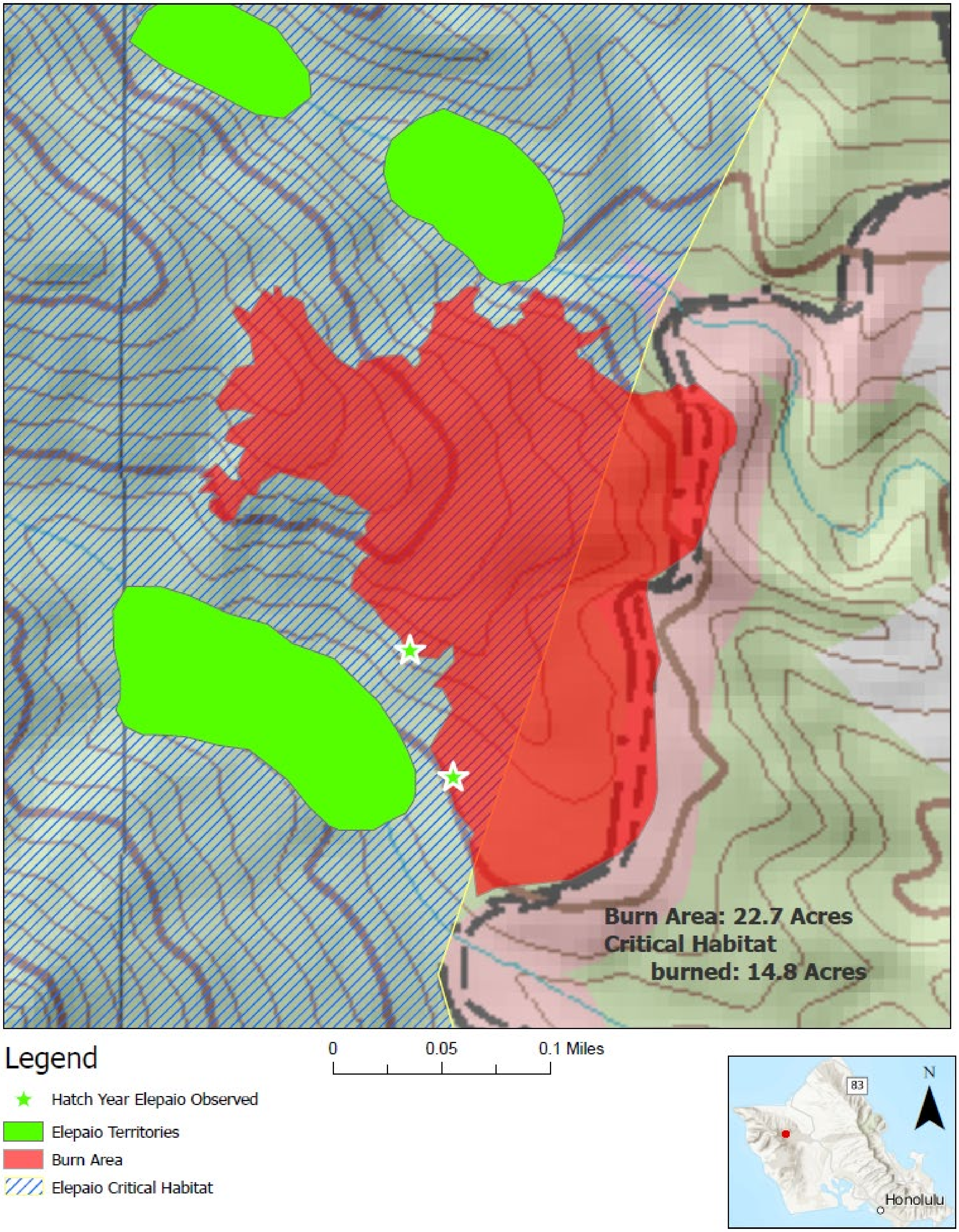
3. CAUSE. The fire appears to have been ignited by a 2.75" rocket fired from Apache helicopters into the impact area below the firebreak road during training around noon on June 5, 2022. The burn index at the time of ignition was 'yellow'. This training is included in our Oahu Training Areas Biological Assessment and the Oahu BO on page 8. The ability to fire 2.75" rockets at Schofield Barracks is essential training for 25th Infantry Division soldiers stationed in Hawaii. The only other location where

these rockets can be used is at Pohakuloa Training Area on Hawaii Island where deployment costs and logistics limit the frequency of training. The Army recognizes the seriousness of this incident and the exceedance of the Army's critical habitat modification allowance and the Oahu elepaio take allowance. As a result, the Army conducted an after action review meeting (AAR). In attendance were Army Wildland Fire, the Training Support Systems Staff, Range Control leadership and the Combat Aviation Brigade. The focus of the AAR was to identify and address challenges, thus minimizing the chance of such a fire reoccurring.

4. AFTER ACTION REVIEW: The AAR identified challenges with the Appropriate Management Response (AMR) approach adopted in the U.S. Army Garrison, Hawaii's Integrated Wildfire Management Plan (IWFMP) for fires starting below the firebreak road. It had become practice to let fires burn when contained within the firebreak road system while using indirect suppression tactics. Army Fire decision makers felt confident that fuels reduction achieved during the April 2022 prescribed burn at SB had adequately reduced the risk of escape. While fires are never allowed to just "burn themselves out," it is common practice of taking an "indirect attack" fire suppression tactic, rather than a "direct attack" suppression tactic, as this is often the safest and best option for firefighters in unexploded ordnance dudded areas. Utilizing the indirect attack suppression tactic, Army Fire utilized roads and natural or man-made barriers to help stop the fire spread for several days incuding several days of burn outs along the north Fire break road as the fire approached their containment lines. Army Fire was utilizing the fire break and previously burned vegetation from the prescribed fire to help keep the fire in check when a spot fire occurred over the fire break. For this fire, helicopter were not requested until day 3.

Unprecedented drought conditions during the course of this fire led to fire spotting over long distances, which has never before been observed at Schofield Barracks. This fire was very difficult to extinguish as ground access for fire fighting was hindered by steep terrain and unexploded ordnance. The fire burned for nearly 1.5 months in heavy Eucalyptus fuels. At present, Army helicopters are on 2-hour and 4-hour call back times for weekdays and weekends, respectively, during daylight hours from 06:00 AM to 06:00 PM. Army Fire is currently evaluating the changing conditions of the fire environment and the increased response needs to combat longer and drier fire seasons. As a result, the Army is creating a step-up-staffing plan that utilizes staffing classes (SC) which raise or lower based off the severity of the fire season. Each SC will have requirements that the Army will implement to be proactive in reducing unwanted wildfires and the potential for long duration fires. As an example, this proactive approach to prescribe increasing firefighters, equipment and or helicopters as needed, depending on the SC. Furthermore, the Army realizes that it must put fires out immediately using all available means, including direct attack with aircraft if warranted. In addition, the Army will not conduct live-fire training under red flag weather conditions. Once the step-up plan is approved by the Senior Commander, this increased attention and response adequacy for fires is an extremely positive change.

Enclosure



Burn Area: 22.7 Acres
Critical Habitat
burned: 14.8 Acres
Legend
Hatch Year Elepaio Observed
Elepaio Territories
Burn Area
Elepaio Critical Habitat
0
0.05
0.1 Miles
83
N
Honolulu

Enclosure 2: SB Fire Photos

The fire burned primarily Eucalyptus-dominated forest

Area below the firebreak opposite critical habitat which burned before the fire jumped above.

Eucalyptus stand burned on ridge

Ohia (Metrosideros polymorpha) affected by the fire.

Enclosure 3: SB Fire Species List

Scientific Name	Common Name
NON-NATIVE PLANTS	
Andropogon virginicus	
Ardisia elliptica	Shoebutton Ardisia
Arundina grammitifolia	Paperbark
Araucaria collumnaris	Norfolk Pine
Blechnum appendiculatum	
Buddleja asiatica	
Casuarina glauca	
Clidemia hirta	Koster's curse
Eucalyptus robusta	
Megathyrsus maximus	Guinea grass
Nephrolepis brownii	
Psidium cattleianum	Strawberry guava
Schinus terebinthifolius	Christmasberry
Spathodea campanulata	african tulip
Syzigium cuminii	java plum
Toona ciliata	Australian Red Cedar

Scientific Name	Common Name
NATIVE PLANTS	
Acacia koa	koa
Alyxia stellata	maile
Cocculus orbiculatus	huehue
Cyperus hypochlorus var. hypochlorus	
Dianella sandwicensis	ukiuki
Dicranopteris linearis	uluhe
Dodonaea viscosa	aalii
Gahnia beechyi	
Leptecophylla tameiameiae	pukiawe
Metrosideros polymorpha	ohia
Odontosoria chinesis	palaa
Psydrax odoratum	alahee

NON-NATIVE ANIMALS	
Acridotheres tristis	common myna
Estrilda astrild	common waxbill
Haemorhous mexicanus	house finch
Zosterops japonicus	Japanese white-eye
Lophura leucomelanos	kalij pheasant
Cardinalis cardinalis	northern cardinal
Leiothrix lutea	red-billed leiothrix
Pycnonotus cafer	red-vented bulbul
Copsychus malabaricus	white-rumped shama

NATIVE ANIMALS	
Chasiempsis ibidis	Oahu elepaio
Chlorodrepanis flava	Oahu amakihi

Appendix ES-9

MEMORANDUM FOR RECORD

Makua Fire June 13-15, 2022

June 13, 2022:

The fire was reported at Makua Military Reservation south of the south fire break road between the Hibiscus Patch and Koiahi gulch on June 13, 2022 at approximately 0130. Army Wildland Fire got a tip about the fire at about 1230 and proceeded to Makua to check on the report as no Range Control personnel were on duty. Army Wildland Fire notified Kapua Kawelo at approximately 0130. Kapua Kawelo received the notification at 0545. The fire was reported to have started mid slope. As there is no reason anyone would have been mid slope in the *Megathyrsus maximus* and *Leucaena leucocephala* scrub at that time, UXO is suspected to be the cause.

Image Redacted
Sensitive Information
Available Upon Request

ARMY NATURAL RESOURCES PROGRAM O'AHU

Map of full fire extent at Makua Military Reservation

Kapua Kawelo and Joby Rohrer worked to coordinate fire response while commuting to work, via the following actions:

- Pilot Josh Lang (K&S Helicopters) was notified and began preparations for response.
- Cooperators listed as having morning flight operations were called and fortunately agreed to delay or reschedule as needed (KMWP, Pono Pacific).
- Range access was confirmed through Army Wildland Fire and Range Control.
- OVPRI was informed that flight operations were going to likely be utilized to support fire fighting.
- Green Team Supervisor (Chelsea Tamayo) was informed that she was needed in Makua.
- Blue Team Supervisor (David Hoppe-Cruz) was informed that he was needed in Makua.
- Conservation Manager (Jane Beachy) was informed of the situation

Left: Fire photo taken at approximately 0200.
Right: Picture from Army Wildland Fire indicating fire location

Fire status at 0645

At 0745 Joby Rohrer and Chelsea Tamayo met pilot Josh Lang at SBS and flew to Makua with all the required firefighting gear for helicopter operations. On entering the valley, they observed a Blackhawk on site, but it had not yet started bucket drops.

When staff flew into the valley at 0800, the fire had crested to the top of Ohikilolo above the Hibiscus Patch and there were many hot spots in the burned area still actively smoldering. The fire was actively spreading on both flanks. On the west flank (ocean side), the fire was burning through the Hibiscus Patch. Approximately1/2 to 2/3 of the patch had already burned. On the east flank (Koiahi side), the fire was actively burning in small sub gulches. Luckily there is much exposed rock cliff at higher elevations in this area and thus spread had been limited to the lower slopes. There was no fire seen inside of the South firebreak.

Josh landed at the upper dip pond and immediately began bucket drops in the Hibiscus Patch. His efforts stopped more of the Patch from burning and throughout the day he continued to return to the Patch as needed, if flare-ups were spotted. Josh was critical to the success of the fire suppression efforts. While he was flying approximately 100 gallons of water in each bucket, as compared to the Army ships large capacity buckets (approximately 660 gal for the Blackhawk and 2000 gal for the Chinook), his speed and accuracy quickly addressed flare-ups before they became larger issues. Josh did 3 fuel cycles and worked on the fire for more than 7 hours (6.8 Hobbs not counting ferry time to Turtle Bay Resort). See timetable summary below.

June 13, 2022 Air Asset Summary for K&S Helicopter N545PH

Time	Note	Approximate number of water buckets completed on fuel cycle
0745	Josh arrives at SBS and picks up Joby and Chelsea	
0800	Arrive at Makua and conduct aerial survey	
0805	Aerial survey complete and water drops started. Hit flare ups in the patch, near firebreak road, Koiahi cliffs.	25
0930	Depart to DMR for fuel	
0945	Josh returns from fueling and continues bucket drops in areas noted above	30
1135	Depart to DMR for fuel	
1155	Josh returns from fueling and continues bucket drops in areas noted above	30
1340	Depart to DMR for fuel	
1410	Josh returns from fueling and continues bucket drops focusing mostly on the western flank	15
1500	David Hoppe-Cruz maps fire with Josh	
1510	Mapping complete, David Hoppe-Cruz assists Josh with packing up gear	
1525	Josh departs to Turtle Bay	

Josh coming to upper dip pond while Blackhawk 440 heads for the lower dip pond.

David Hoppe-Cruz and Jon Winchester arrived in Makua about 0945 and 1015 respectively. David tied in with Army Wildland Fire on a high point inside the South Fire break road. Jon joined Chelsea and Joby at the upper dip pond. A disadvantage to having staff fly to the fire is that they have no transport when on the ground. However, this was remedied by dispatching staff from the baseyard to meet them in the field. ANRPO staff were critical throughout the day spotting flare-ups, educating Army Wildland Fire as to where the resources were located, and thus recommending where air assets needed to be focused.

The 440 Blackhawk based its operations out of the lower dip pond and focused its effort on the west flank and ridge crest. The 440 did three fuel cycles and was working throughout the day under the direction of Army Wildland Fire. Some drops were more effective than others. The configuration of fire-fighting gear on the 440 is difficult, with the bucket on a short (approximately 40') lead line. This prevents the pilots from getting very close to the fire. In addition, airspeed needs to be maintained. If the ship slows too much or comes to a hover, the resulting downdraft can increase fire activity and cause rapid spread. As such, the 440 had to keep elevated well above the fire and keep airspeed up to avoid flare-ups due to downdraft. However, despite this the 440 was an extremely valuable addition to the fire, as it was able to deliver massive amounts of water to the fire with its large capacity bucket. See timetable summary below.

June 13, 2022 Air Asset Summary for Blackhawk 440

Time	Note	Approximate number of water buckets completed on fuel cycle
0730	Arrive at Makua	
0800	Begin bucket drops focused on west flank and ridge crest	15
0930	Depart to Wheeler for fuel	
1015	Return and begin bucket drops same areas as above	15
1150	Depart to Wheeler for fuel	
1230	Return and begin bucket drops same areas as above	15
1410	Depart to Wheeler for fuel	
1445	Return and begin bucket drops same areas as above	8
1525	Departs for Wheeler	

Blackhawk 440 dousing fire on ridge crest while maintaining airspeed to prevent downdraft

The Chinook 204 Hill Climber operated off the upper dip pond and had a long line (approximately 200') configuration. Unfortunately, it very quickly had bucket issues after their first four drops and departed to Wheeler. This was unfortunate as their massive bucket, coupled with a long line, would have been a great asset, as it would not have the downdraft issues of the 440 Blackhawk.

June 13, 2022 Air Asset Summary for Chinook 204 Hill Climber

Time	Note	Number of water buckets completed on fuel cycle
1145	Arrives at upper dip pond and starts to deploy bucket	
1205	Begins bucket drops complete approximately 4 drops	4
1230	Halts and sets down with bucket issues	
1305	Departs Wheeler to get another bucket	
Approx. 1745	Returns to Makua and begins drops on western flank	9
Approx. 1845	Departs to Wheeler	

Throughout the day the fire continued to flare-up on the western flank. In late morning the fire spread westward along the firebreak road below unburned areas located just up slope. Once it reached the unburned fuels the fire rapidly spread upslope due to upslope winds and preheated fuels. This run quickly subsided when the fire hit the crest. Otherwise the continued spread from the western flank towards the ocean and Akoko Patch was kept to a slow pace with constant water drops. There was one last flare-up on the western flank at the end of the day (approximately 1745). The Chinook returned to Makua around 1745, and according to Army Wildland Fire, was very effective at addressing late afternoon flare-ups and effectively prevented the fire from reaching the Akoko Patch. The Chinook delivered about 9 loads and completely doused all the hot spots. The only consideration to add here is that the massive amount of water held by the Chinoook bucket (approximately 1,500 gallons) could damage resources such as those in the Hibiscus Patch. There were no drops done by 204 in the Hibiscus Patch and this should be considered in future.

On the western flank (right side of photo), the fire spread along firebreak road, then exploded upslope into unburnt fuels.

There were a few flare-ups in the Hibiscus Patch throughout the day. Fortunately, with ANRPO staff closely monitoring the fire and directing Josh, these were quickly addressed. For future fires, it is important to consider the impacts of dropping water in the vicinity of endangered plants. Fortunately, the flare-ups were extinguished with Josh's smaller bucket and at no time did we consider directing a larger Army helicopter to the Hibiscus Patch.

View from the firebreak road looking up at unburned sections of the Hibiscus Patch post fire

The Eastern flank had a couple of flare-ups throughout the day, but ANRPO staff did not direct many buckets to this area, and focused resources on the western flank, which was closer to endangered taxa. Flare-ups on the eastern flank were in small sub-gulches or on ridges surrounded by rocks. Fortunately much of the upper elevation in this area is bare rock, thus providing a natural barrier and preventing spread.

Spread was very minimal over the top of Ohikilolo into Keaau. The 440 Blackhawk was effective at addressing the fire in this area and Josh was not directed to the ridge crest at all.


Extent of burn as of mid-afternoon June 13. The burned area extends from the mouth of Koiahi, to below the Hibiscus Patch, and up to the ridge crest. Unburnt sections of the Hibiscus Patch are visible and primarily consist of green *Dodonaea viscosa*.

June 14, 2022:

On the morning of the 14th, David Hoppe-Cruz arrived at Makua at 0545 and met with Army Wildland Fire on site at the location they had held the previous day. For future reference, Range Control staff arrive on site at 0500; if access is required earlier, ANRPO staff should take the key fob. There were two hot spots visible, one on the western edge near the Upper Akoko Patch and one on the east edge. No movement was observed at either site. The spot on the eastern end was a tree stump observed during aerial mapping that had burned into the ground and was continuing to smoke, but there was no unburned fuel in the immediate area. Josh arrived at 0714, hooked up the bucket and began water drops at 0720. Between his first load and 0800, he all but extinguished the stump on the eastern edge of the burn and put enough water on the hotspot on the western edge such that no smoke or steam was visible by 0800. At 0800, Josh landed and remained on stand-by until an Army Blackhawk arrived at 0810. Army air support had been requested for 0700; they are habitually late. Army Wildland Fire informed us that the Blackhawk would remain on standby at the lower dip pond. At this point, Josh loaded his line and bucket into his helicopter (MD500) and departed Makua at 0825. At 0847, small amounts of smoke were observed coming from the hotspot on the western edge, but by 0915, no smoke was visible in the area; the hotspot burned out on its own.

June 14, 2022 Air Asset Summary for K&S Helicopter N545PH

Time	Note	Approximate number of water buckets completed on fuel cycle
0714	Arrive at Makua and conduct aerial survey	
0720	Begin bucket drops.	12
0800	Shut down at Makua	
0825	Depart Makua	

At 0950, Dave Hoppe-Cruz was relieved on site by Kapua Kawelo. Kapua remained on site until 1530. She surveyed for hot spots with the Army Wildland Fire crew at both of their observation points. She discussed challenges with getting Army helicopters to arrive on scene when requested. There was one flare up on the lower eastern flank of the fire at 1330 and the Army fire truck put this out with water from their tanker. The Blackhawk that was on standby at Makua departed at 1230 to get lunch. They were not replaced until 1515 by the Blackhawk crew that had been fighting the SB fire that morning. Kapua and

Army Wildland Fire lead Justin went over and met the Blackhawk crew. Justin explained the firefighting game plan and Kapua explained the importance of their enduring support in these operations and described the valuable endangered species their work was helping to protect. The Blackhawk dropped two buckets on one hotspot at 1630. At the end of the day, Army Wildland Fire considered the blaze 90% contained.

<u>14 June Air Asset Summary for Blackhawks, unknown tail numbers</u>

Time	Note	Number of water buckets completed on fuel cycle
0810	Arrive at Makua and shut down	
1230	Depart for lunch	
1515	Arrive in Makua and shut down	
1630	Drop 2 buckets on Western flank and depart for Wheeler	2

<u>June 15, 2022:</u>

The Army Wildland Fire crew remained on site the whole day and had an Army helicopter on 2 hour call back for the day. They never needed to engage the helicopter for water drops. The fire was declared out at end of the day.

Map of fire in relation to known rare plant locations. The red polygon indicates extent of burn. The red arrow shows the approximate point of ignition.

Key points from fire response:

1. Quick deployment from SBS greatly increased speed of response.
2. Army Wildland FIRE should have home numbers/backups in case they need to reach DPW Environmental/ANRPO in the middle of the night.
3. Effective coordination and communication between Army Wildland Fire and the Army Natural Resources Program on Oahu enabled an effective strategy.
4. Upper dip pond was key in enabling multiple ships to work the fire at the same time. Army ships are slower than Josh, and thus it is good for Josh to have a separate pond to use.
5. Short lead line on Army Blackhawks continues to be difficult, as they cannot slow the bucket or hover and drop. If they slow their airspeed the resulting rotor wash fans the fire and can increase fire activity and spread.
6. Long line configuration on the Chinook was looking like it would be highly effective but mechanical bucket issues interfered.
7. Major challenges getting timely and accurate Army helicopter support for fire-fighting. Army Wildland Fire said that if the Army helicopter had been on site dropping water at 0700 Monday, the fire could have been stopped before it started moving west toward the Hibiscus Patch.
8. The fire spread in a matter of minutes. Rendering support at first light could make the difference between 10 acres and 100 acres.
9. Take key fob if Makua access is needed before 0500.
10. It is good for Army Wildland Fire to send staff to meet Army helicopter crews to give an overview of the game plan, and engage them in the mission.

June 21, Post-Fire Survey Results:

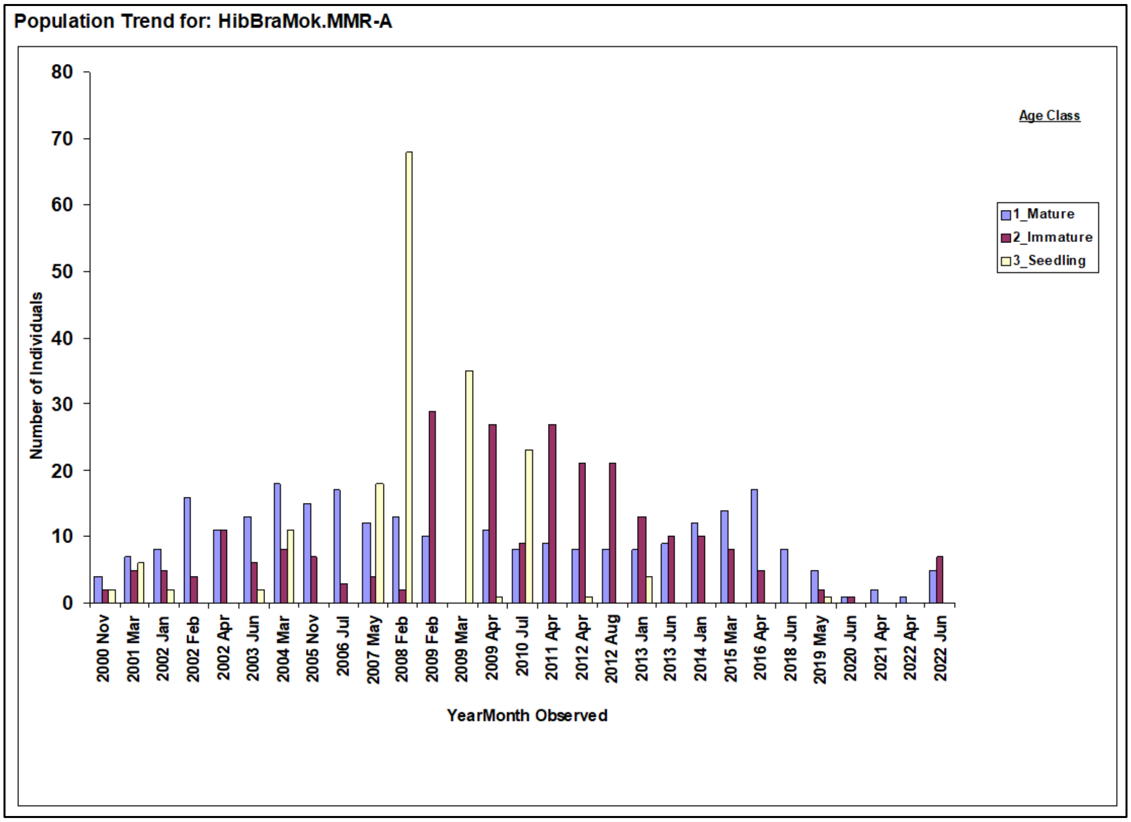
In total, the fire burned 96 acres of dry scrub habitat outside of the firebreak road, on the north slope of Ohikilolo ridge, between Koiahi gulch to the east, the end of Ohikilolo ridge, where it runs parallel to the coast, to the west, the firebreak road to the north, and the crest of Ohikilolo ridge to the south. It burned a large portion of the Ohikilolo Lower MU, spanning an elevation range of 280 – 1200ft, including an actively managed area, the Hibiscus Patch, which is home to an MFS (Manage for Stability) population of *Hibiscus brackenridgei* ssp. *mokuleianus*. ANRPO staff conducted a post-fire survey on June 21, 2022. The survey focused on the Hibiscus Patch and resources therein. In addition, the lower reaches of a wild unmanaged GSC (Genetic Storage) *Tetramolopium filiforme* population was burned. ANRPO staff conducted this survey on August 10, 2022.


ANRPO staff conducting post-fire survey in the Hibiscus Patch

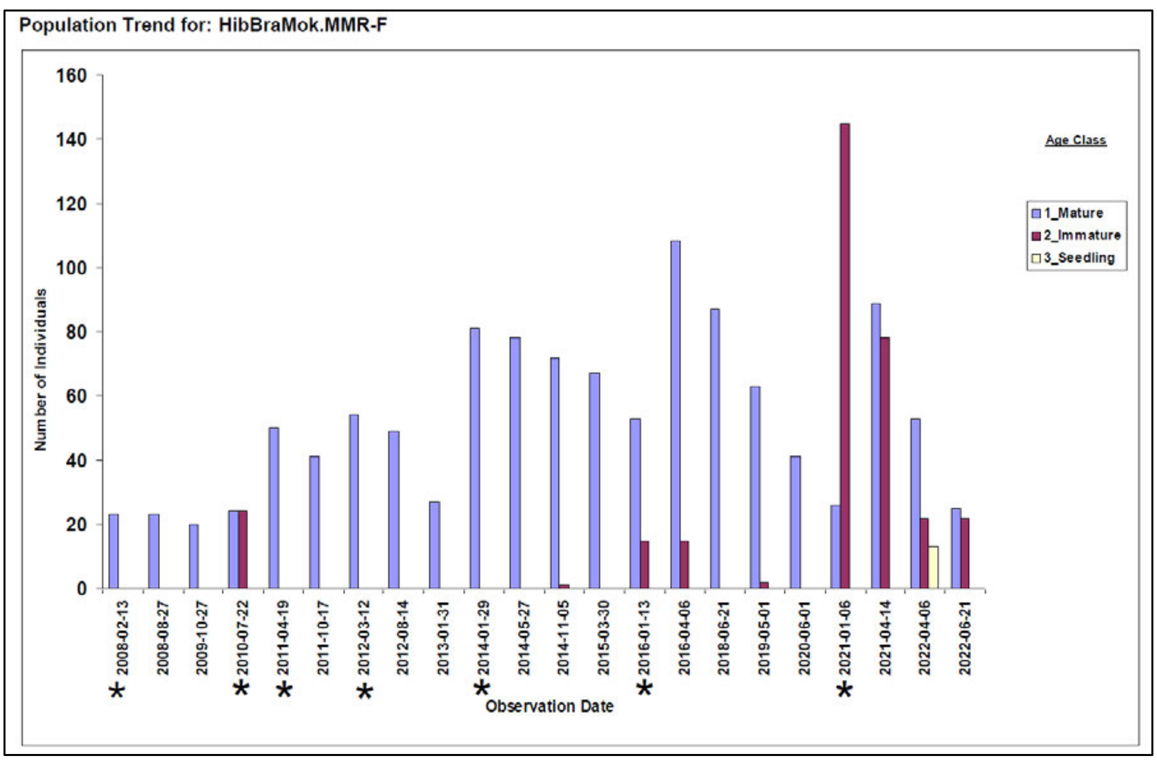
Direct impacts to natural resources, including *Hibiscus brackenridgei* ssp. *mokuleianus*

The fire impacted two *H. brackenridgei* sites, including the *in situ* site (MMR-A) and an augmentation (MMR-F). Both are located in the Hibiscus Patch. The Hibiscus Patch includes steep rocky terrain on the western end (where much of the *in situ* population is located), a rocky drainage through the middle, and grassy sections on rock steps on the eastern side of the patch. ANRPO staff conduct aggressive weed control within the patch to reduce fuels and promote native taxa. The vegetation consists of outplanted species (mainly *Erythrina sandwicensis*, *Myoporum sandwicensis*, *Dodonaea viscosa*, *Chenopodium oahuense*) in addition to weedy grasses and shrubs (*Leucaena leucocephala*, *Megathyrsus maximus*, and *Melinus repens*). Outside this patch, where no management occurs, are monotypic stands of *L. leucocephala* in the overstory and *M. maximus* and *Leonotis nepetifolia* in the understory, which stretch unbroken across the lower slopes of Ohikilolo ridge,and reach upslope to the rocky cliffs and ledges above, closer to the ridge crest.

Individuals of Hibbramok MMR-A were first discovered in 2000 during plant surveys. This population counted towards stability goals of the Implementation Plan. Regular weed control began in 2001. In 2008 the first of the augmentations of *H. brackenridgei* (MMR-F) occurred and many reintroductions have happened since then. Reintroductions to this population have inflated numbers over the years (see Population Trend graphs below), however, there is an overall decreasing trend in *H. brackenridgei* survivorship. Numbers of both the wild and reintroduction populations have oscillated, but shifted toward an overall decline, perhaps due to shorter rainy seasons in recent years and lack of recruitment.



Population trend at Hibbramok.MMR-A from 2000-2022, including June 2022 (post fire).



Population trend at Hibbramok.MMR-F from 2008-2022, including June 2022 (post fire).
Asterisks indicate outplanting years.

The fire in Makua exacerbated this decline as many of the plants were affected. At last census before the fire in April 2022, there were a total of 88 plants (53 mature, 22 immature and 13 F1) at MMR-F and 1 mature plant at MMR-A. The post-fire survey was conducted on 21 June 2022, so it is unlikely plant mortality seen was due to other non-fire causes as there were only two months between events. Plants that could not be found were marked as dead, as the fire likely destroyed them and their identification tags entirely. Staff found a total of 47 plants (25 mature, 22 immature, 1 F1 mature, and 10 F1 immature) at MMR-F. This is a 47% decrease post-fire. Interestingly, there was an increase in plants at the wild site (MMR-A): 5 mature and 7 immature. This increase could be attributed to better detection after the fire and more personnel/time spent combing the entire area.

The effects of the fire to each individual plant differed based on its location, the amount of fuel in the surrounding area, and the age of the plant. Larger (older) plants seemed to fare better in the fire, as larger stems contain more water (see pictures below). Terrain played a large part in survivorship. Plants close to large rock formations/walls seemed to have limited damage or none at all. Fuel loads also played a major part in the intensity of the fire. Although recent weed control efforts included cutting back invasive vegetation and spraying with herbicide, there was still enough vegetation – both invasive and native – present to carry fire through the patch. Parts of the Hibiscus Patch with large amounts of charred vegetation indicate higher intensity fires and many plants did not survive in these locations. Type of grass species was also a factor in the fire intensity. Areas where *Melinus repens* was the dominant species seemed to burn less as this grass is wispier and much less robust than *M. maximus*. *Megathyrsus maximus* is known to have a high burn index, and is particularly important to remove from around *H. brackenridgei* and across the entire Hibiscus Patch.

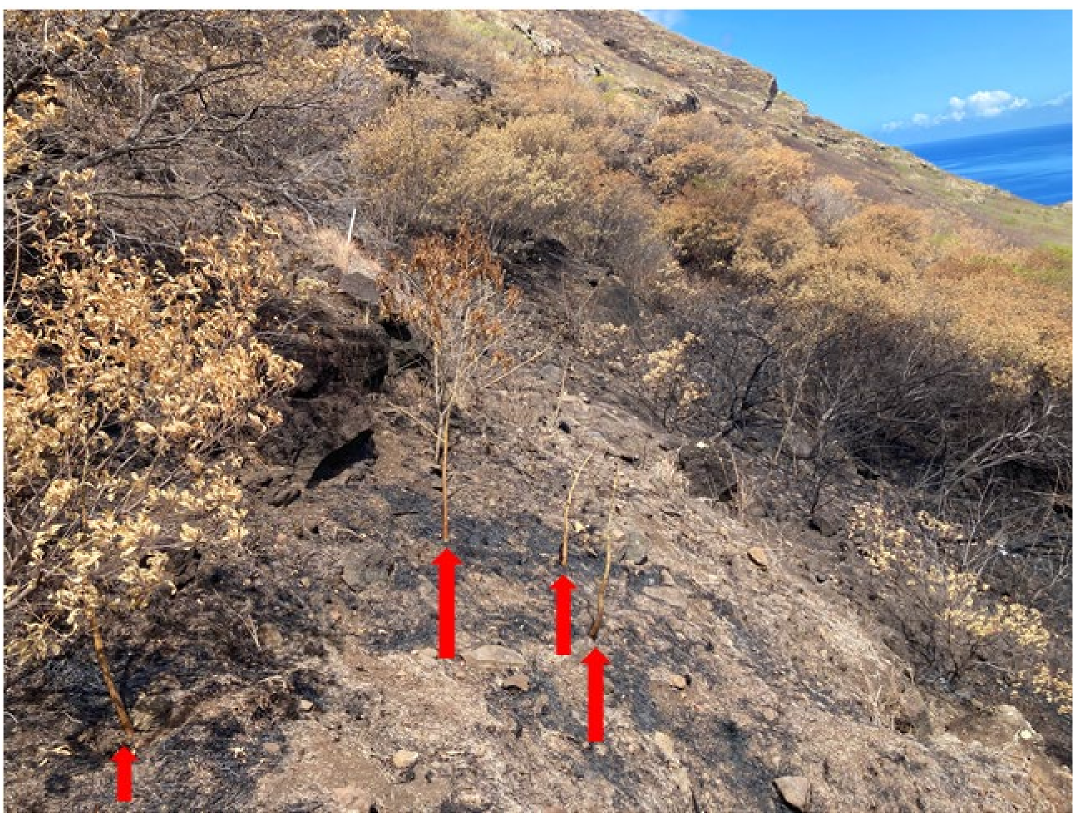
No damage was observed to *H. brackenridgei* from the helicopter water drops.

Effects of fire to a large plant (top) and smaller plant (bottom). The individuals in these photos are not in close proximity to each other. Black char near the plants indicates larger amounts of burnt fuel load and hotter fire temperature. The smaller individual (bottom) is dead, while the larger plant (top) still has a few green leaves and newly emerging leaves, suggesting it may recover.

New leaves emerging from singed or burned *H. brackenridgei*

To limit time spent performing weed control in the Hibiscus Patch, common native plantings were initiated in 2016. Species include: *E. sandwicensis*, *D. viscosa*, *M. sandwicensis*, *Bidens cervicata*, *C. oahuense*, *Eragrostis variabilis* and *Sida fallax*. Other species that occur naturally in the patch include *Psydrax odorata*, *Santalum ellipticum*, *Abutilon incanum*, *Waltheria indica*, *Heteropogon contortus* and *Doryopteris anglica*. All of these species were affected by the fire, with patchy damage across the Hibiscus Patch (see below).

Patchy distribution of fire effects as seen by living *D. viscosa* interspersed in a sea of burnt *D. viscosa*.



The large naturally-occurring *E. sandwicensis* (top) may survive the effects of the fire while smaller outplanted *E. sandwicensis* (indicated by red arrows) will probably not survive (bottom).

There may be a silver lining to the fire, as staff observed previously in areas of Keaau MU burnt during the 2018 Waianae Coast fire, as well as the Kaukonahua fire of 2007. The 2018 fire burned populations of *H. brackenridgei* at Keaau, but the surviving seedbank produced a number of new individuals, which boosted overall plant numbers at the site, and counted towards stabilization goals for the taxon. Staff expect that similar results may be seen at the Hibiscus Patch in Makua. Post-wet season surveys will be conducted to determine the ultimate effects of the fire, including census monitoring of both *H. brackenridgei* sites, analysis of green vs. dead (burned) areas with gigapan imagery, and photopoint reference pictures.

Vegetation management considerations to minimize the impacts of future fires include:

- erecting stone formations (walls) around the perimeter as a fire break;
- planting a green break around the perimeter of the Hibiscus patch; options include succulent species or species which create dense shade that excludes *M. maximus*;
- constructing a bare-dirt fire break around the Patch;
- increasing the diversity of common native outplantings (for example, adding more *S. ellipticum*) to create more dense cover and exclude more grass within the Hibiscus Patch;
- regularly removing all vegetation, especially grasses, from around *H. brackenridgei* quarterly;
- making a smaller footprint of rare resources within the patch and planting *H. brackenridgei* reintroductions in close proximity to each other;
- Work with USGS scientist Lucas Fortini to determine climate impacts and zones for new out-planting areas
- outplanting *H. brackenridgei* near natural topographic features which offer some protection; and
- identifying alternate reintroduction sites elsewhere in Makua which are easier to manage for invasive grasses, and less susceptible to fire.

Given the inability of current methods and person hours to exclude fire from the Hibiscus Patch, a combination of consistent weed control in addition to one or more of these methods will need to be implemented. Staff need to consider ways use limited staff time efficiently.


Impacts of the fire were less severe near natural rock formations, as seen by unaffected vegetation below these the cliffs in this picture.


Minimal fire damage was seen on plants located below rock formations. A surviving *H. brackenridgei* is seen in the right foreground, next to the rock outcropping.

Grim population trends and poor survivorship at both the wild and reintroduced *H. brackenridgei* sites indicate that the extreme environment at Ohikilolo Lower may contribute to a shorter lifespan and reduced survivorship of the next generation of plants. However, staff observations of newly found wild recruits after the 2018 Keaau fire and the 2007 Kaukonahua fore are encouraging, and hopefully will be replicated here. Creating a more resilient outplanting area to supplement the wild population can be done by greatly reducing the number of outplants and limiting planting areas to and around rock formations.

Impacts to infrastructure

The fire also damaged the two water catchments in the Hibiscus Patch. Both are used to support grass control efforts as well as outplanting efforts. New gutters, hoses, and fixtures are needed to restore the catchments to full functionality.

Catchment with gutter and hoses melted by the fire

The edges of the Hibiscus Patch are marked by Seibert Stakes topped with blue reflective discs. These make it easier for pilots to spot the patch and focus water drops in the correct area. Some Seibert Stakes were burned and will be replaced. Others had minimal to no damage; these were generally had little to no grass around them, and were elevated above the ground on rebar.

Left: undamaged Seibert Stake. Right: fire-damaged, melted Seibert Stake

Direct impacts to natural resources, including *Tetramolopium filiforme* ssp. *filiforme*

The upper reaches of the fire burned a portion of *in situ T. filiforme* ssp. *filiforme* (population MMR-H). The western portion of the population was impacted the most. Fire damage was severe in some areas of this population, as evidenced by ash and bare dirt on the ground. Other areas were less intense, which could have been attributed to the terrain. The terrain in this area consists of steep, north-facing, 50 ft tall rocky cliffs interrupted by narrow shelves with sparse vegetation. The vegetation consists mostly of weeds, including *M. repens*, *M. maximus*, *Pluchea carolinensis*, *L. leucocephala*, *Ageratina adenophora*, *Grevillea robusta*, and *Melia azedarach*. There are some native species in the habitat, including *D. viscosa*, *B. torta*, *S. fallax*, *P. odorata.* Small cracks in the rocky cliff faces are where most of the of *T. filiforme* ssp. *filiforme* plants exist and rappelling is needed to safely monitor the population. The plants are monitored irregularly, and no active management is conducted in the area.

Image Redacted
Sensitive Information
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ARMY NATURAL RESOURCES PROGRAM O'AHU

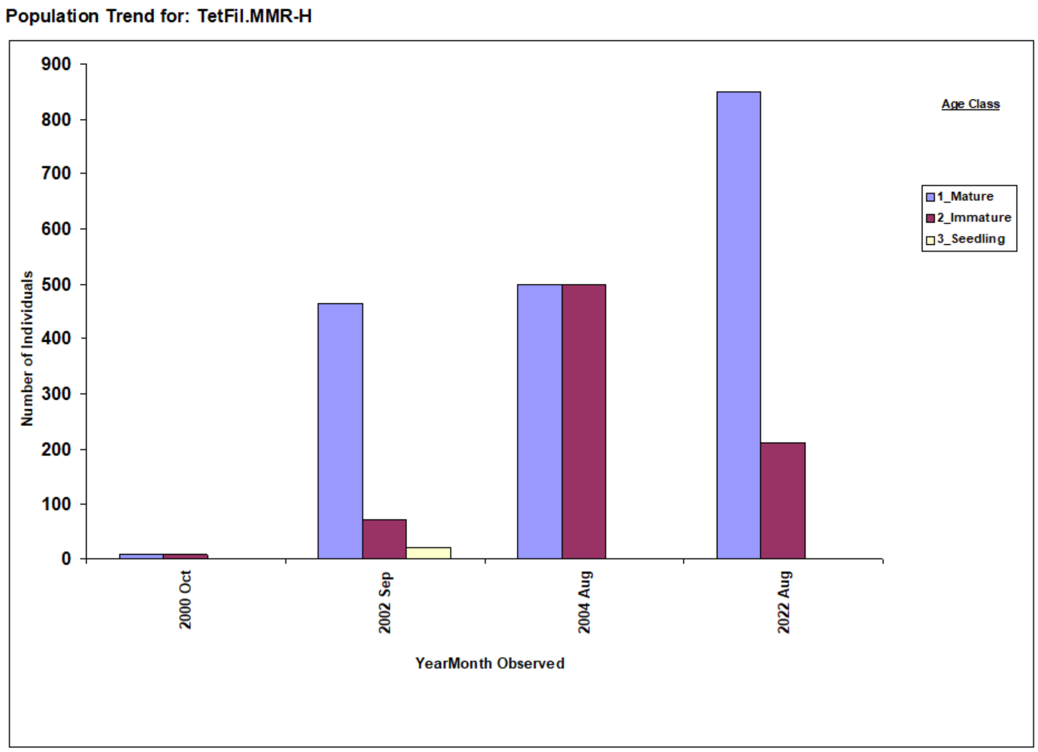
Makua Post Fire Survey area

Ohikilolo Ridgeline showing fire damage on the North side (left) and fewer fire impacts on the South side (right).

Cliff habitat of *T. filiforme* var. *filiforme*.

Survival of *T. filiforme* var. *filiforme* due to natural rock formations that act as firebreaks in cliff habitat.

This population of *T. filiforme* ssp. *filiforme* (MMR-H) was discovered in 2000. Many sites persist along the north-facing slope of Ohikilolo ridge ranging in elevation from about 3000 ft to 1200 ft, with MMR-H being the lowest population at about 1200 ft. The last census conducted in August 2004 estimated that the population total was about 1000 individuals with 500 mature and 500 immature plants, however, the census was not conducted on rope. Post-fire survey numbers were difficult to assess, as the fire intensity varied across the area. A few rappelling lines were utilized to census the population post-fire, however, some of the population total was estimated. The total population at MMR-H was estimated to be 1060 plants (See Population Trend graph below). The total amount observed dead or dried out was 100-150. With the difficulty of determining the true number of burned plants, we extrapolated numbers based on the density of plants in the unburned area as compared to the burned area. We estimated this to be about 20-30% of the 2004 census, or 200-300 plants.



Population trend at Tetfil.MMR-H from 2000-2022, including August 2022 (post fire).

Impacts of fire to *T. filiforme* in open rock areas.

Less intense fire-impacted areas along cliffs did not affect non-native grasses, but had greater impacts to other species: *D. viscosa* and *T. filiforme*.

There is a *Spermolepis hawaiiensis* site known from the top of the ridge within the area affected by the fire. The site has not been surveyed recently and there was no expectation that plants would be up in the summer. Staff will work to conduct a survey next winter to determine possible impacts. *Silene hawaiiensis* is also know from up above the burn impacted area. Staff looked for plants while on the survey but none were found. Other native species affected by the fire include: *D. viscosa*, *P. odorata*, *E. sandwicensis*, *B. torta* and *Eragrostis variabilis*. Large *P. odorata* trees were badly affected and will probably not survive. There was no evidence or damage to the plants due to helicopter water bucket drops. No infrastructure was affected by the fire. The fire intensity was not immense near the top of the ridge, leaving no damage to the fence's structural integrity.

Other concerns with the changing landscape caused by the fire include invasive species incursion. Fire-loving species such as *C. setaceus* are present along the ridge and thrive in post-fire ecosystems. A few Incipient Control Areas (ICAs) for *C. setaceus* already exist along Ohikilolo ridge, neighboring Keaau Valley and Makua Military Reservation. It is important to note that *C. setaceus* ideal habitat is very similar to the open rock that is home to the *T. filiforme* sites on Ohikilolo. In addition, other weeds that invade pastures and open areas such as *Cirsium vulgare* and *Chromolaena odorata* have been discovered within the Makua Military Reservation and have potential to spread into the burned area. There is no active management in this area, as the *T. filiform* population is a genetic storage population (GCS). Census surveys happen irregularly, or as needed. Actions to minimize fire damage to endangered species in the future may include: stopping the spread of invasive *C. setaceus* from expanding on Ohikilolo Ridge, monitoring the *T. filiforme* population (MMR-H) more often and ensuring genetic storage goals are met, and restore habitat to increase fire-resiliency in the surrounding ecosystem.

Endangered plant taxa impacted and/or threatened by the June fire

The table below lists all rare and endangered plants within 1,300 meters of the fire. In total, it includes 21 species represented by 38 Population Reference Sites of at least one individual. This list does not include endangered snails, insects or birds.

MU	Scientific Name	Taxon Code	Population Ref. Code	Taxon Code + Pop. Ref. Code
Ohikilolo	*Bobea sandwicensis*	BobSan	MMR-D	BobSan.MMR-D
Ohikilolo	*Bobea sandwicensis*	BobSan	MMR-G	BobSan.MMR-G
Ohikilolo Lower	*Bonamia menziesii*	BonMen	HNHP	BonMen.HNHP
Ohikilolo Lower	*Capparis sandwichiana*	CapSan	MMR-B	CapSan.MMR-B
Ohikilolo	*Dracaena forbesii*	DraFor	MMR-B	DraFor.MMR-B
Ohikilolo	*Dracaena forbesii*	DraFor	MMR-F	DraFor.MMR-F
Ohikilolo	*Dracaena forbesii*	DraFor	MMR-G	DraFor.MMR-G
Ohikilolo	*Dubautia herbstobatae*	DubHer	MMR-D	DubHer.MMR-D
Ohikilolo	*Dubautia herbstobatae*	DubHer	MMR-E	DubHer.MMR-E
Ohikilolo	*Dubautia herbstobatae*	DubHer	MMR-F	DubHer.MMR-F
Ohikilolo Lower	*Euphorbia celastroides* var. *kaenana*	EupCelKae	MMR-D	EupCelKae.MMR-D
Ohikilolo Lower	*Hibiscus brackenridgei* subsp. *mokuleianus*	HibBraMok	MMR-A	HibBraMok.MMR-A
MMR no MU	*Hibiscus brackenridgei* subsp. *mokuleianus*	HibBraMok	MMR-B	HibBraMok.MMR-B
Ohikilolo Lower	*Hibiscus brackenridgei* subsp. *mokuleianus*	HibBraMok	MMR-F	HibBraMok.MMR-F
MMR no MU	*Hibiscus brackenridgei* subsp. *mokuleianus*	HibBraMok	MMR-G	HibBraMok.MMR-G
Ohikilolo	*Korthalsella degeneri*	KorDeg	MMR-A	KorDeg.MMR-A
Ohikilolo	*Lepidium arbuscula*	LepArb	MMR-B	LepArb.MMR-B
Ohikilolo	*Lobelia niihauensis*	LobNii	MMR-A	LobNii.MMR-A
Ohikilolo	*Lysimachia remyi*	LysRem	MMR-A	LysRem.MMR-A
Ohikilolo Lower	*Melanthera tenuifolia*	MelTenf	MMR-D	MelTenf.MMR-D
Ohikilolo	*Melanthera tenuifolia*	MelTenf	MMR-E	MelTenf.MMR-E
Ohikilolo	*Melanthera tenuifolia*	MelTenf	MMR-I	MelTenf.MMR-I
Ohikilolo	*Neraudia angulata angulata*	NerAng	MMR-A	NerAng.MMR-A
Ohikilolo	*Neraudia angulata angulata*	NerAng	MMR-J	NerAng.MMR-J
Ohikilolo	*Nototrichium humile*	NotHum	MMR-E	NotHum.MMR-E
Ohikilolo	*Pritchardia kaalae*	PriKaa	MMR-B	PriKaa.MMR-B
Ohikilolo	*Pritchardia kaalae*	PriKaa	MMR-I	PriKaa.MMR-I
Ohikilolo	*Pteralyxia macrocarpa*	PteMac	MMR-D	PteMac.MMR-D
Ohikilolo	*Schiedea mannii*	SchMan	NA	SchMan.NA
Ohikilolo	*Silene lanceolate*	SilLan	MMR-A	SilLan.MMR-A
Ohikilolo Lower	*Spermolepis hawaiiensis*	SpeHaw	MMR-A	SpeHaw.MMR-A
Ohikilolo	*Tetramolopium filiforme*	TetFil	MMR-B	TetFil.MMR-B
Ohikilolo	*Tetramolopium filiforme*	TetFil	MMR-C	TetFil.MMR-C
Ohikilolo	*Tetramolopium filiforme*	TetFil	MMR-H	TetFil.MMR-H
Ohikilolo	*Tetramolopium filiforme*	TetFil	MMR-O	TetFil.MMR-O
Ohikilolo	*Tetramolopium filiforme*	TetFil	MMR-P	TetFil.MMR-P
Ohikilolo	*Viola chamissoniana chamissoniana*	VioChaCha	MMR-D	VioChaCha.MMR-D

Appendix ES-10

MEMORANDUM FOR RECORD

Makua Fire August 19-28, 2022

August 19, 2022:

The fire was reported at Makua Military Reservation near the base of the Koiahi ridge, on its North exposure on August 19, 2022 at 1245 hrs. Range Control reported the fire to Army Wildland Fire (Army Fire) just before DPW Environmental was contacted. There was no training in the valley on August 19. Grass cutters were working inside the fire breaks. The ignition point was approximately 50-100 meters above the fire break road in an area dominated by *Leucaena leucocephala* and *Megathyrsus maximus*. Range control staff, Army Wildland Fire, and Environmental share the opinion that the fire was started by a UXO item that was activated in the heat of the day, though this cannot be verified.

Left: Picture taken by Range Control staff soon after ignition
Right: Picture taken at approximately 1315 as fire rapidly spread in dry fuels.
Both: Smoke direction indicates on-shore west wind pushing fire east into the valley

Kapua Kawelo and Joby Rohrer worked to coordinate fire response via the following actions:

- Pilot Josh Lang (K&S Helicopters) was notified and began preparations for response.
- Range access was confirmed through Army Fire and Range Control.
- OVPRI was informed that flight operations were going to likely be utilized to support fire fighting.
- Green Team Supervisor (Chelsea Tamayo) was contacted and queried about her availability to respond.
- Blue Team Supervisor (David Hoppe-Cruz) was contacted and queried about his availability to respond.
- Conservation Manager (Jane Beachy) was informed of the situation.

As ignition occurred on a state holiday, it was challenging to determine what resources to activate. David Hoppe-Cruz was able to go directly to Makua from his house in Makaha and was on site at 1320 hrs. David reported on the fire status and took pictures. Unfortunately, as he came from home he did not have the necessary equipment needed to manage flight operations. Based on David's report of the fire behavior, Joby Rohrer reported to work from home at 1300 hrs. This timing worked out as Josh Lang was not available to report to Makua until 1430 hrs. Joby Rohrer came to base, collected all the required gear using the SOP checklist, checked in with Range Control, and was at SBS LZ by 1420 hrs. Kapua Kawelo coordinated the Army response with Range Control and Army Fire and conducted flight following for Joby Rohrer. Kapua worked hard to get Army choppers on site asap. Initial estimate, because 19 Aug was an ADONSA day was 2 hr report time for the helicopters. Kapua also provided numerous updates to the IOC and range division regarding status of fire and helicopter support.

Joby Rohrer and Josh Lang entered Makua Valley at 1445 hrs from the south, via Kolekole Pass. At that time, the fire was very active and the entire back of the valley was filled with smoke. At the time of ignition, the winds were blowing on-shore out of the west thus driving the fire east toward the back of the valley. As the fire spread east it moved under increasing amounts of upslope dry fuels (again *Leucaena leucocephala* and *Megathyrsus maximus*). These fuels were pre-heated and the flames rapidly spread up to the crest of Koiahi ridge. There was no way to stop this fire spreading up to the ridge crest.

Photo looking down at Koiahi ridge crest. Extreme fire behavior observed as west winds push fire up the valley to the east into and below heavy loads of dry fuel. The kukui canopies of Koiahi gulch are seen in the top of the photo.

Joby Rohrer and Josh Lang landed at the upper dip pond, configured the fire bucket and began water drops at 1455 hrs. Josh focused his efforts on preventing further spread up the valley on the eastern edge of the fire. Fortunately, the lower reaches of the Koiahi ridge are not known to support native resources. Thus, the area with the most extreme fire behavior was not a priority. Josh continued to focus his efforts for the remainder of the day on the east and north fronts of the fire, as these were threatening rare resources (see summary of efforts below). Army Blackhawk 228 arrived in Makua at 1554 hrs (see summary of efforts below). Army Blackhawk 483 arrived in Makua at 1711 hrs (see summary of efforts below). Army CH 47 470 arrived in Makua at 1745 hrs (see summary of efforts below).

Once the fire crested the Koiahi ridge, fire spread slowed on the northwest edge. Unfortunately, the fire was able to travel east below additional upslope fuels before the Army helicopters arrived. This resulted in another period of rapid spread to the north and east. This spread was slowed/stopped by a combination of grass-free rocky cliffs and forest. Once Army ships were on site, all air resources were directed by Army Fire and Environmental to focus suppression on the north and east fire fronts. Army Blackhawks were equipped with a 660 gallon bucket on a short lead line and the Chinook had a massive 2,000 gallon bucket on a long line. The Chinook was very impressive as its capacity is 20 times that of the Hughes 500 bucket and 3 times the Blackhawk bucket in volume. In addition, the long line configuration is far superior to the shorter lead on the Blackhawk as it prevents downdrafts from fanning the fire. All Army helicopters were very effective and took direction well from Army Fire and Josh. The team worked efficiently to combat further fire spread. At the end of the day there were no active flames but many hot-spots remained.

<u>August 19, 2022 Air Asset Summary for K&S Helicopter N545PH</u>

Time	Note	Approximate number of water buckets completed on fuel cycle
1430	Arrive at SBS and pick-up Joby Rohrer	
1445	Arrive at Makua and conduct aerial survey of fire	
1455	Aerial survey complete and water drops started. Worked north and east fire edges.	25
1625	Depart to DMR for fuel	
1640	Josh returns from fueling and continues bucket drops in areas noted above	30
1819	Depart to DMR for fuel	
1830	Josh returns from fueling and continues bucket drops in areas noted above	30
1900	Josh and Joby fly a quick perimeter of the fire and depart Makua	
1910	Joby dropped at SBS and Josh headed to TBR	

<u>August 19, 2022 Air Asset Summary for Army Blackhawk 228</u>

Time	Note	Approximate number of water buckets completed on fuel cycle
1543	Arrive in Makua and set up bucket	
1554	Begin water drops	15
1645	Packed bucket to depart	
1657	Depart Makua	

August 19, 2022 Air Asset Summary for Army Blackhawk 483

Time	Note	Approximate number of water buckets completed on fuel cycle
1711	Arrive in Makua and set up bucket	
1734	Begin water drops	15
1830	Packed bucket to depart	
1842	Depart Makua	

Army Chinook 470 drops 2000 gallons of water on the norther edge of the fire drenching downslope fuels and preventing further spread.

August 19, 2022 Air Asset Summary for Army Chinook 470

Time	Note	Approximate number of water buckets completed on fuel cycle
1735	Arrive in Makua with bucket on. Begin drops immediately.	15
1856	Depart to Makua	

August 20, 2022:

Joby Rohrer debriefed operations with OVPRI and requested permission to park a truck at his private residence to facilitate an early morning response directly to Makua. Permission was granted. Joby report to Makua at 0700 hrs on the morning of August 20, 2022. Josh had been scheduled to return at 0730 hrs to ensure a quick response to any new fire flare-ups. Fortunately, the fire was not very active in the morning. Josh arrived as scheduled and picked up Joby to map the extent of the burn. The shape was synced to ArcGIS online and ANRPO GIS Analyst Linda Koch produced a map, which was used to report up the chain of command (Installation Operations Center). Once mapping was complete, Josh went directly into bucket drops.

Image Redacted
Sensitive Information
Available Upon Request

Map of fire extent as of 0730 hrs on August 21, 2022. Rough perimeter based on beginning of day helicopter survey.

Fire as seen on Saturday August 20 at 0715 hrs. Some smoke is visible on the north and east edges of the fire (photo looks south; east is on the left of the photo).

Army Blackhawk 528 arrived in Makua at 0809 hrs (see summary of efforts below). Army Blackhawk 483 arrived in Makua at 0820 hrs (see summary of efforts below). All three ships worked to suppress occasional flare-ups on the north and east edges of the fire. When there were no flare-ups, they saturated the edges of the fire. Joby Rohrer was on site until 1200 hrs. Green Team Supervisor Chelsea Tamayo reported to Makua at 1130 hrs and was briefed by Joby and Army Fire.

August 20, 2022 Air Asset Summary for K&S Helicopter N545PH

Time	Note	Approximate number of water buckets completed on fuel cycle
0730	Arrive at Makua and conduct mapping with Joby	
0740	Begin water buckets drops	30
0925	Depart to DMR for fuel	
0935	Josh returns from fueling and continues bucket drops	30
1110	Depart to TBR	

August 20, 2022 Air Asset Summary for Army Blackhawk 528

Time	Note	Approximate number of water buckets completed on fuel cycle
0809	Arrive in Makua, recon, and set up bucket	
0821	Begin water drops	15
0943	Packed bucket to depart	
0950	Depart Makua	
1055	Arrive in Makua and setting up bucket	
1105	Begin water drops	15
1330	Packed bucket to depart to Schofield	

August 20, 2022 Air Asset Summary for Army Blackhawk 483

Time	Note	Approximate number of water buckets completed on fuel cycle
0820	Arrive in Makua, recon, and set up bucket	
0840	Begin water drops	15
0945	Packed bucket to depart	
0956	Depart to Makua	
1030	Arrive in Makua and setting up bucket	
1036	Begin water drops	
1140	Departed for scheduled maintenance	

August 21, 2022:

August 21, 2022 Air Asset Summary for K&S Helicopter N545PH

Time	Note-GWS and JL Fly from SBS to Makua	Approximate number of water buckets completed on fuel cycle
1145	GWS and JL Arrive at Makua and relieve DHC	
1200	Begin water buckets drops and brief with Army Fire	20
0130	Depart to DMR for fuel	
0145	GWS and JL back to SBS	
0200	Pau ops JL headed back to TBR	

August 21, 2022 Air Asset Summary for Army Blackhawk 424

Time	Note-GWS and JL Fly from SBS to Makua	Approximate number of water buckets completed on fuel cycle
0725	First UH60 arrives (442)	
0730	442 begins drops	
0925	442 departs for fuel	
0955	442 back on site	
1005	442 resumes drops	
1130	442 departs Makua	

August 21, 2022 Air Asset Summary for Army Blackhawk 528

Time	Note-GWS and JL Fly from SBS to Makua	Approximate number of water buckets completed on fuel cycle
0732	UH60 528 arrives at Makua	
0736	528 begins drops, both ships dropping water	
0900	528 departs for fuel	35 (both ships)
1025	528 back on site	
1130	528 departs Makua	

Key points from fire response:

1. Deployment on a state holiday was slower than ideal. Had the fire started in a more critical site for rare resources a 2-3 hour deployment could cost valuable resources.
2. Army Fire is an outstanding resource. During the June fire, ANRPO made good contacts and were able to provide useful direction. This success clearly strengthened our relationship and made coordination even smoother on this August incident.
3. The upper dip pond position was key in enabling multiple ships to work the fire at the same time. Army helicopters are slower than Josh, and thus it is good for Josh to have a separate dip pond to use.
4. Filling the upper dip pond is clearly a limitation as there are no water lines plumbing it and thus must be filled by trucking or flying water in. This is ineffective and slow. We should support Army Fire's effort to get a permanent water source available to fill the pond.
5. Long line configuration on the Chinook was very effective. The combination of the long line and the 2,000 gallon bucket is by far the most superior air resource on island.
6. While Army helicopters were slow to respond on the 19th they were effective at their water delivery on Aug 19 and 20 while ANRPO was observing. This is an improvement from the June fire.
7. It is beneficial for Army Fire to send staff to meet Army helicopter crews in person on the ground to give an overview of the game plan, convey importance and engage them in the mission.

<u>August 29, Post-Fire Survey Results:</u>

Kapua Kawelo, Jessica Adinolfi and Clay Trauernicht conducted this post fire survey to document native species and federally listed taxa and critical habitat affected. This fire burned 132.6 acres.

Image Redacted
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Map below was produced using MAXAR satellite imagery, more accurate acreage.

Most of the area which burned on lower Koiahi ridge is dominated by introduced vegetation composed of *Megathyrsus maximus* and *Leucaena leucocephala.* Approximately 90% of the burned area occurred where introduced species are dominant. The remaining 10% affected cliffs, shrubland and forest that contained native vegetation. Small rocky ledges on the north side of Koiahi ridge had substantial cover of *Psydrax odoratum*, *Dodonaea viscosa* and *Diospyros sandwicensis*. In addition, on the eastern edge of the fire, native forest dominated by *Diospyros sandwicensis*, *Psydrax odoratum* and *Erythrina sandwicensis* was burned. While no occurrences of endangered plants, animals or critical habitat burned, the fire came within 100 m of four listed plant taxa; *Lobelia niihauensis*, *Korthalsella degeneri*, *Neraudia angulata* and *Melanthera tenuifolia*. Below is a species list of affected plant taxa, and photos of the fire and impacts observed.

Koiahi Fire: Plant Species Affected

Scientific Name	Common Name
NON-NATIVE PLANTS	
Aleurites molucanna	kukui
Ageratina adenophora	hamakua pamakani
Cheilanthes viridis	
Coffea arabica	coffee
Cordyline fruticosa	ti
Grevillea robusta	silk oak
Hyptis pectinata	
Lantana camara	
Leucaena leucocephala	koa haole
Melia azedarach	pride of India
Melinus repens	natal redtop
Neonotonia wightii	
Nephrolepis brownii	
Opuntia ficus-indica	prickly pear
Passiflora edulis	lilikoi
Passiflora suberosa	corky passionvine
Psidium cattleianum	strawberry guava
Rivinia humilis	
Schinus terebinthifolius	christmasberry
Spathodea campanulata	african tulip
Stachytarpheta australis	
Stapelia gigantea	
Syzygium cumini	java plum
Toona ciliata	australian red cedar
Megathyrsus maximus	guinea grass

Scientific Name	Common Name
NATIVE PLANTS	
Artemisia australis	ahinahina
Bidens cervicata	kookoolau
Coleus australis	alaalawainui puaki
Diospyros sandwicensis	lama
Dodonaea viscosa	aalii
Doryopteris decipiens	
Erythrina sandwicensis	wiliwili
Myoporum sandwicensis	naio
Osteomeles anthyllidifolia	ulei
Peperomia blanda	alaalawainui
Plumbago zeylanica	iliee
Psilotum nudum	moa
Psydrax odoratum	alahee
Sapindus oahuensis	lonomea
Schiedea mannii	
Sida fallax	ilima
Waltheria indica	uhaloa

Koiahi Fire Photos

Koiahi fire from firebreak road
en route to blue trail.

Koiahi fire from west,
View from base of ridge.

Native forest burned along blue
trail, lama and wiliwili affected

Lonomea, *Sapindus oahuensis*
burned along fire perimeter

Enclosure 9: Koiahi Fire Photos

Photos below and above: Alahee, aalii and lama trees burned above rocky ledges, Koiahi north slope.

Mixed native and koa haole forest burned below Koiahi cliffs.

View looking northeast below Koiahi gulch at south side of ridge.

frontiers in Conservation Science

ORIGINAL RESEARCH
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The Disconnect Between Short- and Long-Term Population Projections for Plant Reintroductions

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The reintroduction of rare species in natural preserves is a commonly used restoration strategy to prevent species extinction. An essential first step in planning successful reintroductions is identifying which life stages (e.g., seeds or large adults) should be used to establish these new populations. Following this initial establishment phase, it is necessary to determine the level of survival, growth, and recruitment needed to maintain population persistence over time and identify management actions that will achieve these goals. In this 5-year study, we projected the short- and long-term population growth rates of a critically endangered long-lived shrub, *Delissea waianaeensis*. Using this model system, we show that reintroductions established with mature individuals have the lowest probability of quasi-population extinction (10 individuals) and the highest increase in population abundance. However, our results also demonstrate that short-term increases in population abundances are overly optimistic of long-term outcomes. Using long-term stochastic model simulations, we identified the level of natural seedling regeneration needed to maintain a positive population growth rate over time. These findings are relevant for planning future reintroduction efforts for long-lived species and illustrate the need to forecast short- and long-term population responses when evaluating restoration success.

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

INTRODUCTION

The reintroduction of rare plants is a commonly used restoration strategy to prevent species extinction (Maschinski and Haskins, 2012; Soorae, 2013). The end goal of this management strategy is to promote species recovery and establish new populations that will persist over time (Falk et al., 1996; Pavlik, 1996). With an increase in rare and at-risk species and continued anthropogenic change in environmental conditions (Wilcove et al., 1998; IUCN, 2013), the reintroduction of rare species has become an increasingly important component of many recovery efforts (Maunder, 1992). While many studies have evaluated initial signs of reintroduction success, including the survival of reintroduced individuals and rates of natural regeneration (Menges, 2008; Godefroid et al., 2011; Dalrymple et al., 2012; Guerrant Jr, 2013; Liu et al., 2015), our understanding of how likely and under what conditions the reintroduction of rare species will promote species recovery and long-term persistence is limited (but see, Bell et al., 2003, 2013; Liu et al., 2004, 2015; Maschinski and Duquesnel, 2007; Colas et al., 2008; Albrecht et al., 2018).

Previous assessments on the use of reintroductions as a successful restoration strategy have yielded mixed results (Menges, 2008; Godefroid et al., 2011; Dalrymple et al., 2012; Guerrant Jr, 2013; Liu et al., 2015). Contradictions among previous studies are driven, in part, by differences in the generation time of rare species, the criteria used to define success, and the timeframe that reintroductions were monitored for following initial establishment (Menges, 2008; Godefroid et al., 2011; Dalrymple et al., 2012; Guerrant Jr, 2013; Liu et al., 2015). While the abundance of short-lived species with fast generational turnover can decline rapidly following initial establishment, reintroduced individuals of long-lived species can survive for many years. Thus, to fully understand the usefulness of species reintroductions as a restoration tool, there is an increased need for analyses that can be used to make comparisons between short- vs. long-lived species and project the probability of short- and long-term population persistence.

Within the population ecology literature, there are a small but growing number of studies that have moved beyond evaluating initial benchmarks of reintroduction *success*, such as initial establishment, reproductive maturity, and recruitment (Bell et al., 2003; Maschinski and Duquesnel, 2007; Colas et al., 2008). Those studies used long-term population projection models to examine if the reintroduction of rare species will likely result in the desired outcome (i.e., establishing new populations that will persist over time). While useful for making comparisons among species, long-term projections rarely match short-term changes in population abundances. The mismatch in short- and long-term population dynamics has led to increased skepticism in the use of demographic models to evaluate restoration success.

The mismatch in short-term population dynamics (e.g., annual increases in population abundance) and long-term projections can be explained, in part, by the effect of the stage structure on the near-term population growth rate (Fox and Gurevitch, 2000; Koons et al., 2005; Haridas and Tuljapurkar, 2007). For populations with artificially skewed stage structures (e.g., only reproductively mature plants), the population growth rate can fluctuate in the near-term as outplanted individuals senesce and natural regeneration fill in early life stages (Haridas and Tuljapurkar, 2007). The skewed stage structure of newly established populations can also influence population inertia; wherein the population growth rate will eventually settle to long-term asymptotic dynamics but at a much higher or lower population abundance (Keyfitz, 1971; Stubben and Milligan, 2007; Ezard et al., 2010; Stott et al., 2011).

The use of short- and long-term population projections to characterize how skewed stage structures influence plant population dynamics over time has become increasingly important for understanding the effects of environmental change on fundamental patterns in ecology. For example, short- and long-term projections have been used to characterize plant population responses to herbivory pressure (Maron et al., 2010), harvesting (Gaoue, 2016), biological invasion (McMahon and Metcalf, 2008; Ezard et al., 2010), severe catastrophic events (Crain et al., 2019), and habitat disturbance (Ezard et al., 2010; Bialic-Murphy et al., 2017). While it is likely that the distinction between short- and long-term dynamics is particularly important for assessing the likely outcome of plant reintroductions with artificially skewed stage structures, there is a dearth of demographic studies on this topic (but see, Wong and Ticktin, 2015).

Here, we leverage a long-term demographic dataset of a multi-year reintroduction effort to characterize how the population dynamics of newly established reintroductions fluctuate over time. Specifically, we (i) compare the short- and long-term population growth rates of the newly established reintroduction effort, (ii) quantify the risk of quasi extinction in the short- and long-term, (iii) identify the management actions that would have the greatest positive effect on the short- and long-term population growth and, (iv) evaluate the level of seedling recruitment that would be needed to maintain positive population growth over time. We focused on setting biologically meaningful benchmark goals for seedling recruitment because it was the only life stage that could be improved by management.

METHODS

Study Species

Delissea waianaeensis (Campanulaceae) is a critically endangered long-lived shrub endemic to the island of Oʻahu (Wagner et al., 2012). Campanulaceae is the largest Hawaiian angiosperm family (Givnish et al., 2009) with 159 taxa (Soorae, 2018). This Campanulaceae family is also one of the most threatened Hawaiian groups, with over 60% of the endemic Hawaiian species extinct in the wild (Soorae, 2018). *Delissea waianaeensis* has a single or branched erect stem that 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 and 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).

Two of the main stressors implicated in the decline of *D. waianaeensis* are frugivory by *Rattus rattus* (black ship rat) and seedling herbivory by non-native molluscs (Mollusca: Gastropoda) (Joe and Daehler, 2007; Kawelo et al., 2012; Shiels et al., 2014; Bialic-Murphy et al., 2018). Frugivory by *Rattus rattus* and herbivory by non-native molluscs have pronounced negative effects on seedling recruitment of rare island endemics, including *D. waianaeensis* (Joe and Daehler, 2007; Shiels and Drake, 2011; Shiels et al., 2014; Bialic-Murphy et al., 2018). The density of *R. rattus* can be highly variable from year to year and is a primary driver of temporal variability in seedling recruitment (Innes et al., 2001; Meyer and Butaud, 2009; Franklin, 2014). At our field site, *R. rattus* consume, on average, 83% of the mature fruits (Bialic-Murphy et al., 2018). Similarly, non-native molluscs decrease seedling density of endemic plants in Hawaiʻi by up to 33% (Kawelo et al., 2012). The suppression of these pests is among the most used management strategies to increase seedling regeneration for rare species across tropical islands, included *D. waianaeensis*. While the technologies used to suppress non-native pests continue to improve, the levels of pest control management and increases in seedling regeneration needed to reach the desired restoration outcome (e.g., population persistence) often remain unclear.

Study Site and Reintroduction Details

The study site is in the Central Kaluaʻā gulch of the Honouliuli Forest Reserve, which is located in the northern Waiʻanae Mountains, on the island of Oʻahu (HON; $21°28\prime^{N}$, $-158°6\prime^{W}$). 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, proximity to naturally occurring *D. waianaeensis* (∼4,000 m away), and relatively accessible location in the historic geographical distribution of naturally occurring *D. waianaeensis* (Dan Sailer, personal communication). In 2001, The Nature Conservancy constructed an ungulate exclusion fence at Central Kaluaʻā, eradicated feral pigs (*Sus scrofa*) from within the constructed fence, 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 Kaluaʻā Gulch, starting with the clearing of invasive species across the reintroduction location and the outplanting of 43 reproductively mature plants. The reintroduction site was ∼1 acre. The founders used for the Kaluaʻā *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 Kaluaʻā reintroduction to avoid potential outbreeding depression and the loss of local adaptations (Kawelo et al., 2012). Prior to outplanting, seeds from the five Kaluaʻā founders were grown in a greenhouse for one growing season. In 2004, the management of the Kaluaʻā *D. waianaeensis* reintroduction was transferred to the U.S. Army's Natural Resources Program on Oʻahu. The program outplanted an additional 303 plants from 2004 to 2012. The mean height of all reintroduced plants at the time of outplanting was 56 cm in height to the apical meristem (OANRP, rare plant database). The 2012 outplanting included genetic representation from two additional individuals that were discovered in close proximity to the five original founders used for the Kaluaʻā reintroduction. 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.

Data Collection

From 2010 to 2015, we collected annual demographic data for a total of 597 permanently tagged *D. waianaeensis* plants at the field site. Based on a combination of field observations and size measurement data over the 2010–2011 transition year, we divided the life cycle of *D. waianaeensis* into four life stages: reproductively mature (height >35 cm to the apical meristem and reproductive), large non-reproductive plants (height > 35 cm and vegetative), small non-reproductive plants (height 2–35 cm tall and no cotyledons), and seedlings (<2 cm tall with cotyledons). We determined the cut-off for the reproductively mature life stage by identifying the minimum size that plants flowered during the 2010–2011 transition year. Similarly, the cut-off for the seedling life stage was determined by evaluating the maximum size for true seedlings (new germinates with cotyledons that were <1-year old). The non-reproductive life stages are referred to hereafter as immature individuals. The stage structure of the population at the start of the study included 74 reproductively mature plants, 131 small and large immature plants, and 217 seedlings. The stage structure of the population in 2010 was based on census count data (i.e., plant size was not measured) so the total number of small and large immatures was unknown.

In the first year of the study, a minimum of 50 plants in the reproductively mature, large immature, and small immature life stages were haphazardly selected and permanently tagged. To maintain a sufficient sample size for each life stage in subsequent years, new individuals were tagged when needed. For each tagged plant, we recorded survival, height to the apical meristem, and reproductive status (i.e., evidence of flowers and/or fruits) annually in January or February. Each year, we also counted the total number of new seedlings (<1 year old) and reproductively mature plants in the population. The total number of new seedlings counted in the population ranged from 23 to 217 individuals. These annual count data were used to estimate the mean number of seedlings produced per mature plant (i.e., total number of seedlings/total number of mature plants the previous year), which is referred to hereafter as *seedling recruitment*. Surveys for new seedling recruitment were extended to ∼5 m beyond the boundary of the reintroduction site. Since the focus of this study was local population viability, we did not examine long-distance seed dispersal outside of the population.

Projection Matrix Construction

We used the demographic data to construct a 4 x 4 Lefkovitch matrix **A** (Caswell, 2001) for five transition years (2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015). Matrix **A** can be decomposed into **two** matrices: a survival-growth matrix **U** and fertility matrix **F**. Matrix **A** captured the yearly transition rate of stasis σ, survival and growth to the next stage class γ, shrinkage ρ, and seedling recruitment φ_m for the following discrete life stages: reproductively mature (*m*), large immature (*li*), small immature (*si*), and seedling (*s*). For φ_m, which represents the mean number of seedlings produced per mature plant, we were able to calculate an additional transition rate for year 2009–2010. Since the seed bank dynamics were not known for *D. waianaeensis*, we did not include this life stage transition in our matrix model.

$$\mathbf{A} = \begin{pmatrix} 0 & 0 & 0 & \varphi_m \\ \gamma_{s-si} & \sigma_{si} & 0 & \rho_{m_{si}} \\ 0 & \gamma_{si-li} & \sigma_{li} & \rho_{m_{li}} \\ 0 & \gamma_{si-m} & \gamma_{li-m} & \sigma_m \end{pmatrix}$$

The dominant eigenvalue of matrix **A** represents the long-term population growth rate λ, which has an associated stable stage distribution *w* and reproductive value *v* (Caswell, 2001). Specifically, the stable stage distribution represents the proportion of individuals in each stage class based on the matrix **A** transition probabilities and the reproductive value is the mean number of offspring that an individual contributed to the next generation. While the dimensions of a matrix can influence population projections, previous work suggests a 4 × 4 matrix is sufficient for comparative studies and species with relatively simple life cycles (Salguero-Gomez and Plotkin, 2010).

Matrix elements with 0 represent transition probabilities that were either not biologically feasible (e.g., seedlings remaining seedlings) or not observed during the study (e.g., large immatures shrinking to small immatures). The yearly transition rates used to construct the **A** and **F** matrices were derived from a subset of randomly selected individuals that were outplanted over multiple reintroduction efforts, starting in 2002, and a subset of first filial individuals. All analyses were done in R version 3.1.0.

Temporal Variability of Seedling Recruitment φ_m

Non-native pests influence the temporal variability of seedling recruitment (Innes et al., 2001; Meyer and Butaud, 2009) and can drive population decline (Bialic-Murphy et al., 2018). In Hawai'i natural areas, the density of rats (Shiels, 2010) and slugs (Stephanie Joe, personal communication) fluctuate from year-to-year and the intensity of seasonal pest control management can be highly variable due to budget constraints.

To capture the effects of year-to-year fluctuations in seedling recruitment and variable intensities of pest control management, we modeled the frequency of high seedling recruitment years as a stochastic process. We did this by 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*), based on the across year average (φ_a =0.69). Seedling recruitment φ_{m1} in year 1 was 3.09 seedlings per mature plant and seedling recruitment φ_{m2-6} in years 2–6 ranged from 0.569 to 0.021 seedlings per mature plant respectively (see **Appendix S1**). Based on our classification, seedling recruitment φ_{m1} in year 1 was *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 (see below for the high and low recruitment probabilities used for each scenario). 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 a stochastic array of **U** matrices (i.e., survival-growth matrix elements only) assuming an identically independent distribution (*i.i.d*). For modeling purposes, we assumed fertility and survival-growth were not linked through life history trade-offs and simulated each process independently.

Stochastic Long-Term Population Dynamics

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

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

where $\mathbf{X}(t)$ is a random transition matrix selected for at a given time *t* as the sum of two selected matrices **U** and **F** (see above), one from a pool of five **U** matrices (for transition years 2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015) and the other from a pool of six **F** matrices (for transition years 2009–2010, 2010–2011, 2011–2012, 2012–2013, 2013–2014, and 2014–2015). The vector $n(t)$ represents the number of individuals in each of the four life stages at a given time *t*, and $n\,(t+1)$ represents the number of individuals at time $t+1$. For modeling proposes, we used the observed stage structure in 2015 as the initial condition. Since long-term asymptotic projections exclude transient dynamics, using 2015 as the initial condition had no effect on our long-population growth rate projections. We used this framework to project population dynamics for six scenarios **F1**– **F6**, differing in temporal variability of recruitment. For scenario **F1,** the probability that a high seedling recruitment year (h) is selected each time step *t* was 0.1666. 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 of a high seedling recruitment year (*h*) being selected each time step *t*. For each consecutive simulation (**F2–F6)** we increased the probability of a high seedling recruitment year (*h*) being selected each time step *t*, with the probability of a high seedling recruitment year ranging from 0.33 to 1 for scenarios **F2** to **F6** respectively. For all scenarios **F1–F6,** matrix **U** was selected with equal probability at each time step *t* from the pool of **U** matrices. We calculated the stochastic long-term growth rate λ_s by simulation, using 50,000 iterations following Tuljapurkar et al. (2003):

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

where $N(t)$ 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 estimated as the standard error of the mean, following methods outlined in Morris and Doak (2002). We used a density independent model, which is likely reasonable for a rare species, like *D. waianaeensis*, with low seedling recruitment.

In addition to projecting the asymptotic stochastic population growth rate for scenarios **F1–F6**, we conducted long-term stochastic elasticity analysis. These long-term elasticity projections allowed use to identify the relative importance of perturbations in vital rates on the stochastic population growth rate λ_s with respect to perturbation of the variance $E^{s\delta}$ (Tuljapurkar et al., 2003; Haridas and Gerber, 2010). Stochastic elasticity analysis captures the effects of an increase or decrease in the temporal variability in matrix elements (e.g., seedling recruitment) on the long-term population growth rate λ_s. It is important to note that long-term stochastic elasticity analysis is dependent on asymptotic dynamics and is not influenced by the initial population stage structure.

Stochastic Transient Population Dynamics

The *D. waianaeensis* reintroduction was established with only reproductively mature plants, and thus the population structure was expected to be initially far from its stable stage distribution. Thus, to characterize how the population would likely fluctuate in the near-term, we calculated the stochastic transient population growth rate r_s. For our simulations we used 10,000 independent sample paths of $t = 5$ 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 was established using only reproductively mature individuals, we set the initial population 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 many plant reintroductions, similarly to the case of *D. waianaeensis,* are established with later life stages because they have the highest initial establishment rate (Maschinski and Haskins, 2012).

For our short-term transient projections, we chose a timeframe of t = 5 years because prior studies suggest plant reintroductions are typically monitored for less than 5 years (Godefroid et al., 2011; Liu et al., 2015) and peer review assessments are typically reliant on ≤3 years of transition data (Dalrymple et al., 2012). Thus, our results provide insight to how short-term assessments will likely differ from long-term outcomes. The use of a 5 year timeframe to capture transient projections for *D. waianaeensis* was supported by the damping ratio $\rho = |\lambda_{subdom}|/\lambda_{dom}$ of the mean matrix **A**, which is the ratio of the subdominant (λ_{subdom}) and dominant (λ_{dom}) eigenvalues (Haridas and Tuljapurkar, 2007). The damping ratio is a metric of convergence to the stable stage equilibrium: ρ close to 0 indicates that the population is far from equilibrium and a ρ close to 1 suggests a population that will converge to long-term dynamics relatively rapidly. The damping ratio for *D. waianaeensis* was $\rho = 0.39$, suggesting the population structure was relatively far from equilibrium.

In addition to the effects of the initial stage structure on the near-term population growth rate, plant populations dominated by mature life stage are expected to amplify beyond the long-term dynamics (Ezard et al., 2010; Stott et al., 2010, 2011). Thus, to characterize the effect of transient amplification on the *D. waianaeensis* population, we compared the projected population abundance for a reintroduction established with mature plants only to a population at a stable stage equilibrium (Stubben and Milligan, 2007). To further examine the viability of the *D. waianaeensis* population over time, we quantified the probability of quasi extinction in a stochastic environment at t = 5 years and t = 50 years (Caswell, 2001). For each scenario F1–F6, we simulated 1,000 independent sample paths of 5 and 50 time-steps respectively. For modeling purposes, we set the quasi-extinction threshold at 10 individuals.

To identify the relative importance of life stages on the stochastic transient population growth rate for scenarios **F1–F6,** we determined the stochastic transient elasticity with respect to perturbation of the variance $e^{s\delta}$ at $t = 5$ years. The transient elasticity captures the instantaneous influence of a single 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). Stochastic transient elasticity with respect to perturbations in the variance captures the effects of temporal variability in matrix elements (i.e., plant vital rates) and the effects of the initial stage structure (Ellis and Crone, 2013).

RESULTS

The long-term stochastic population growth rate λ_s of *D. waianaeensis* for scenario **F1** was 0.967 (95% CI of 0.963–0.972). These results indicate that the population will decline by 3.3% per year based on observed field conditions (**Figure 1A**). A two-fold increase in the probability of high recruitment years from 0.17 to 0.33 (scenario **F2**) resulted in a population growth rate close to 1 [$\lambda_s = 0.996$ (0.995, 1.00)]. A three-fold increase in the probability of high recruitment years from 0.17 (scenario **F1**) to 0.50 (scenario **F3**) shifted the long-term stochastic population growth rate from a 3.3% decline to a 2% increase in population size per year [$\lambda_s = 1.020$, (1.015, 1.026); **Figure 1A**]. For scenarios **F3–F6,** the long-term stochastic population growth rates λ_s were > 1 indicating projected growing populations (**Figure 1A**). Consistent with our long-term population growth rate projects, we found that scenario F1 had the highest probability of quasi extinction within a 50-year timeframe (0.19 probability of dropping below 10 individuals), followed by scenario F2 (0.09 probability) and scenarios F3–F6 (0 probability) respectively (**Figure 2**).

In contrast to the long-term projections, the near-term transient projections suggest the *D. waianaeensis* reintroduction will grow moderately for all scenarios (**Figure 1B**). We also found that establishing the *D. waianaeensis* reintroduction with mature individuals resulted in a higher population size than a population close to its stable stage equilibrium (**Figure 2**). These results show that a population established with later life stages will not

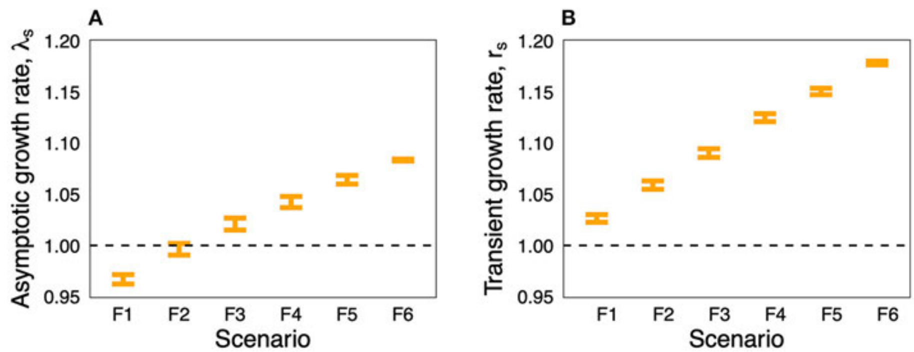

FIGURE 1 | Stochastic **(A)** asymptotic and **(B)** transient growth rates with 95% confidence intervals, calculated from 1,000 bootstrap samples. For scenario **F1** (i.e., field conditions), the probability of high recruitment years was 0.17 (i.e., once every 6 years). For scenarios **F2–F6**, the probability of high recruitment increased by 0.17 for each consecutive simulation.

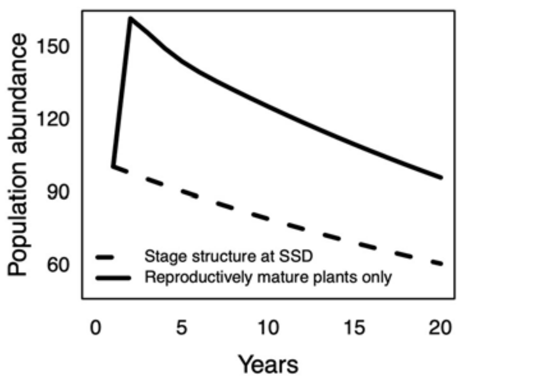

FIGURE 2 | Change in population abundance over time for a plant reintroduction established with mature plants only compared to a population at a stable stage distribution from time *t* to time *t*+20 years. Differences in abundance illustrate the effect of population amplification on the density of plant reintroductions over time.

only grow faster than a population started with early life stages, but it will also ultimately result in a greater population density over time. Additionally, the *D. waianaeensis* population had an extremely low probability of quasi extinction in the near-term for all scenarios **F1–F6** (**Supplementary Figure 1**).

Long-term elasticity for all life stages varied between scenarios **F1–F6**. However, the survival of mature plants (stasis) was projected to have a substantially greater effect on the long-term population growth rate than all other life stage transitions (**Figure 3A**). An increase in the probability of high recruitment years increased the relative importance of the seedling to the small immature life stage transition. However, these changes in seedling survival and growth did not change the ranking of which life stage transitions would have the greatest effect on the long-term population growth rate (**Figure 3A**).

Like our results for the long-term stochastic elasticity analysis, survival of mature plants (stasis) was projected to have the greatest effect on the transient near-term population growth rate for scenarios **F1–F2** (**Figure 3B**). Interestingly, when the probability of high seedling recruitment years was $\geq$0.50 (i.e., scenarios **F3–F6**), seedling recruitment had a greater influence than mature plant survival on the near-term population growth rate (i.e., transient phase) (**Figure 3B**).

DISCUSSION

The reintroduction of rare species is a commonly used restoration strategy to prevent rare species extinction worldwide (Maunder, 1992; Maschinski and Haskins, 2012). However, recent studies on the *success* of reintroduction yielded mixed results (Godefroid et al., 2011; Dalrymple et al., 2012; Guerrant Jr, 2013; Liu et al., 2015). Apparent contradictions of previous studies are due, in part, to the monitoring timeframe used following plant reintroduction efforts and the metric used to define success (e.g., initial survival, recruitment, etc) (Guerrant Jr, 2013; Liu et al., 2015). Here, we highlight the use of demographic data and short- and long-term population projections to evaluate the likely outcome of rare plant reintroduction efforts and set biologically meaningful benchmark goals. Our results are relevant for guiding reintroduction efforts for other long-lived species and evaluating restoration outcomes.

Population Growth Rate Projections

Wong and Ticktin (2015) found that restored populations of a long-lived woody vine that was composed of small individuals grew slower in the short-term than in the long-term. In contrast, our focal *D. waianaeensis* population that was composed of mature plants was projected to increase over the next 5 years for all six scenarios (**Figure 1B**). The short-term projections were also consistently higher than the long-term projections. Based on observed field conditions (scenario **F1**), the population was projected to slowly decline in the long-term (**Figure 1A**). The higher growth rate in the transient phase than in the asymptotic phase can be explained by the initial population structure dominated by life stages with high initial reproductive value, which can cause population amplification prior to reaching

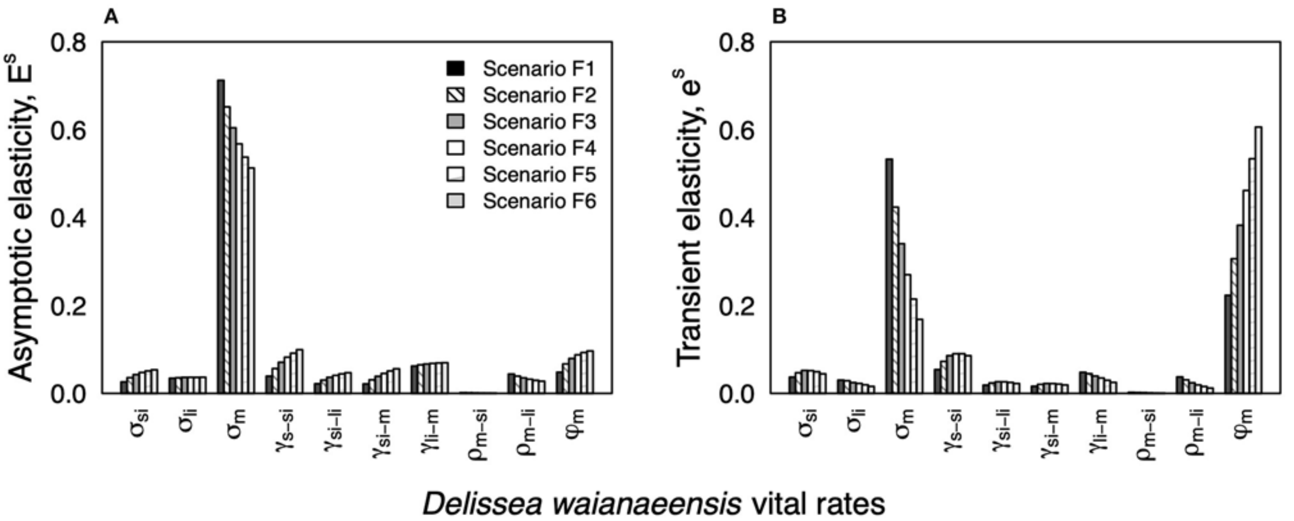

FIGURE 3 | Stochastic **(A)** asymptotic elasticity $E^{s\delta}$ and **(B)** transient $e^{s\delta}$ to the mean and variance. Seedling (S); small immature > 40 cm (SI); large immature, >40 cm (LI); and mature signs of reproduction (M). For scenario **F1** (i.e., field conditions), the probability of high recruitment years was 0.17 (i.e., once every 6 years). Elasticity values are grouped by demographic process (i.e., stasis σ, survival and growth to the next stage class γ, shrinkage ρ, and seedling recruitment φ_m). For scenarios **F2**–**F6,** the probability of high recruitment increased by 0.17 for each consecutive simulation.

a stable stage distribution (Keyfitz, 1971; Stubben and Milligan, 2007; Ezard et al., 2010; Stott et al., 2011).

Since large individuals are more likely to survive and successfully establish a new population than seedlings, restoration ecologists often use this life stage to establish new plant populations (Maschinski and Haskins, 2012). Here, we demonstrate that establishing rare plant populations with reproductively mature individuals can lead to an increase in the short-term population growth rate. However, as demonstrated by higher growth rate for *D. waianaeensis* in the short-term (r_s) than in the long-term (λ_s), our results provide a mechanistic understanding for why *intrinsic* asymptotic growth rate projections commonly do not match *realized* population abundance (i.e., short-term change in population size) (Guerrant Jr, 1996). Our findings also suggest that stochastic transient projections are more appropriate than asymptotic projections to characterize the near-term population growth rate because it explicitly incorporates the effects of the initial stage structure and captures more realistic environmental variation based on current field conditions. We also illustrate that the near-term population projections of plant reintroductions established with mature individuals can be overly optimistic of long-term outcomes. These finds highlight the importance of decoupling short- and long-term responses when evaluating the use of reintroductions as a successful restoration tool.

For newly established populations that are projected to decline over time, it is essential to identify the level of management needed to achieve long-term goals. For *D. waianaeensis*, we found that seedling recruitment was temporally variable. We also found that a three-fold increase in the probability of years with high seedling recruitment would be required for the *D. waianaeensis* reintroduction to persist over time (**Figure 1B**). A potential restoration strategy to increase the frequency of years with high seedling recruitment (i.e., 3 seedlings per reproductively mature plant) would be to suppress non-native frugivores and seedling herbivores (Bialic-Murphy et al., 2018). While our simulations provide insight into the population-level responses of increased seedling recruitment *via* pest control, many other exogenous factors can influence temporal variability in seedling recruitment. For example, temporal variability in plant pollinator densities can influence year-to-year fluctuations in seed rain. In this context, hand-pollination could be an additional management strategy to bolster seed production for pollen limited species like *D. waianaeensis*. Regardless, our simulations 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. It should be noted that we did not account for potential autocorrelation of stochastic processes (e.g., boom-and-bust cycles of seedling herbivores), 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.

Elasticity Analysis

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). Furthermore, 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 elasticity patterns for *D. waianaeensis* diverged and varied based on the probability of years with high recruitment. Our results also illustrate that the 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). 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 (e.g., seedling recruitment).

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 would have the greatest positive impact on native plant recovery (e.g., increasing mature plant survival), these recommendations are not always feasible in a naturally variable environment (Ehrlén and Groenendael, 1998; Mills et al., 1999). In this study, we found that maintaining high survival of mature plants in the transient phase would have the greatest influence on populations that were projected to decline over time (scenarios **F1–F2**) (**Figure 3A**). However, this management strategy would not lead to the desired outcome (population persistence). Interestingly, we also found that an increase in seedling recruitment would be the most beneficial management strategy for populations that were projected to persist over time (i.e., scenarios F3–F6). Globally, these findings illustrate the use of short- and long-term elasticity analyses to identify the life stages that, if improved by management, will have the greatest impact on population recovery over time.

As demonstrate by our short-term elasticity analysis with respect to perturbation of the variance $E^{s\delta}$, we show that the population growth rate in the near-term transient phase is strongly influenced by temporal variability in seedling recruitment. Considering the density of non-native pests are often cyclical and dependent on resource availability (Chr, 1999; Korpimäki et al., 2005; Oksanen and Oksanen, 2005), our results suggest a potential management strategy to reduce variation in *D. waianaeensis* seedling recruitment would be to prioritize the control of biotic stressors in years with high pest outbreaks. However, further investigation is needed to accurately predict the boom-and-bust cycles of non-native pests and explicitly link these fluctuations to changes in *D. waianaeensis* seedling recruitment. While we did not conduct a manipulative experiment to explicitly test the effects of targeted management actions, our results are informative for setting biologically meaningful benchmark goals for this taxon and balancing the needs between multiple restoration efforts.

CONCLUSION

Our study has several important conservation implications. First, we demonstrate that the use of later life stages can maximize the establishment and initial short-term growth of plant reintroductions and lead to a larger population abundance than would be expected based on long-term projections (*via* transient amplification). These results support previous research and illustrate the benefits gained by using larger individuals to establish new populations (Guerrant Jr, 1996; Guerrant Jr and Kaye, 2007). Secondly, we show that long-term asymptotic projections do not capture the dynamics of newly established populations with skewed stage structures in the short-term. Thus, to fully evaluate the probability of population persistence in the short- and long-term requires the combined use of transient short-term and asymptotic long-term projects. Lastly, we demonstrate that the effect of restoration (e.g., increasing the survival of seedling or mature individuals) on the population growth rate is dependent on the timescale of interest and is context specific. Management actions that have the greatest positive effect early in the establishment process differ from management actions that have the greatest effect on the population dynamics once the structure of the population reaches a stable stage distribution. As demonstrated by a pronounced effect of temporal variability in *D. waianaeensis* seedling recruitment on the short-term population growth rate, our results illustrate the benefit gained by promoting high seedling recruitment early in the reintroduction process for long-lived species that were established with later life stages (reproductively mature plants). These results illustrate the use of short- and long-term elasticity analyses to pinpoint which management actions will have the greatest positive effect and at which time point these actions will be most beneficial. Globally, our results provide empirical support for the claim that caution should be taken when using isolated components of population fitness (e.g., seedling recruitment or mature plant survival) to evaluate the use of reintroductions to promote species recovery and long-term persistence of rare species. This is particularly true when making comparisons between reintroductions that were monitored at different time points and were established with different life stages (seedlings vs. mature plants).

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

LB-M conducted the demographic modeling analyses and led the writing, with substantial input and revisions from all authors. LB-M, TK, KK, and OG contributed to the conceptual framework and development of the project. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2021.814863/full#supplementary-material

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Hawaiʻi forest review: Synthesizing the ecology, evolution, and conservation of a model system

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ABSTRACT

As the most remote archipelago in the world, the Hawaiian Islands are home to a highly endemic and disharmonic biota that has fascinated biologists for centuries. Forests are the dominant terrestrial biome in Hawaiʻi, spanning complex, heterogeneous climates across substrates that vary tremendously in age, soil structure, and nutrient availability. Species richness is low in Hawaiian forests compared to other tropical forests, as a consequence of dispersal limitation from continents and adaptive radiations in only some lineages, and forests are dominated by the widespread *Metrosideros* species complex. Low species richness provides a relatively tractable model system for studies of community assembly, local adaptation, and species interactions. Moreover, Hawaiian forests provide insights into predicted patterns of evolution on islands, revealing that while some evidence supports "island syndromes," there are exceptions to them all. For example, Hawaiian plants are not as a whole less defended against herbivores, less dispersible, more conservative in resource use, or more slow-growing than their continental relatives. Clearly, more work is needed to understand the drivers, sources, and constraints on phenotypic variation among Hawaiian species, including both widespread and rare species, and to understand the role of this variation for ecological and evolutionary processes, which will further contribute to conservation of this unique biota. Today, Hawaiian forests are among the most threatened globally. Resource management failures – the proliferation of non-native species in particular – have led to devastating declines in native taxa and resulted in dominance by novel species assemblages. Conservation and restoration of Hawaiian forests now rely on managing threats including climate change, ongoing species introductions, novel pathogens, lost mutualists, and altered ecosystem dynamics through the use of diverse tools and strategies grounded in basic ecological, evolutionary, and biocultural principles. The future of Hawaiian forests thus depends on the synthesis

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of ecological and evolutionary research, which will continue to inform future conservation and restoration practices.

1. Introduction

The eight main Hawaiian Islands (Hawai'i, Maui, Lāna'i, Kaho'olawe, Moloka'i, O'ahu, Kaua'i, Ni'ihau) have inspired biologists for centuries, serving as a living laboratory and a model study system for ecology and evolution. Owing to their extreme isolation and steep environmental gradients, the Hawaiian Islands provide unparalleled opportunities to investigate biogeography, community ecology, assembly theory, biogeochemistry, and adaptive radiations. Increasingly, the global threats of habitat loss, non-native species, and climate change are radically altering the abundance and distributions of the highly endemic biota, inspiring new research in restoration ecology and conservation biology. Whereas previous reviews have synthesized specific aspects of Hawaiian biology, including forest population dynamics (Mueller-Dombois et al., 2013), invasion biology (D'Antonio et al., 2017), nutrient cycling (Vitousek, 2004), carbon cycling (Selmants et al., 2017), and forest restoration ecology (Friday et al., 2015), none have explicitly tried to integrate broadly across fields, leaving the literature on evolutionary processes largely separated from that on global threats and conservation. Moreover, while earlier reviews often encompass multiple ecosystems, we focus here on forests because of their dominance in terrestrial Hawai'i. Our goal is to synthesize forest research broadly across evolution, ecology, and conservation because these fields are inherently linked, and new insights may be gained by considering them simultaneously.

Hawaiian forests have served as a biological microcosm in part because their evolutionary and ecological processes are amenable to study. Features of Hawaiian forests that facilitate study include younger lineages distributed across a well-characterized island-age gradient, less complex trophic webs, and more simplified species interactions, at least among the native species (Gruner, 2004). Especially noteworthy is that most Hawaiian forest overstories, particularly on Hawai'i Island, are dominated in large part by a singular tree species, *Metrosideros polymorpha*, across broad environmental gradients and sharp ecotones. Although several other dominant and co-dominant canopy species occur in forests, dominance is high and diversity is low in Hawai'i compared to tropical forests elsewhere (Craven et al., 2018; Ostertag et al., 2014). With their simple species composition and structure, and partitioning across islands of known ages, Hawaiian forests offer an opportunity to explore the patterns and processes of speciation (Choi et al., 2020; Gillespie, 2016; Roderick and Gillespie, 1998), community formation (Gillespie, 2004; Shaw and Gillespie, 2016), the roles of niche versus neutral processes in structuring plant diversity in tropical forests (Hubbell, 2006; Kraft et al., 2008; Leibold and McPeek, 2006), and the importance of biodiversity for ecosystem functioning (Poorter et al., 2017).

We focus on native forests because they are an extensive ecosystem type in the main Hawaiian Islands (Appendix A), harboring a largely endemic biota and dominating the islands' watersheds and nutrient cycling (Selmants et al., 2017). While there is a vast literature on Hawaiian forests, we do not aim to include every study in our review. Instead, our purpose is to highlight key areas of discovery in Hawaiian forest research, and to identify gaps in knowledge that should serve as a basis for future study. We first provide a brief overview of the physical environment in order to provide context for subsequent discussions of adaptive radiations, forest diversity, tree demography, and the evolution of island syndromes. Species interactions are less well studied in Hawaiian forests, perhaps owing to dramatic shifts in native species abundances and distributions over recent centuries. Throughout this review, we will highlight gaps in our knowledge about historical native species interactions and discuss how invasions have led to novel interactions, often with cascading effects on population dynamics, community patterns, and ecosystem function. We then discuss how restoration and conservation scientists have addressed global threats such as climate change and invasions, expanding our understanding of Hawaiian forests. Given that Hawai'i's Indigenous people (Native Hawaiians) have complex and dynamic relationships with forests and native biodiversity (Winter et al., 2020a, c), we also consider how biocultural perspectives shed new light on Hawaiian forest ecology and function, particularly in the context of restoration and conservation.

2. Physical environment

Understanding the physical environment is paramount to any discussion of Hawai'i's vegetation. Of fundamental importance is the volcanic substrate, which changes with age and interacts with climate and vegetation to provide the chemical and physical soil structure on which plants grow (Chadwick et al., 1999; Vitousek, 2004). The volcanic nature of the Hawaiian Islands and high surface water flow lead to the formation of steep elevation gradients and sharp ecotones that interact with trade-winds and disturbances such as seasonal storms and wildfires to establish the complex and striking environmental heterogeneity that underlies the forest structure and function.

2.1. Volcanic origin and soils

The Hawaiian Islands are born from an oceanic hotspot where magma emerges through the earth's crust, producing new submarine volcanoes that eventually emerge as basaltic shield volcanoes (Appendix B). As plate tectonics shift the Pacific Plate towards the northwest at 7–10 cm per year, a young volcano eventually moves beyond the hotspot and transitions from the shield-building stage to a post-shield stage where subsidence and erosional processes dominate (MacDonald et al., 1983; Ziegler, 2002). The combination of near-constant eruption of magma from the hotspot and tectonic movement has created an archipelago of 132 land formations—including islands, atolls, and seamounts—spanning > 2500 km from Lō'ihi Seamount to Kure Atoll (Eakins et al., 2003). Importantly, the bathymetry shows that many of the individual islands of today were historically connected during times of lower sea levels (e.g., Maui, Kaho'olawe, Lāna'i, and Moloka'i, known as Maui Nui (Price, 2004)), and that over time, the sizes and degree of isolation of islands have changed, influencing the distributions of species (Funk and Wagner, 1995; Price and Elliott-Fisk, 2004).

The islands and volcanic substrates of Hawai'i have been dated with considerable certainty (Sherrod et al., 2007), yielding an unusually precise temporal context for studies of the evolution and assembly of biological communities. For example, the dates of formation of the Hawaiian Islands provide fairly robust calibration points for performing molecular dating analyses (Baldwin and Sanderson, 1998). These data enable a detailed understanding of the tempo and mode of lineage diversification in response to local biological, climatological, and geographical conditions or events, and permit researchers to piece together the order of community assembly across the islands (Rominger et al., 2016).

The gradient in substrate age, in combination with complex variability in climate, topography, and assemblages of colonizing organisms, has led to remarkably diverse soils across the main Hawaiian Islands (Appendix C). Ten of the twelve global soil orders and at least 250 distinct soil series are represented. The most widespread soils are Andisols (39 %), Histosols (26 %), Oxisols (10 %), and Mollisols (8%), with the six other orders making up the remaining 17 % (Deenik and McClellan, 2007). The soil orders are not uniformly distributed across the islands. Volcanically derived Andisols are most common on the younger islands of Maui (40 %) and Hawaiʻi (52 %), whereas highly weathered Oxisols are common on the older islands of Kauaʻi (44 %), Oʻahu (37 %), Molokaʻi (39 %), and Lānaʻi (48 %). Soils with high organic matter content, Histosols, make up a large proportion of Hawaiʻi Island substrate (39 %) but are rare on the older islands (0–4 %) (Deenik and McClellan, 2007). Andisols develop from ash, cinder, pumice or other ejecta, and weather into soils that hold high amounts of organic matter and water; they support the most productive and carbon-dense woody ecosystems (Deenik and McClellan, 2007). Histosols form on lava flows as early successional vegetation decays, and thus have high organic matter that can support vast *M. polymorpha*-dominated forests, spanning dry to wet environments. Oxisols support somewhat less productive woody ecosystems as a result of nutrient limitations that occur over long substrate-weathering gradients, which explains why they are more common on older islands (Vitousek, 2004).

Nutrient availability in the three most abundant soil types is strongly related to soil order and climate. All soils in Hawaiʻi start out limited by nitrogen (N), owing to the lack of N in the initial volcanic substrate (Crews et al., 1995). Over time, N accumulates in the ecosystem through atmospheric deposition and biological N fixation (Crews et al., 1995). In wetter areas, the Andisols and Histosols on the younger islands experience significant loss of nutrients, especially N, calcium (Ca), and potassium (K), and these conditions can lead to soil acidification, accumulation of aluminum (Al), and binding of phosphorus (P) into forms that are not readily available for plant uptake (Deenik and McClellan, 2007). Over time, this leads to a shift in the ratio of N and P across the Hawaiian Islands as well as other chronosequences globally (Wardle et al., 2004). These infertile conditions also characterize Oxisols, in which considerable weathering has led to high levels of Al and iron (Fe) oxides and low cation exchange capacity (Deenik and McClellan, 2007). How forest productivity is maintained as rock-derived nutrients such as P, Ca, magnesium (Mg), and K weather away was not well understood until recently, when isotopic tracer techniques were able to demonstrate that cations arrive as marine aerosols while P is imported via dust from Asia (Chadwick et al., 1999) and northern Africa (Vogel et al., 2021). Much remains to be learned, however, about how these atmospherically derived nutrients, especially P, cycle within Hawaiian soils and interact with climate (Helfenstein et al., 2018), as well as other nutrient inputs such as those from seabirds (Mulder et al., 2011).

2.2. Climate

The climate of the Hawaiian Islands is characterized by wide and steep gradients in both temperature (Appendix D) and precipitation (Appendix E). Owing to the high and steep topography of the main islands, mean annual temperature varies from 4 to 24 °C, with temperature gradients up to 8 °C per kilometer (e.g., Northern Molokaʻi, Central Kauaʻi, and Waipiʻo Valley on Hawaiʻi Island). Seasonal temperature variability is low, however, because of the tropical latitude and the buffering effects of the ocean. In contrast to temperature, for much of Hawaiʻi, rainfall is seasonal and occurs primarily between October and April. Mean annual precipitation (MAP) varies from 204 to 10,200 mm across the islands, with precipitation gradients as steep as 2200 mm per kilometer. Due to orographic lift of the northeasterly trade-winds across Hawaiʻi's mountainous terrain, windward areas receive on average twice as much rainfall (2400 mm) as leeward areas (1200 mm). Yet not all precipitation in Hawaiʻi is trade wind-driven, with other weather patterns contributing to total precipitation and extreme rainfall events (Kodama and Barnes, 1997). Southerly Kona storms that typically occur in the winter, for instance, provide 20 % of MAP on average for leeward areas (Kaiser, 2014). Elevational gradients in climate relate to the occurrence of the trade wind inversion on the taller islands, which inhibits cloud formation above roughly 2000 m above sea level. Reduced clouds above the inversion lead to greater insolation and lower precipitation and relative humidity at high elevations (Cao et al., 2007). The trade wind inversion has a major effect on moisture availability for plants, effectively setting the maximum elevation limit of forests (Kitayama and Mueller-Dombois, 1994; Loope and Giambelluca, 1998). Beyond local factors, Hawaiʻi's climate is also partly determined by naturally occurring inter-annual variability including the El Niño-Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Pacific/North American teleconnection pattern (PNA) (Frazier et al., 2018).

Hawaiʻi's climate is in a state of flux. Long-term climate records show an increasing number of days with no rain and a substantial drying trend, particularly in dry forests (Frazier and Giambelluca, 2017; Timm et al., 2015). Drying effects on forests are likely to be exacerbated by significant warming trends for the entire archipelago (Kagawa-Viviani and Giambelluca, 2020). On the windward sides of the islands, a recently documented increase in trade wind inversion days could mean steeper precipitation gradients near the top of the forest line (Krushelnycky et al., 2016), and there is some evidence that a lifting cloud base in at least part of the archipelago may be driving declines in mean annual precipitation in low- to mid-elevation forests (Kagawa-Viviani and Giambelluca, 2020).

Beyond these inter- and intra-annual trends, projecting long-term climate shifts for Hawaiian forests is challenging and requires consideration of both regional and local dynamics. The existing precipitation projections for the state have generally agreed on a future in which wet areas remain stable or become wetter, and dry areas become drier (Timm et al., 2015; Zhang et al., 2016). However, these patterns are based on a limited number of models, and a broader set of regional climate models is needed to understand the robustness of these projections. Beyond shifts in mean precipitation, emerging research indicates changes in climate extremes as well. Notably, tropical cyclones, or hurricanes, only rarely reach the Hawaiian Islands compared to other islands, particularly those in the Caribbean, but the frequency of hurricane occurrence is projected to increase with global warming (Murakami et al., 2013). Ongoing climate shifts may also lead to either increasingly intense or frequent ENSO events, which generally lead to drier winter conditions in Hawaiʻi (Cai et al., 2018; Freund et al., 2019; Lu et al., 2020). Changes in storm tracks may lead to more frequent high-intensity storms over the islands than has historically been the case (Sugi et al., 2017; Tamarin-Brodsky and Kaspi, 2017).

These shifts in climate are likely to disproportionately influence Hawaiʻi's native flora as island species tend to have more narrow distributions and small population sizes than their continental counterparts (Harter et al., 2015). Hawaiian forest species vary in their abundances and distributions, making it difficult to predict how climate change will influence their persistence in the future (Box 1, Fig. 1). Given the limited potential for species on islands to shift their distributions latitudinally, Hawaiian forest species are largely restricted to shifting distributions in elevation. Pollen records indicate historical shifts in Hawaiian forests as a result of climate change (Hotchkiss and Juvik, 1999). Recent research indicates that expecting simple warming-related upslope shifts in species and forest communities is overly simplistic (Crimmins et al., 2011; Gibson-Reinemer and Rahel, 2015). For example, the upper elevation forest limit in Maui is determined not only by temperature, but also moisture (Crausbay et al., 2014). A study of changing species distributions over time on Mauna Loa, Hawaiʻi Island showed that between 1970 and 2010, native species contracted their low-elevation range limits without expanding at their upper range limits, likely because they had already reached the upper limit set by the trade wind inversion (Koide et al., 2017). This finding contrasted with the trend observed for non-native species, which inhabited lower elevations in 1970, and have since expanded upward, presumably as a result of suitable habitats at high elevations. Whereas both native and non-native plants are likely similarly limited by the trade wind inversion, increasing abundances of non-native species at high elevations may restrict the ability of native species to adapt or shift ranges in response to climate change.

Box 1
Conserving Hawaiian forest under a changing climate.

Hawaiian forests include species that vary considerably in their spatial distributions (Section 4, Figure 1). Managing Hawaiian forests under a changing climate to maximize persistence of species that vary so dramatically in climate niche breadth is complex and likely to require multiple strategies rather than a single one-size-fits-all approach. An important first step was a recent vulnerability assessment, which found that the future climatic niches of hundreds of Hawaiian plant species may not coincide with their current ranges, and furthermore, that many native plant species currently occupy ranges that by 2100 will not match their optimal observed climatic niche (Fortini et al., 2013). Because these assessments did not incorporate potential intraspecific variation in climate stress tolerance or account for discrepancies between the current distributions used to quantify climate envelopes and historical distributions before human activities and invasive species altered species distributions, additional research is still needed.

For widespread species, it is generally assumed that populations that span steep climatic gradients are locally adapted, leading to ecotypes. While population genetic differentiation and evidence for local adaptation has been detected for some species in parts of their ranges, especially for *M. polymorpha* (Section 4), most Hawaiian plant species have not been examined for local adaptation to climate variables. For microendemics with narrow climate ranges, even less is known about climate stress tolerance to inform management under changing climates. Because assisted migration is likely to be required to translocate species to suitable future climates, precise population-scale data on climate-stress tolerance is needed to ensure suitable matching between seed source and out-planting sites. Growing mismatches between current and historical climates may already contribute to reduced seedling emergence of *M. polymorpha* across a precipitation gradient on Oʻahu Island (Barton et al., 2020), emphasizing the urgency of research in this area. Finally, phenotypic plasticity and genetic variation available for local adaptation to changing climate may be viable strategies for short-lived forest species, but these data are generally absent for most Hawaiian plant species (Leopold and Hess, 2019; Westerband et al., 2020; Westerband et al., 2019).

It has remained difficult to scale up species-specific predictions of future distributions to the entirety of Hawaiʻi's forests. This is partly due to the poor fit of current, widely used ecosystem models that were originally developed for continental systems (Bachelet et al., 2015; Maguire et al., 2015). Nevertheless, recent ecological models for Hawaiʻi indicate a possible expansion of climatic conditions suitable for the dry and wet extremes of forests, and narrowing of areas currently most suitable for the more mesic forests, which are the most diverse of Hawaiʻi's forest types (Fortini and Jacobi, 2018). Whereas drier conditions have been linked to increased tree mortality and decreased growth in some tropical forests (Allen et al., 2017; Engelbrecht and Kursar, 2003; McDowell et al., 2018), little is known about how forests in Hawaiʻi's dry areas will respond to increased drying trends. Depending on the scale and species' responses, it is plausible that future changes in Hawaiʻi's climate could trigger dramatic shifts in plant community composition and ecosystem processes. For example, a study of native plant mortality on Mauna Loa during an El Niño drought suggests that severe drought can cause a shift in dominance from woody to herbaceous species (Lohse et al., 1995), often with cascading effects on wildfire regimes (see next section).

2.3. Disturbance

Physical disturbances are regular, natural features of island ecosystems (Mueller-Dombois and Fosberg, 1998). Typically, the spatial extent and intensity of disturbance are inversely correlated with frequency (e.g., limbfalls are more common than island-wide cyclones). Although Hawaiʻi Island is well known for patterns of disturbance and plant succession associated with volcanic eruptions and earthquakes, the most common disturbances in forests are flooding and landslides caused by extreme rainfall events, wind damage from tropical cyclones, and wildfire (Box 2, Fig. 2).

The Hawaiian Islands regularly experience localized, extreme rainfall events, e.g., 940 mm in 24 h on Hawaiʻi Island in 2000 and 254 mm in 12 h on Oʻahu in 2004 (Chu et al., 2009), which can cause landslides owing to Hawaiʻi's steep topography (MacDonald et al., 1983). In 2018, a national rainfall record was set on Kauaʻi with 1262 mm within a 24 -h period (Arndt et al., 2018), causing widespread landslides and flooding. Aside from these extreme events, little is known about landslide frequency or severity in Hawaiʻi (Restrepo and Vitousek, 2001; Restrepo et al., 2003). The most comprehensive assessment, based on 50 years of aerial photographs from southeast Oʻahu, estimated that landslides range in size from 10–5860 m^2 (median 111 m^2, mean 291 m^2), are typically triggered by heavy rainfall, and affect about 0.6 % of the susceptible landscape per year (Peterson et al., 1993). For Hawaiʻi Island, however, landslide disturbance rates as high as 15 % biomass loss per century have been reported (Restrepo et al., 2003).

Tropical cyclones (formally called hurricanes in the Central North Pacific) can affect terrestrial ecosystems in several ways; high winds blow down limbs and trees, heavy rains cause landslides and flooding, and storms flood coastal lowlands (Lugo, 2008; Smith et al., 2012). The Central North Pacific experiences an average of three hurricanes per year (range 0–10), with frequencies during El Niño years three times as high as in La Niña years (Clark and Chu, 2002). Because the main Hawaiian Islands occupy only a small portion of this region, they experience strong hurricanes at relatively long intervals, although the frequency is expected to increase with global warming (Murakami et al., 2013). Models estimate that the islands experience hurricanes with wind speeds of 230, 204, 185, and 148 km/h at intervals of 137, 59, 33, and 12 years, respectively (Chu and Wang, 1998). In contrast to storm damage to other tropical forests (Chazdon, 2003), storm damage to Hawaiian forests from tree mortality and increased litterfall has not been well documented. An exception is Hurricane Iniki on Kauaʻi (Asner and Goldstein, 1997; Harrington et al., 1997; Herbert et al., 1999). Efforts to determine the effects of major historical storms on present forest structure could capitalize on the extensive Hawaiian language newspaper record of over 125,000 printed pages from 1834 to 1948 (Businger et al., 2018). These newspapers detail weather and geophysical events such as hurricanes and earthquakes, for example, the Category-3 Hurricane in 1871 that devastated the islands of Hawaiʻi and Maui (Businger et al., 2018).

Wildfires are a disturbance commonly associated with volcanic activity, although there is also evidence of non-volcanic fires in Hawaiʻi from charcoal aged >7300 years old, well before Polynesians arrived (Kinney et al., 2015). Studies of soil charcoal demonstrate that wildfires occurred historically in evergreen broadleaf wet forests (Smith and Tunison, 1992), with a mean fire return of 700–1000 years (Mueller-Dombois et al., 1977). Naturally occurring wildfires in Hawaiʻi were likely localized, of low intensity, and initiated by lightning or lava after extended periods of drought (Ainsworth and Kauffman, 2010; Mueller-Dombois, 1981; Sorenson, 1979; Vogl, 1969). As a result, native Hawaiian plants tend to have limited adaptations to wildfire as a frequent natural disturbance (LaRosa et al., 2008), although re-sprouting following fire, and heat- and smoke-tolerant seeds indicate historical

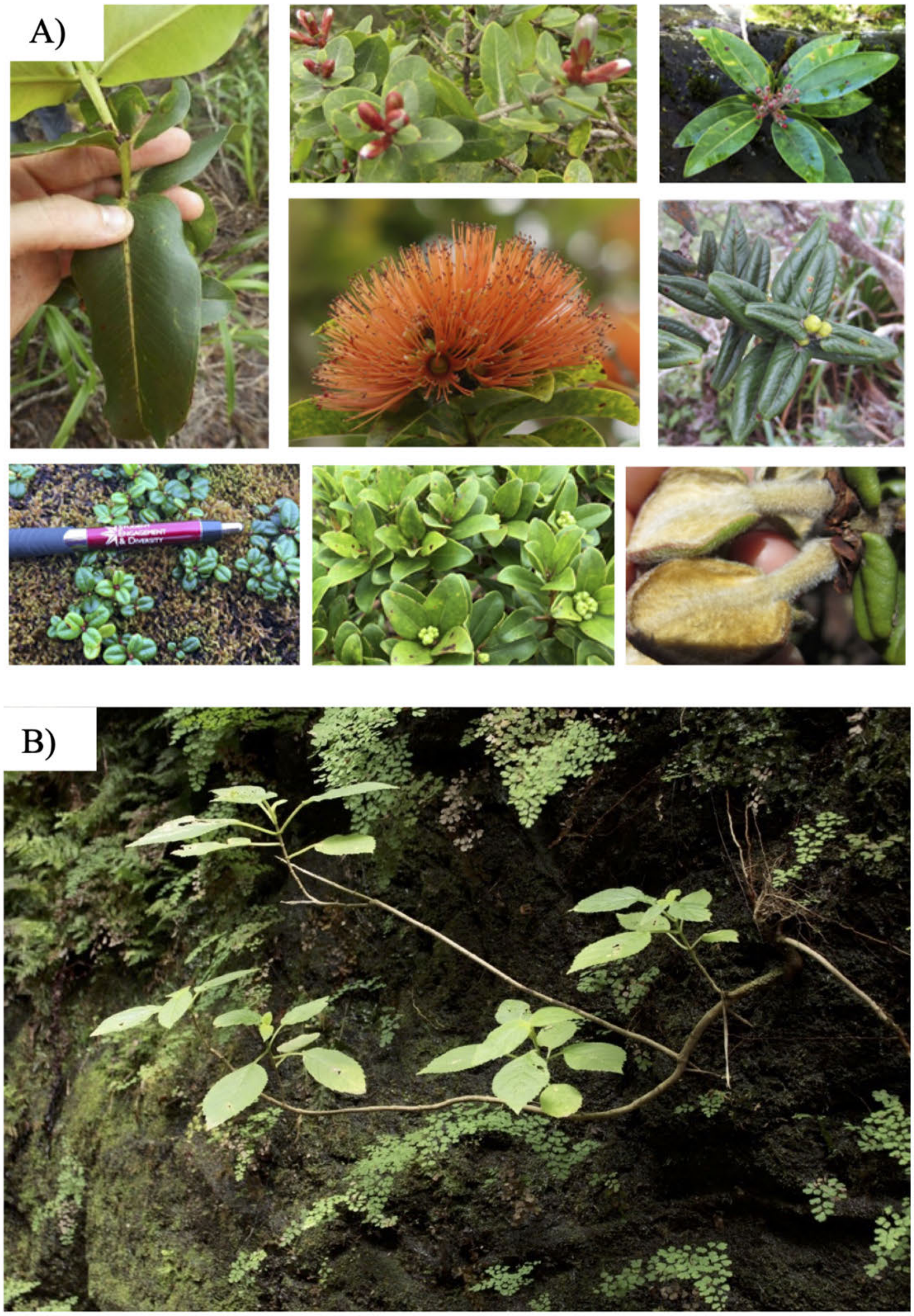

Fig. 1. Hawaiian forests include widespread abundant species such as the foundational *Metrosideros polymorpha* (A), as well as micro-endemics with highly constrained distributions, such as *Cyrtandra dentata* (B), restricted to gulches on Oʻahu Island. Photo credits: Elizabeth Stacy (A) and Adam Williams (top left image in A), Kapua Kawelo (B).

or *in situ* evolution of fire tolerance in at least some native trees and shrubs (Ainsworth and Kauffman, 2009; Loh et al., 2009).

The Hawaiian Islands have undergone drastic changes in wildfire dynamics due to the introduction and spread of non-native plants and humans themselves who ignite fires at a much greater rate than has occurred naturally (Trauernicht et al., 2015). The non-native species-wildfire cycle (D'Antonio and Vitousek, 1992) has been widely studied in Hawaiʻi and is one of the more important causes of native forest degradation, particularly in dry and mesic habitats (D'Antonio et al., 1998; Ellsworth et al., 2014; Mack and D'Antonio, 1998). For example, wildfires fueled by non-native C_4 grasses have resulted in the loss of >60 % of seasonally dry sub-montane native forest (D'Antonio et al., 2000; Hess et al., 1999; Hughes and Vitousek, 1993; Hughes et al., 1991), greatly reducing the occurrence of *Acacia koa* - *Deschampsia nubigena* parklands (Karpa and Vitousek, 1994; LaRosa et al., 2008), and contributing to the loss of more than 90 % of the lowland forests in dry regions (Bruegmann, 1996; Cabin et al., 2002; Litton et al., 2006). Grass-fueled wildfires greatly increase fire frequencies by amplifying fine fuel loads and changing microclimatic conditions (D'Antonio and Vitousek, 1992; Freifelder et al., 1998). Over the past century in Hawaiʻi

Box 2
Disturbance regime change in Hawaiian forest.

Physical disturbances are regular, natural features of island ecosystems, and while lava flows are commonly associated with Hawai'i, they are relatively rare at the archipelago-scale compared to hurricanes and flooding (Figure 2). The frequency of big storms is expected to increase in Hawai'i as a consequence of climate disruption (Murakami et al., 2013). Intense storms disturb forest habitats by causing flooding and landslides, by causing damage to trees through limb breakage and treefall, and by altering biogeochemical dynamics (Herbert et al., 1999). Such disturbances have cascading effects on forest dynamics by exposing substrate for invasive plant spread (Ostertag and Verville, 2002), reducing habitat for associated rare and threatened birds and snails, and potentially spreading invasive pathogens (Barnes et al., 2018). In addition to shifts in storm frequencies and severities, fire has increased dramatically in recent years, with devastating consequences for Hawaiian forests (Trauernicht et al., 2015). Contemporary fires in Hawai'i are largely human-caused due to military and recreational activities (Figure 2). Other small-scale disturbances due to invasive animals and human-caused habitat modifications are widespread and can have disproportionately large effects on forest dynamics. For example, invasive pigs alter soil structure with their rooting behavior, with cascading effects on seedling recruitment.

One of the primary challenges following disturbances such as landslides, fire, or even small-scale events is that cleared substrate provides an opportunity for displacement of native plants by fast-growing invasive species. Mitigation of these threats under changing disturbance regimes is challenging, particularly due to the remote location of many remaining native forests, and by the limited availability of native seeds to disperse (naturally or by managers) into disturbed sites to facilitate native forest regeneration (Friday et al., 2015). Production of native seeds for restoration requires knowledge of plant phenology, seed dormancy, and seedling establishment, which while increasing in scope, remain unknown for most native Hawaiian forest species, illustrating the value of explicit integration of basic ecology with conservation and restoration sciences.

Volcanoes National Park on Hawai'i Island, there has been a more than three-fold increase in the number of fires and a 60-fold increase in average fire size (Tunison et al., 2000), and these trends are characteristic of changes in wildfire activity across the entire archipelago (Trauernicht et al., 2015). While non-native grasses have received most of the attention in studies assessing the invasion-wildfire regime change, invasion by other plant forms may also change wildfire dynamics by altering fine fuels and microclimate (Ainsworth and Kauffman, 2009). Continued research on the non-native species-wildfire cycle would increase the capacity to restore and conserve native ecosystems archipelago-wide (Ellsworth et al., 2015; Trauernicht, 2019).

3. Distribution, classification, and structure of Hawaiian forests

3.1. Distribution

Hawai'i's forests are distributed across a range of environments (Appendix A), and currently cover approximately 34 % of the main islands, occurring in dry (6%), mesic (10 %), and wet (18 %) environments (Jacobi et al., 2017). Forests also occur across almost the full spectrum of soils present in Hawai'i (Appendix C). Due to biogeographic and evolutionary patterns of the flora (Section 4), many of the same woody species are abundant across a variety of soil types and climates. This situation is rare in continental tropical forests and presents an

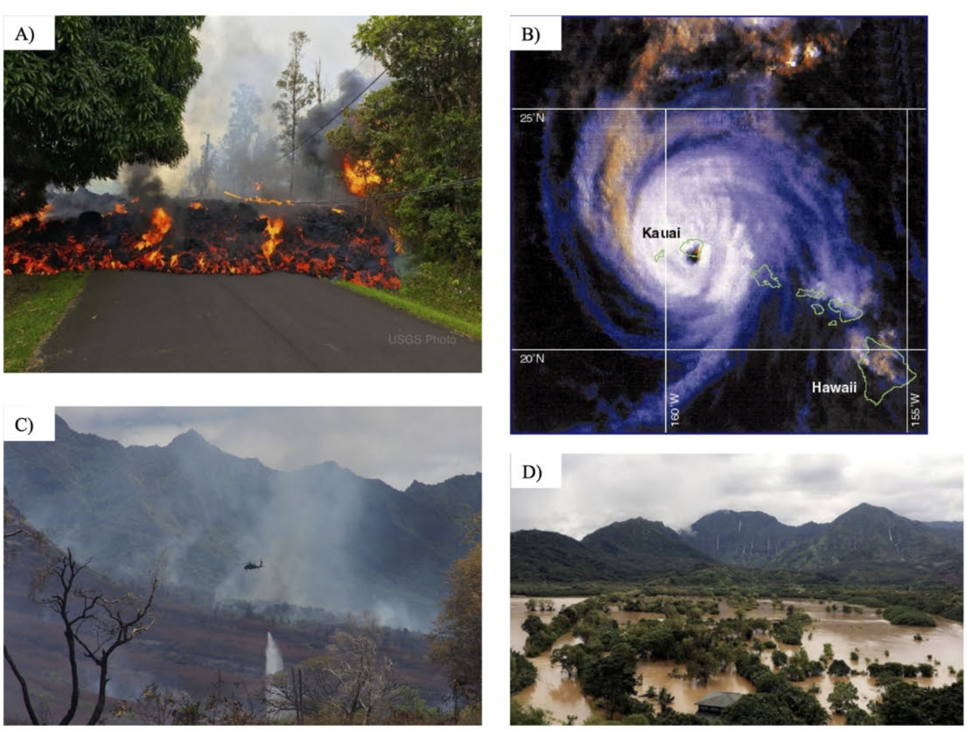

Fig. 2. Physical disturbances are regular, natural features of island ecosystems and can include lava flows (A, Kīlauea volcano, Hawai'i Island. 3 May 2018; photo credit: USGS); hurricanes (B, high resolution infrared image of Hurricane Iniki making landfall on Kaua'i. 11 Sept 1992; photo Credit: NOAA); fires (C, 2018 West Side Fires on O'ahu Island, which burned approx. 6,000 acres; photo credit: P. Trauernicht); and flooding (D, Hanlalei Valley, Kaua'i following heavy rains. April 2018; photo credit: T. Rex).

Box 3
Indigenous resource management (IRM) in Hawai 'i.

Indigenous resource management (IRM) is the body of philosophies, strategies, and practices employed by Indigenous Peoples to systematically manage abundance in context of habitats at the scale of landscapes and seascapes. IRM in Hawai'i involved the dividing of each island vertically – from mountains to sea – into social-ecological regions (*moku*), each of which were further subdivided into social-ecological communities (*ahupua'a*) that also typically extended from the mountains to the sea (Figure 3). The islands were also divided horizontally into social-ecological zones, which spanned across regions and connected communities to one another in a contiguous manner via managed habitats. While each island had a different suite of zones to manage resources, each community had to have at least one type of forest zone in order to properly function while most communities managed several. One of the zones that was managed on each of the high islands, but not in every community, was a sacred forest zone (wao akua), which is a zone of cloud forest managed as a refuge for endemic biodiversity that maintained core watershed function. Within this system freshwater, nutrients, and sediment were managed vertically within each community; while species abundance and connectivity were managed horizontally on a regional scale. This system of Hawaiian IRM began to break down in the 19th century after European contact, with the last vestiges of it enduring into the middle of the 20th century (Winter et al., 2018). However, this system of IRM is currently being revived in some communities under the auspices of biocultural restoration (Winter et al., 2020b; Winter et al., 2020c) and is seen as a viable model to solve issues of sustainability and conservation at both local and global scales (Gon and Winter, 2019; Winter et al., 2020b).

opportunity to investigate the role of soil and climate in driving plant ecological processes and ecophysiological function.

While there are still large, contiguous regions of forest across the islands, changes in resource management over the last two centuries have led to a dramatic reduction in the percentage of area covered by forests. During Hawai'i's pre-contact era, Indigenous resource management strategies aimed to maintain forested landscapes (Box 3, Fig. 3) (Winter et al., 2018, 2020a). Post-contact, these methods gave way to an approach that prioritized plantations and pasturelands. The proliferation of non-native species has further shrunk the footprint of native-dominated forest. Of the remaining forested area, Hawai'i Island has the highest percentage of native-dominated forests, whereas human-modified forests now dominate much of the landscape on the other islands, particularly on O'ahu (Jacobi et al., 2017). Furthermore, on each of the islands, more than half of the land area is covered by plant communities of primarily non-native plant species (Jacobi et al., 2017).

3.2. *Classification*

Given the extreme variation in Hawai'i's physical environment (Section 2), developing a classification system for vegetation that works across the islands is notoriously difficult (Mueller-Dombois and Fosberg, 1998). First, most vegetation classifications do not account for substrate age and corresponding soil properties, which are known to influence forest structure and composition. Second, the most common way to characterize Hawaiian landscapes, and thus their plant communities, is by climate, particularly mean annual temperature and rainfall (Appendices D, E). While convenient, using climate as the primary means for delineating communities is overly simplistic in Hawai'i. For example, although mean annual precipitation is a key predictor of plant communities on a global scale (Holdridge, 1947), some Hawaiian regions show no association between mean annual rainfall and soil moisture, as the latter is also greatly influenced by fog, topography, seasonality, soil texture, and soil age (Price et al., 2012). In addition, rainfall is difficult to measure with high spatial resolution given Hawai'i's orographically driven rainfall and topographic complexity (Frazier and Giambelluca, 2017; Giambelluca et al., 2013).

Considering the extreme environmental heterogeneity of the Hawaiian Islands, a system for classifying plant communities (Appendix F) was developed based on elevation (a proxy for temperature), moisture, and dominant physiognomy (Wagner et al., 1999). According to this system, there are 58 unique woody plant communities in Hawai'i, excluding the coastal zone (Gagne and Cuddihy, 1990). Rather than further delineate Hawai'i's woody plant communities, we take a holistic view here, synthesizing research carried out in all of Hawai'i's native forest types. In some communities, plants are of low stature, and these

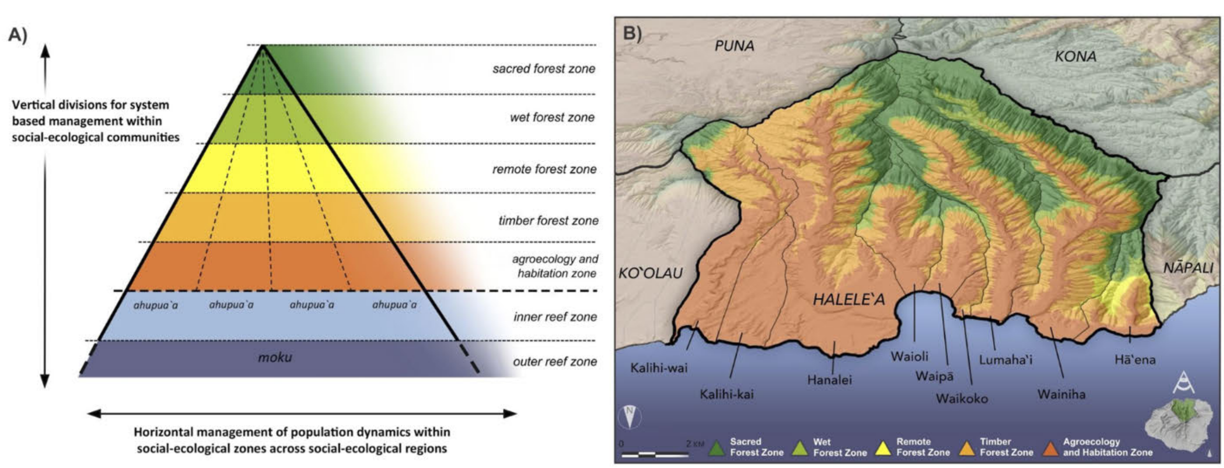

Fig. 3. Reproduced from Winter et al. 2018: A schematic model (A) and a spatial model (B) depicting the layout of a single social-ecological region (*moku*) based on the Hawaiian social-ecological system on the island of Kaua'i. (A) The terrestrial and oceanic social-ecological zones and their subcategories are oriented horizontally. *Ahupua'a* or social-ecological communities are oriented vertically. (B) The *moku* of Halele'a encompasses numerous *ahupua'a*, each with jurisdiction over a full spectrum of terrestrial and oceanic social-ecological zones within its boundaries.

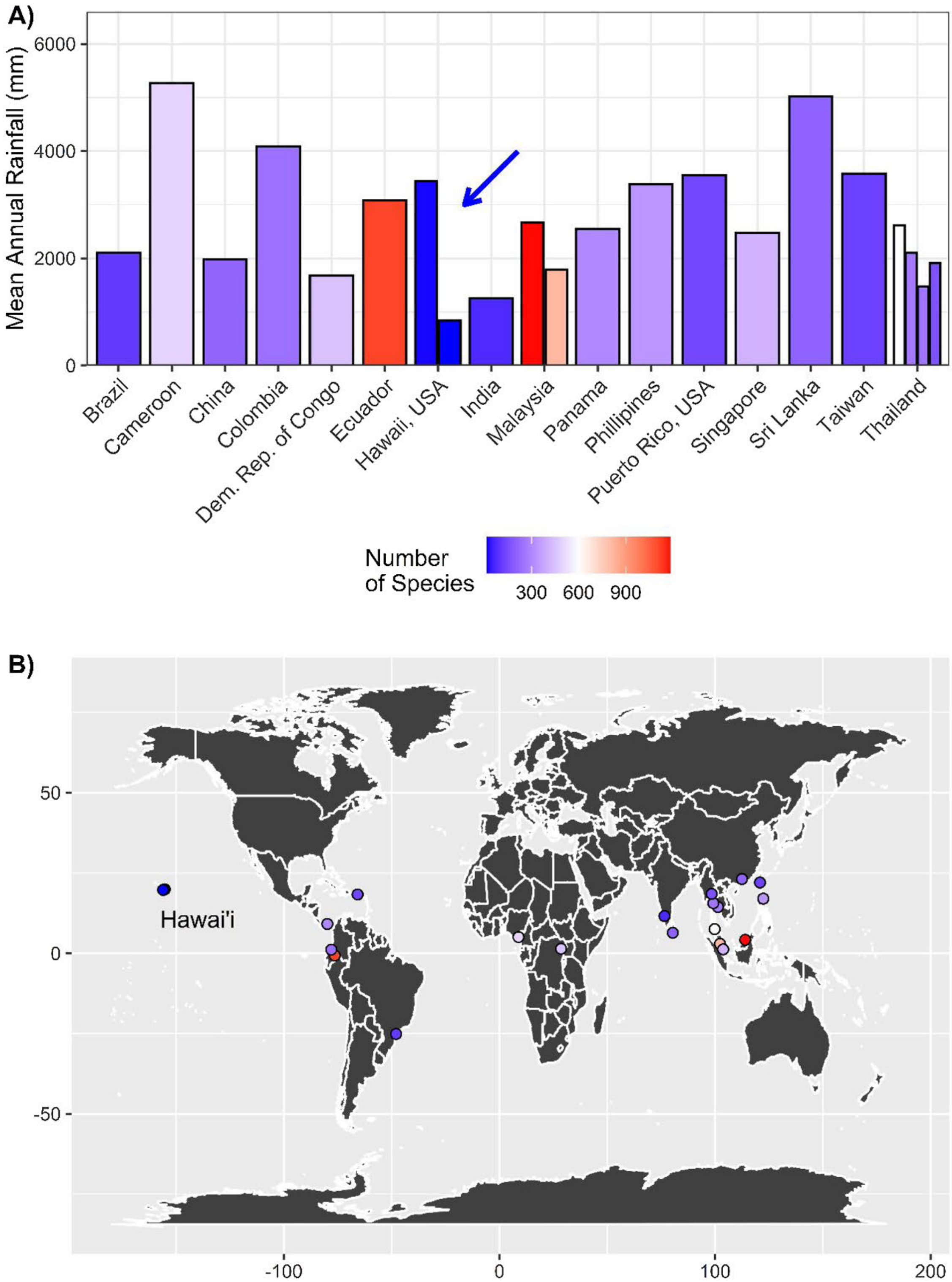

Fig. 4. Comparisons of species diversity and mean annual rainfall for tropical forests that form part of the ForestGeo network (https://forestgeo.si.edu/), based on previously published data (Davies et al., 2021; Ostertag et al., 2014). Species richness was calculated from species area curves, generated by plotting the cumulative number of species against the number of 20 m x 20 m quadrats sampled (area) in each 4-ha (200 m x 200 m) plot until the entire plot was sampled. A) Hawai'i is similar to other tropical forests in mean annual rainfall but has B) dramatically lower species richness compared to forests on continents and islands at similar latitudes. Multiple bars represent different sites within each country or region.

might arguably be referred to as shrublands; we include those here as forests because they are often contiguous with higher-statured forest stands.

As mentioned above, Hawaiian forests differ from many tropical forests in having dominance by relatively few tree species and overall low species richness (Fig. 4) (Ostertag et al., 2014). Some of the most

Table 1
Ranked species list of the ten most and least abundant plant species surveyed in the 530 forest plots compiled in the OpenNahele database (Craven et al., 2018). Plots are situated across all the main Hawaiian Islands, with the greatest sample area on Hawai'i Island. Relative abundance is the proportion of individuals for that species among the total 43,590 individuals sampled across all plots.

Species	Origin	Rank Abundance	Relative Abundance
Metrosideros polymorpha	native	1	0.330
Psidium cattleyanum	non-native	2	0.204
Cibotium glaucum	native	3	0.090
Cibotium menziesii	native	4	0.050
Cheirodendron trigynum	native	5	0.035
Schinus terebinthifolia	non-native	6	0.029
Leucaena leucocephala	non-native	7	0.022
Acacia koa	native	8	0.016
Psidium guajava	non-native	9	0.011
Ardisia elliptica	non-native	10	0.011
Dracaena aurea	native	174	5.73E-06
Dracaena konaensis	native	175	5.73E-06
Dubautia plantaginea	native	176	5.73E-06
Melicope anisata	native	177	5.73E-06
Myrsine lanaiensis	native	178	5.73E-06
Pittosporum glabrum	native	179	5.73E-06
Wikstroemia furcata	native	180	5.73E-06
Euphorbia multiformis	native	181	2.72E-06
Senna gaudichaudii	native	182	8.59E-07
Pittosporum terminalioides	native	183	1.43E-07

common woody genera in Hawai'i, which occur as dominants or co-dominants in multiple community types and across elevation and moisture gradients, include *Acacia*, *Diospyros*, *Dodonaea*, *Metrosideros*, *Leptecophylla*, *Nestegis*, *Sapindus*, *Cheirodendron*, *Bobea*, *Psychotria*, and *Vaccinium* (Appendix F). For some of these taxa, dominance appears to be driven by the large number of ecologically diverged forms that exist and whose physical traits allow them to establish over a range of substrate ages and environmental conditions (Appendix G). For example, *Metrosideros polymorpha* (Myrtaceae) is the most abundant and widespread tree (Table 1), and it dominates many of the woody plant communities across a range of substrate age (including recent lava flows), precipitation, and elevation, as well as various successional stages from pioneer to climax communities. *Metrosideros* likely arrived in the Hawaiian Islands 3–4 mya when the oldest main islands, Kaua'i and O'ahu, were still forming (Dupuis et al., 2019; Percy et al., 2008), thus providing a source of wind-dispersed seeds (Drake, 1992) for the colonization of each younger island as it arose. Today, *Metrosideros* (predominantly *M. polymorpha*) accounts for approximately one-third of all tree stems in forest monitoring plots (Craven et al., 2018). More work remains to be done to clarify why *Metrosideros*, a genus of slow-growing species, have come to dominate Hawai'i's forests, although tolerance of a wide range of environmental conditions seems to be key.

3.3. Structure

The structural characteristics of Hawaiian forests, such as stand density, basal area, and biomass, are diverse and influenced by climatic, substrate age, and soil properties. A combined approach of remote sensing and plot-level data indicate that there are higher proportions of aboveground biomass and lower proportions of litter and downed woody debris in forests that occur in wet environments (Asner et al., 2011, 2016; Hughes et al., 2014; Selmants et al., 2017). Total biomass generally increases with precipitation (Ostertag et al., 2014), but not with temperature in mature wet forests (Selmants et al., 2014). Even within similar climates, aboveground biomass can vary considerably: from 14 to 108.1 Mg/ha in forests on the drier end and 200–958.9 Mg/ha in wetter forest environments (Imhoff, 1995; Litton et al., 2006; Ostertag et al., 2014). In addition, live and detrital biomass in wetter conditions generally increases with substrate age (Aplet and Vitousek, 1994; Kitayama et al., 1997b). The variation in biomass values is certainly due to factors other than climate, but should be evaluated carefully due to inconsistencies among studies in how biomass is measured and estimated. Thus, the abiotic factors underlying aboveground biomass accumulation in Hawai'i's forests are complex, and

Table 2
Characteristics of the ForestGeo forest dynamics plots arranged from low to high mean annual precipitation. Elevation, MAP, plot size, and number of trees reported in (Davies et al., 2021); other variables reported in (Ostertag et al., 2014).

Site	Plot Code	Land Type	MAP (mm)	Dry Season Months	Mean Elevation (m)	Plot Size (ha)	No. of Trees	Trees/ha	Basal area (m2/ha)	Aboveground biomass (Mg/ha)
Palamanui, HI, USA	PLN	Island	835	12	265	4	15,652	3913	8.6	29.4
Mudumalai, India	MUD	Mainland	1255	6	1050	50	25,500	510	25.5	174.2
Huai Kha Khaeng, Thailand	HKK	Mainland	1476	6	596	50	72,500	1450	31.2	211.2
Ituri, D.R. Congo	ITU	Mainland	1682	3.5	775	40	288,000	7200	35.4	
Pasoh, Malaysia	PAS	Mainland	1788	1	80	50	300,211	6004.22	31	339.8
Doi Inthanon, Thailand	DOI	Mainland	1908	6	1670	15	73,269	4884.6	39.8	
Dinghushan, Guangdong, China	DIN	Mainland	1985	0	350	20	71,617	3580.85		
Ilha do Cardoso, Brazil	ILH	Mainland	2100	1	6	10.2	40,000	3921.569	29	
Mo Singto, Thailand	MOS	Mainland	2100	5	770	30.5	134,942	4424.328	31.77	
Bukit Timah, Singapore	BUK	Island	2473	0	99	4	17,239	4309.75	34.5	
Barro Colorado Island, Panama	BCI	Mainland	2551	3	120	50	208,400	4168	32.1	306.5
Khao Chong, Thailand	KHA	Mainland	2611	3	235	24	121,500	5062.5		
Lambir, Malaysa	LAM	Island	2664	0	174	52	359,600	6915.385	43.5	497.2
Yasuni, Ecuador	YAS	Mainland	3081	0	230	50	297,778	5955.56	33	282.4
Palanan, Philippines	PAL	Island	3380	4.5	97	16	78,205	4887.813	39.8	290.1
Laupahoehoe, HI, USA	LAU	Island	3440	1	1160	4	14,641	3660.25	67.3	247.9
Luquillo, Puerto Rico	LUQ	Island	3548	0	381	16	154,177	9636.063	38.3	276.1
Nanjenshan, Taiwan	NAN	Island	3582	0	320	5.88	12,133	2063.435	36.3	
La Planada, Colombia	LPL	Mainland	4087	0	1818	25	105,400	4216	29.8	177.6
Sinharaja, Sri Lanka	SIN	Island	5016	0	500	25	193,400	7736	45.6	357.9
Korup, Cameroon	KOR	Mainland	5272	3	195	50	329,000	6580	32	

characterizing the interactions among these factors warrants consideration of local environmental properties but also, the component of plant structure measured.

A hallmark of ecological and biogeochemical studies in Hawaiʻi has been the ability to isolate the impact of single or multiple driving variables on the structure and function of terrestrial ecosystems by examining natural environmental gradients. The advantage of examining these gradients in Hawaiʻi is two-fold; the islands comprise extreme variation in environmental conditions, yet because species richness is low, species turnover is not nearly the confounding factor it is in other locations. For example, the use of chronosequences – substrate-age gradients – to infer processes such as substrate development, forest succession, and ecosystem development over time – is best done in systems like Hawaiʻi that have low biodiversity and disturbances of low frequency and severity (Walker et al., 2010). The long substrate-age gradient across the island chain, ranging in age from *ca.* 300 to >4.1 million years (Crews et al., 1995), has been used to study ecosystem development including soil nutrient availability (Crews et al., 1995; Vitousek et al., 1988), ecosystem productivity (Herbert and Fownes, 1999), plant resource-use efficiency (Treseder and Vitousek, 2001), fine root dynamics (Ostertag, 2001), decomposition (Hobbie and Vitousek, 2000), and forest succession (Kitayama and Mueller-Dombois, 1995). This space-for-time substitution approach has helped to define our understanding of ecosystem development over long time periods and has been generalized to far-removed ecosystems (Selmants and Hart, 2010). Resource gradient studies have also yielded important insights. For example, the Mauna Loa matrix gradient includes a series of sites that together can disentangle effects of elevation from temperature and precipitation, as well as lava flow age and lava type (Aplet and Vitousek, 1994; Crews et al., 1995; Kitayama et al., 1995). Other studies have focused on rainfall (Austin and Vitousek, 2000; Schuur, 2001; Schuur et al., 2001) and mean annual temperature gradients (Bothwell et al., 2014; Giardina et al., 2014; Iwashita et al., 2013; Litton et al., 2011; Pierre et al., 2017; Selmants et al., 2014).

It can be instructive to examine Hawaiian forests in the context of other tropical forests. Hawaiʻi has two long-term forest dynamics plots on Hawaiʻi Island as part of the Smithsonian's ForestGeo network, in which all plots employ the same standardized methods, mapping and measuring all stems ≤ 1 cm diameter at breast height. Laupāhoehoe is a montane wet forest at 1160 m elevation, with a mean annual temperature (MAT) of 16 °C and mean annual precipitation (MAP) of 3440 mm. Pālamanui is a lowland dry forest at 265 elevation, 20 °C MAT and 835 mm MAP. The two Hawaiian plots have strikingly low species richness, with only 21 species at Laupāhoehoe and 15 species at Pālamanui (Fig. 4). When forest structure is compared to the four sites within ±300 mm rainfall (Table 2), the montane wet forest site is similar in biomass, in the intermediate range in terms of tree density, and high in basal area (due to its high tree fern abundance, while other sites do not have tree ferns). Thus, low species richness does not seem to constrain many of the typical structural attributes found in this climatic zone, and the structure of the Laupāhoehoe forest is also similar to other montane wet forests in Hawaiʻi that are not part of this global network (Ostertag et al., 2014). At the drier end of the spectrum, however, Hawaiʻi's forests stand out in two ways: 1) very low basal area and biomass, and 2) dry periods that are year-round rather than a wet/dry seasonality. One indicator of a forest's dryness is the number of dry-season months, defined as months with < 100 mm rainfall (Mooney et al., 1995). A global comparative study of climate relationships in dry forests from Central America, South America, Africa, Asia, and Australia catalogued dry seasons ranging from 0.6 to 5.9 months per year (Malhi and Wright, 2004). However, several of the forests in Hawaiʻi experience 12 dry season months per year (Ostertag et al., 2014; Sandquist and Cordell, 2007). None of the other ForestGeo plots have such dry year-round conditions (Table 2). Even the sites with the greatest seasonality (6-months dry season at DOI, HKK, MUD) are not similar in terms of diameter distributions or basal area, but the Hawaiian forest structure may be confounded by lava flow age.

There are several attributes of Hawaiian forests that may be extremely consequential and that deserve more study in a comparative framework. First, despite having a stem density similar to that of other tropical wet forests (Table 2), the canopy of Hawaiian forests tends to be quite open (Funk and McDaniel, 2010; McDaniel and Ostertag, 2010), which influences understory vegetation dynamics including recruitment and may be partially responsible for high invasion rates (see Section 5). Second, Hawaiian climatic records show extreme inter-annual variability in precipitation, especially in drier sites (Frazier and Giambelluca, 2017; Sandquist and Cordell, 2007). The low predictability of rainfall in Hawaiian forests likely affects plant function, and future studies could examine how this variability shapes the evolution of seed production and seedling regeneration, similar to approaches applied in fire-prone ecosystems (Keeley et al., 2011).

3.4. *Human-induced regime shifts*

Island forests have been profoundly affected by humans. A number of plants, mammals, and pathogens introduced by humans have adversely influenced native biodiversity and led to various waves of extinctions, each of which has had profound ecological ramifications in island systems (Wood et al., 2017). Hawaiʻi is no exception, being first impacted when seafaring Polynesians discovered the islands *ca.* 1000 years ago (Wilmshurst et al., 2011). The Polynesians brought with them a suite of plants and animals (including most notably the dominant food crops *kalo* (taro, *Colocasia esculenta*) and ʻuala (sweet potato, *Ipomoea batatas*) as well as the Polynesian pig), which collectively comprised a portable biocultural toolkit (*sensu* Winter et al., 2018b) that ensured their survival in their new island home and allowed them to perpetuate their cultural traditions. Using Indigenous resource management, Hawaiians employed their biocultural toolkit to create mosaicked cultural landscapes (Box 3, Fig. 3), including areas dedicated to agroforestry that combined native and introduced species within highly managed novel plant communities (Winter et al., 2018, 2020a). A modeled prototypical land division from the ancient Hawaiian period (Box 3, Fig. 3) showed that as much as 40 % of the land area in low-elevation regions was dedicated to these cultural landscapes and novel forests (Winter and Lucas, 2017), with an even smaller percentage of area representing forested landscapes that were converted to field agro-ecology for the cultivation of crops such as taro and ʻuala (Kurashima et al., 2019). The remaining 60 % was dedicated to maintaining various native forest types, including the wao akua (sacred forest), a zone of montane cloud forests that functioned as source populations for native species and preserved core watershed areas (Winter et al., 2018; Winter and Lucas, 2017).

Paleoecological data indicate that forests in the Hawaiian Islands have transitioned through a series of stable states over time (Athens et al., 2002; Burney et al., 1995, 2001; Hotchkiss and Juvik, 1999), punctuated by species turn-over driven by human-caused species introductions and referred to as "regime shifts" (Folke et al., 2004). Polynesian arrival is thought to have led to one of these regime shifts, largely driven by the introduction of the Pacific rat (*Rattus exulans*), which led to the initial collapse of lowland forest through seed depredation, a pattern observed following rat introductions to islands globally (Drake and Hunt, 2009). For example, in the mid-Holocene, lowland forests of Oʻahu were dominated by *Pritchardia* palms, the leguminous shrub *Kanaloa kahoolawensis*, and *Dodonaea viscosa*, but seed depredation by Pacific rats led to rapid collapse of these lowland forests and conversion to grasslands within the span of 50–100 years (Athens et al., 2002). Radiocarbon data indicate that human settlement into these disturbed lowland habitats occurred after collapse of the forests, supporting the conclusion that the Pacific rat was the primary driver of this regime shift (Athens et al., 2002). Various native animal species similarly declined during the period after Polynesian arrival, including the large birds such as the moa nalo (*Thambetochen chauliodous*) and Big Island Goose (*Branta rhuax*) (James et al., 1987; Paxinos et al., 2002).

Box 4
Community assembly of Hawaiian forest: the kīpuka model system.

Community assembly at the archipelago-scale reflects long-distance dispersal to the Hawaiian Islands followed by diversification and inter-island migration, as discussed in Section 4. In addition, local-scale community assembly processes have been relatively well studied in Hawai'i, particularly on Hawai'i Island where forest fragments of various sizes occur throughout a landscape dominated by young lava flows (Figure 5). These remnant forest fragments, the kīpuka system, provide a model system for investigating classic ideas about assembly processes with respect to habitat size and isolation from source communities as originally formalized by the Island Biogeography Theory (MacArthur and Wilson, 1967) and later refined to account for matrix features affecting dispersal and meta-population dynamics (Laurance, 2008). Diversity across the kīpuka system corroborates general patterns reported elsewhere – higher species richness in larger kīpuka with relatively lower edge/area ratios, and more similar community composition among more connected kīpuka for birds (Flaspohler et al., 2010), spiders (Vandergast and Gillespie, 2004), and root-associated fungi (Vannette et al., 2016). However, links between kīpuka size, connectivity and diversity are not always observed, suggesting that dispersal across the lava matrix may not be a hard barrier to more mobile forest organisms, such as canopy arthropods (Petillon et al., 2020; Tielens et al., 2019).

The kīpuka system may provide insights into forest responses to novel sources of fragmentation associated with agriculture, animal husbandry, forestry plantations, suburbanization, and urbanization, which have reduced forest habitat and dissected previously large tracts of forest into fragments of varying size and connectivity. How these landscape modifications intersect with invasive species and climate change to affect Hawaiian forests are likely to be devastating to the future persistence of native island forest species, both in Hawai'i and globally (Gillespie et al., 2008). For example, invasive species are becoming so abundant in Hawaiian kīpuka that they dilute any potential relationship between native species richness and kīpuka size or connectivity in birds and spiders (Flaspohler et al., 2010; Petillon et al., 2020), and invasive rats can alter kīpuka food web dynamics (Wilson Rankin et al., 2018). Notably absent from kīpuka community assembly research are studies of plant diversity, most likely as a consequence of the dominance of *Metrosideros polymorpha* within these forest fragments. However, the extrapolation of kīpuka research as a model for understanding forest fragmentation dynamics in Hawai'i is limited by the absence of plant diversity studies, particularly for the older Hawaiian Islands where community assembly is not dominated by *M. polymorpha*. Considering the negative effects of fragmentation on forest canopy structure (Vaughn et al., 2014), cascading effects on plant diversity are likely.

The loss of these species eliminated the guild of large browsing herbivores from the Hawaiian Islands (see Section 7.1 for further discussion), with cascading effects on forest food webs (James and Burney, 1997). Although evidence reveals that over time, *R. exulans* spread into higher elevations, forests remained dominated by native species for centuries, likely because Hawaiians limited activity in montane areas (Athens et al., 2002; Burney et al., 1995, 2001). This altered stable state was in place for centuries until the arrival and proliferation of other non-native species in the 19th century, including the black rat (*Rattus rattus*), mosquitoes (*Culex* spp.), and Eurasian pigs (*Sus scrofa*), which interbred with the Polynesian pig and then became feral (Burney and Kikuchi, 2006). These arrivals triggered the current regime shift and led to widespread declines in native-dominated forests at all elevations. In short, extinction events and ecological changes started with the arrival of Indigenous peoples in Hawai'i, then increased significantly in the colonial and post-colonial periods with further species introductions and altered land-management strategies, a pattern common within island systems globally (Wood et al., 2017).

Indigenous resource management strategies and practices limited the human footprint to low elevations (Gon et al., 2018) and promoted connectivity throughout species distributions in the Hawaiian era (Winter et al., 2018). The abandonment of those practices, along with the proliferation of large-scale agriculture (e.g., cattle ranching and monotypic plantations) in the 19th century, led to the rapid loss and degradation of native ecosystems through increasing dominance by non-native plants. This process has accelerated in the modern era (Gon

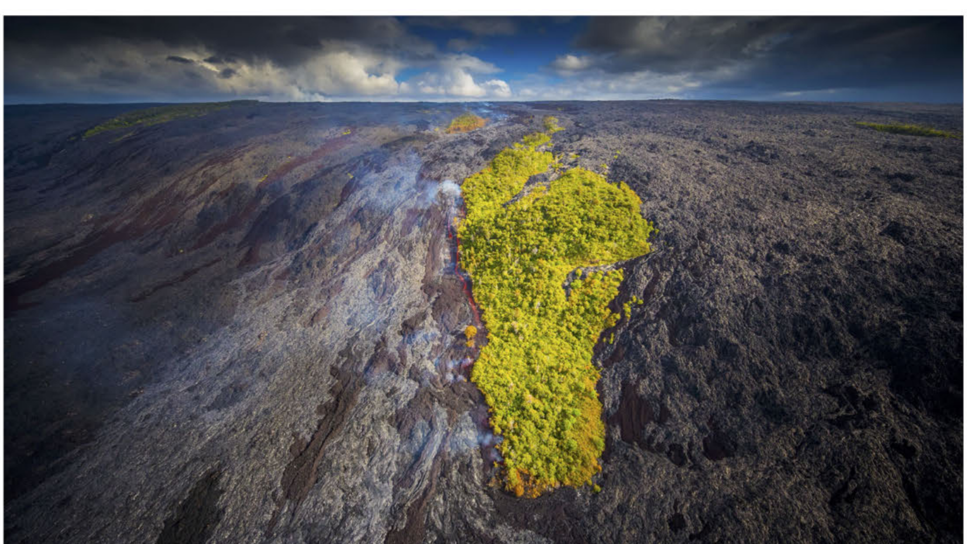

Fig. 5. Hawai'i Island Kīpuka. Photo credit: Andrew Richard Hara.

et al., 2018). In addition, the Hawaiian landscape has become more fragmented since human settlement. Whereas fragmentation is a natural consequence of the active volcanoes that make up the younger Hawaiian Islands (Vaughn et al., 2014), human-caused fragmentation is particularly important on the older islands where volcanism is millions of years in the past (Box 4, Fig. 5). Forest fragmentation likely influences plant community dynamics via negative effects on reproduction and fitness (Aguilar et al., 2006), by increasing conduits for non-native species, and by altering the physical environment. Although natural fragmentation caused by lava flows has been extensively researched in Hawai'i (Flaspohler et al., 2010; Vaughn et al., 2014), the consequences of anthropogenic fragmentation on Hawaiian forests has not been studied.

4. Diversity patterns and processes

The Hawaiian Islands have long been held as a model study system for disentangling the roles of community assembly and evolutionary processes in biodiversity (Emerson and Gillespie, 2008). As established in the previous section, the archipelago comprises a geographically isolated chronosequence of volcanic islands of known age (Sherrod et al., 2007) and striking structural and climatological complexity. This combination of features allows the study of the tempo and mode of lineage diversification in response to local biological, climatological, and geographical conditions and allows the tracking of community assembly and whole-ecosystem evolution across islands (Rominger et al., 2016).

Habitat suitable for colonization has existed on the islands for roughly 30 million years (Clague, 1996), but the vast majority of extant lineages derive from colonists that arrived within the past five million years (Price and Clague, 2002). While the focus of this review is on forests, in this section on diversity patterns, it is difficult to limit our discussion only to forests, because almost all studies have been conducted on an archipelago-scale. Studies focusing on diversity patterns by habitat type would be extremely fruitful, given variation in selective pressures across environments.

4.1. Biotic disharmony

As a result of Hawai'i's striking isolation from continental landmasses, its biota is characterized by striking *in situ* species radiations and the notable absence of whole groups that are widespread outside of the islands. Strong barriers to dispersal have led to a biota comprising predominantly angiosperms, ferns, arthropods, gastropods, and birds (Carr, 1987). The islands' endemic biota is derived almost entirely by *in situ* speciation of a limited number of lineages, which allows researchers to study the ecological and geographic drivers (Gillespie and Baldwin, 2009) and life history correlates (Price and Wagner, 2004) of biodiversity. Some Hawaiian lineages are hyper-diverse following spectacular radiations within the islands (e.g. lobeliads, honeycreepers, some insect groups) while many lineages that are well represented on continents are absent from Hawai'i (e.g., mangroves, figs, parrots, doves, terrestrial mammals except bats). Endemism is a common feature of island biotas, and thus the diversity patterns and processes characterized in the Hawaiian Islands may be represented of those of other systems (Gillespie et al., 2013).

The origin of the Hawaiian flora is global. A recent update of Fosberg's classic study (Fosberg, 1949) reports that of the 259 Hawaiian plant lineages examined, 78 are of widespread origin, whereas other common sources of the Hawaiian flora are Indo-Malayan (31), Neotropical (34), North American (30), Australasian (28), East Asian (10), and unknown (48) (Price and Wagner, 2018). A substantial number of lineages arrived in Hawai'i via previous dispersal from other Pacific Islands (Price and Wagner, 2018), indicating the importance of stepping stones in colonization process. The younger islands were typically seeded by initial colonizations from older islands following Funk and Wagner's progression rule (Funk and Wagner, 1995; Shaw and Gillespie, 2016). The widely observed unidirectional colonization of, and subsequent diversification on, younger islands is likely the consequence of limited niche availability and strong competition with resident populations constraining colonization of older islands. Several counter-examples exist, however, of successful back-colonization of older islands, such as species of *Schiedea* (Wagner et al., 1995), *Cyrtandra* (Johnson et al., 2017), *Clermontia* (Givnish et al., 2013), and *Metrosideros* (Percy et al., 2008; Stacy and Sakishima, 2019).

Natural colonization of the Hawaiian Islands by plants requires high dispersibility and occurs via three major dispersal modes in increasing order of importance: abiotic dispersal (water and wind), external bird dispersal through adhesion of small seeds, and internal bird dispersal via ingestion (Carlquist, 1974; Price and Wagner, 2004, 2018; Sakai et al., 1995). These dispersal types show geographic patterning; external dispersal by bird is proportionally higher from North American taxa and lower in Pacific taxa, whereas internal bird dispersal is proportionally higher in Austral and Pacific taxa, and lower in widespread taxa (Price and Wagner, 2018). Because, on average, seed size is smaller for herbaceous plants than for forest trees, Hawai'i's colonizing angiosperms were likely predominantly herbaceous (Carlquist, 1974).

The native angiosperm flora found in all biomes across the main islands comprises 1039 species derived from just 259 presumed colonists (Price and Wagner, 2018). The exceptional endemism of Hawai'i's angiosperms (90 % at the species level) is due to dramatic radiations within just a handful of these lineages. Indeed, the ten largest lineages represent just 4% of original colonists yet comprise 41 % of Hawai'i's angiosperm species (Price, 2004). In ferns and lycopods, diversification is more modest, presumably due to the greater passive dispersibility (and thus broader species distributions) of ferns, multiple colonizations to the same island, and lower speciation rates (Driscoll and Barrington, 2007), but there is still remarkably high endemism at 78.1 % of the 210 species (Ranker et al., 2019).

Hawai'i is also home to a disharmonic animal biota that plays important roles in forests, including snails, spiders, and insects (Cowie and Holland, 2008; Gillespie and Roderick, 2002; Holland and Cowie, 2009). For example, it has been estimated that there are approximately 10,000 native insect species derived from a mere ~350−400 colonization events from around the Pacific (Eldridge and Miller, 1995; Howarth and Mull, 1992). Conversely, the only terrestrial vertebrates native to Hawai'i are birds and one insectivorous bat species; reptiles, amphibians, and non-volant mammals are absent from the native fauna, likely reflecting the barriers to dispersal of large, non-flying animals. The presence of such a disharmonic animal biota led to distinct plant-animal interactions in Hawaiian forests compared to continental forests, interactions which are now severely threatened by extinctions and altered by invasions (discussed below).

4.2. Diversity patterns

Patterns of plant diversity at the scale of whole archipelagoes have received extensive theoretical and empirical attention. According to the dynamic theory of island biogeography, species richness is expected to have a hump-shaped pattern with island age (Borregaard et al., 2017; Lim and Marshall, 2017; Whittaker et al., 2017, 2008). Young islands are expected to have low species richness that increases over time as colonization from the older islands occurs; speciation rates are also highest on young islands, as a consequence of high niche availability. As islands age, they subside and lose size, eventually leading to a decline in richness, and these trends on young and old islands is expected to result in a peak in species richness on intermediate-aged islands. The latter prediction is well supported by datasets from the Azores, Canaries, Galápagos, Marquesas, and Hawaiian Islands (Whittaker et al., 2008). For the current main Hawaiian Islands, species richness of plants is greatest on Kaua'i, and lowest on Hawai'i Island (Craven et al., 2019; Price, 2004), indicating that Kaua'i is currently at the intermediate age of Whittaker's model and will lose species richness in the future. This pattern of diversity extends to individual clades as well (Price, 2004), with a majority of angiosperm lineages having peak richness on the oldest island, Kaua'i (seven of the ten richest lineages), and the lowest species richness on the youngest island, Hawai'i Island (true for nine of the ten richest lineages).

Diversity patterns of Hawai'i's non-flowering plants are not as well-characterized as those of flowering plants, although there are island checklists for ferns and fern allies (Palmer, 2003; Ranker et al., 2019) and mosses (Staples et al., 2004). Unlike angiosperms, ferns and lycophytes tend to be widespread across all of the main islands (Ranker et al., 2019), and thus do not appear to follow Whittaker's model. Relatively few studies have examined patterns of functional diversity among ferns and lycophytes (Waite and Sack, 2010, 2011), and this is an important gap in our knowledge as these are dominant members of the Hawaiian forest understory.

Extant plant diversity in Hawai'i is heavily represented by naturalized non-native species, which are abundant and widespread in Hawaiian forests (Table 1, Fig. 6), with several of the most abundant also occurring across diverse forest types (Ainsworth and Drake, 2020). Between 1840 and 1999, 7866 ornamental species were brought to the islands; of these, 420 have naturalized, 141 are listed as invasive, and 39 of those are identified as noxious (Schmidt and Drake, 2011). A more recent estimate on the native and naturalized non-native plant species in all Hawaiian biomes lists 1365 native and 1470 non-native species (Wagner et al. 2005). A forest-specific inventory revealed that the relative abundance of non-native plants varies considerably across islands (Craven et al., 2018). Some non-native plants in Hawaiian forests have clearly reached the final stages of invasion in which they contribute to declines in native flora and fauna and disrupt ecosystem function (Blackburn et al., 2011). Nonetheless, even with these examples, it remains difficult to predict which of the more recent arrivals will spread and disrupt Hawaiian forests in the future.

4.3. Diversity processes: adaptive radiations

As mentioned above, a majority of Hawai'i's biodiversity stems from adaptive radiations of relatively few colonizing lineages. These radiations are shaped by the striking environmental heterogeneity of the islands and facilitated by the disharmonic nature of Hawai'i's biota, which is thought to leave open niches (Carr, 1987). Through adaptation to contrasting environments, many Hawaiian plant groups display great morphological diversity (Appendix G) and occur across a much broader array of habitats than their mainland counterparts (Baldwin and Sanderson, 1998; Carlquist, 1974; Funk and Wagner, 1995; Ganders and Nagata, 1984). Whereas some lineages provide evidence for the importance of pollination mode and growth forms (woody versus herbaceous) as drivers of adaptive radiation (Weller et al., 2017), mode of seed dispersal is the most important correlate (Price and Wagner, 2004). Specifically, lineages with seeds that are internally dispersed by birds are the most speciose, and those with abiotically dispersed seeds are the least species-rich. Moreover, Price and Wagner (2004) found that broadly distributed lineages comprising isolated populations derived through internally-bird-dispersed seeds are most likely to have undergone radiations. While this pattern indicates that stochastic processes in small populations may contribute substantially to plant speciation in Hawai'i, the importance of genetic drift and mutation in these adaptive radiations is not known. Further, with just a few exceptions (Ekar et al., 2019; Givnish et al., 2004; Morrison and Stacy, 2014), the specific abiotic factors associated with, and likely responsible for, species diversification across Hawai'i's heterogeneous landscape have not been examined.

Because of the recency of most colonization events, variation at molecular markers used for plant phylogenetic analyses is low despite high morphological diversity in many Hawaiian groups (Appendix G). This problem is expected for recent and rapid radiations, and it frustrates attempts for species-level phylogenies and thus robust tests of evolutionary hypotheses in Hawaiian plants. For example, high cross-fertility and frequent hybridization among closely related taxa may have contributed to many Hawaiian plant radiations (Dunbar-Co et al., 2008; Johnson et al., 2019; Nepokroeff et al., 2003; Wagner et al., 1999). Natural hybridization that results in high fertility of first-generation

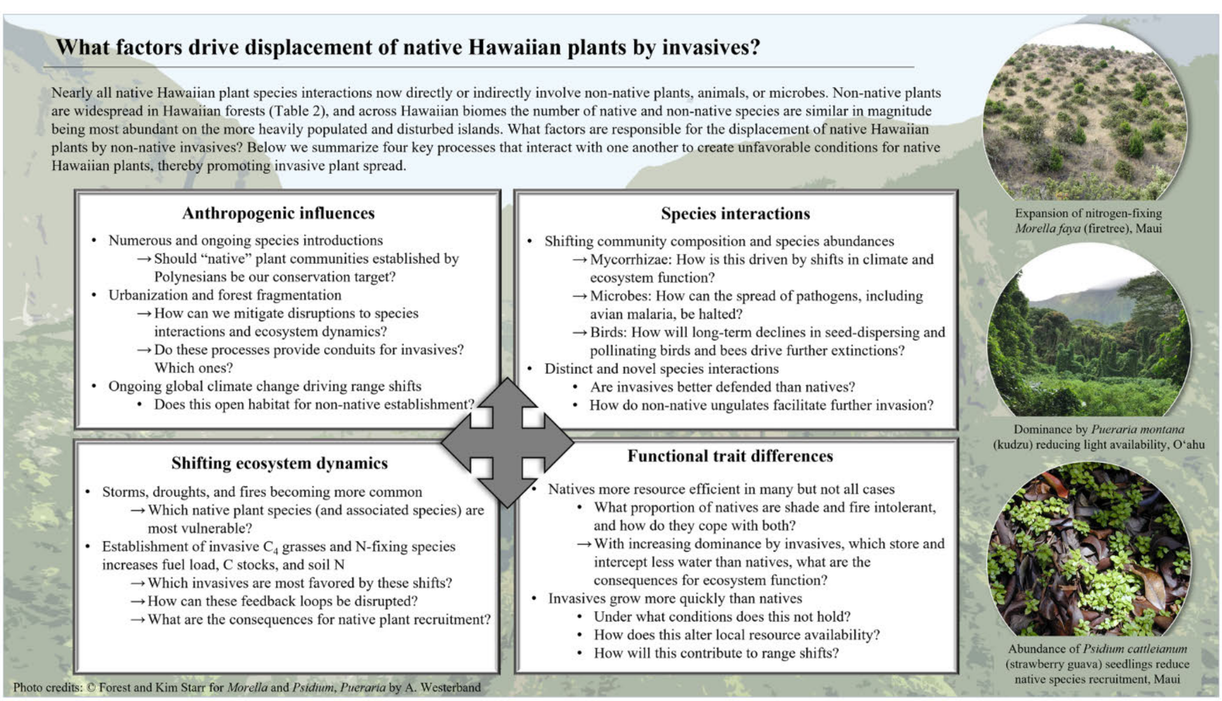

Fig. 6. Simultaneous and interacting factors underly the displacement of native by non-native plants in Hawaiian forests.

hybrids and thus allows for introgression between taxa appears to be a regular feature in species-rich lineages such as *Bidens* (Ganders and Nagata, 1983), as well as the forest trees *Euphorbia* (Koutnik, 1990), and *Cyrtandra* (Carr, 1987; Ziegler, 2002). Introgressive hybridization among incipient forms creates novel gene combinations that may promote adaptation to novel environments (Carr, 1987; Lewontin and Birch, 1966) and thus adaptive radiation (Seehausen, 2013). Consistent with this mechanism, recently evolved species of *Scaevola* originating from hybridization have been confirmed through molecular data (Howarth and Baum, 2005). In addition, intraspecific hybridization within the hypervariable *M. polymorpha* (Stacy et al., 2016) has been suggested as a source of some of the many varieties of this species (Ziegler, 2002). The recency of evolutionary diversification of Hawaiian plant groups and their propensity for hybridization make them ideal systems for investigating the role of introgression in the evolution of exceptional species richness (Meier et al., 2017).

Recent applications of next-generation DNA sequencing, are allowing much improved insight into plant evolution in Hawaiʻi (Choi et al., 2020; Izuno et al., 2017; Knope et al., 2020). As these new techniques allow for the construction of more accurate phylogenies, there is now an opportunity to investigate intersections between functional traits (Medeiros et al., 2019) and community diversity patterns. While such research is flourishing in other geographic regions (Cadotte et al., 2019), these synthetic approaches, merging community ecology and evolution, are lacking for Hawaiʻi.

4.4. *Diversity processes: incipient plant radiations and non-radiating lineages*

While the most species-rich groups have attracted the greatest attention from evolutionary biologists, there are many widespread species with tantalizing morphological variation that have received little attention (Appendix G). Such species are especially interesting because they offer the best opportunity for studying divergence and speciation in progress (Ramsey et al., 2003; Via et al., 2000).

The best example of a lineage undergoing incipient radiation is Hawaiian *Metrosideros*. Only five species of *Metrosideros* are recognized in Hawaiʻi, and all are likely derived from a single colonist to the islands 3.1 ± 0.6 mya (Dupuis et al., 2019) to 3.9 ± 2.5 mya (Percy et al., 2008). Yet studies of the most ecologically and geographically dominant member of this genus, *M. polymorpha*, reveal considerably more taxa than the eight varieties currently described (Dawson and Stemmermann, 1990). These varieties and tentative races are distinguished through vegetative characters and are non-randomly distributed across Hawaiʻi's heterogeneous landscape, from wet forests and bogs to new lava flows, deserts, subalpine zones, riparian zones, and windy cliffs (Stacy et al., 2020). On Koʻolau Volcano, Oʻahu, leaf micromorphological characters differentiate six of seven infraspecific taxa of *M. polymorpha* (Sur et al., 2018), and all taxa examined to date on Hawaiʻi and Oʻahu show evidence of local adaptation to particular environments or isolated abiotic features of these environments (Cordell et al., 2000, 1998; Ekar et al., 2019; Kitayama et al., 1997a; Morrison and Stacy, 2014; Stemmermann, 1983). The three most abundant varieties of *M. polymorpha* on Hawaiʻi Island also show heritable variation in floral characters consistent with biotic selection across elevational and successional gradients (Stacy and Johnson, 2021). The partial but significant reproductive isolating barriers observed between taxa within islands (Rhoades, 2012; Stacy et al., 2017) and the broad variation in the extent of genetic isolation of these forms (DeBoer and Stacy, 2013; Izuno et al., 2017; Stacy et al., 2014; Stacy and Sakishima, 2019; Stacy et al., 2020) are consistent with ongoing adaptive radiation in Hawaiian *Metrosideros* (Stacy et al., 2014), including the emergence of a riparian variety through incipient sympatric speciation (Choi et al., 2020). Evidence from across the genus suggests that *Metrosideros* may have a high capacity for adaptation to extreme environments, as evidenced by four independent origins of stenophyllous rheophytes in Hawaiʻi, New Caledonia (Dawson, 1992), Lord Howe Island (Green, 1990), and South Africa (Van Steenis, 1981).

In spite of Hawaiʻi's spectacular radiations, most angiosperm lineages comprise single species (Price, 2004). While some of these monotypic groups display intriguing morphological variation (Appendix G), at least 15 endemic species appear monomorphic despite being widely distributed throughout the islands (St. John, 1946). These species may have evolved to become generalists as a consequence of ecological release, although the reason for the failure of speciation in these groups, many of which are species-rich in other parts of the world, is unknown.

4.5. *Diversity processes: non-adaptive radiations*

In some species-rich lineages, divergence does not seem to correspond to abiotic or biotic variation, suggesting that diversification occurred allopatrically through drift (i.e., that radiations are non-adaptive). Among angiosperms, the species-rich genus *Cyrtandra* may result from largely non-adaptive diversification (Carlquist, 1974). *Cyrtandra* is a species-rich genus distributed throughout the Pacific with recent diversification in the Hawaiian Islands (Johnson et al., 2017). Nearly all *Cyrtandra* species are narrowly distributed within wet upland forest understories; 57 of 60 species in Hawaiʻi are single-island endemics (treating Maui Nui as a single island) with many described as micro-endemics. Speciation within this group appears to have occurred predominantly through geographic isolation of small populations following founder events (Cronk et al., 2005; Johnson et al., 2017), with associated phenotypic divergence through drift, and hybridization in sympatry limited by postzygotic barriers (Johnson et al., 2015). Purported examples of non-adaptive radiations should be viewed with caution, however, as they may result from agents of selection that are more difficult to measure.

4.6. *Adaptive shifts in phenotypes*

The preponderance of adaptive radiations in Hawaiʻi offers a unique opportunity to investigate the evolution of phenotypic diversity and ecological release. Some of the phenotypic trends observed in Hawaiian plants are consistent with trait syndromes predicted for other island biotas (Burns, 2019; Patiño et al., 2017), while others are not.

Shifting species interactions and migrations from coastal to inland habitats are thought to have driven phenotypic shifts in native Hawaiian plants. Most plant colonizations to Hawaiʻi occurred in open, dry, or coastal areas, with many groups secondarily expanding into and adapting to wet forests (Carlquist, 1974). Altered dispersibility associated with shifts in dispersal vectors have been described. For example, in *Bidens*, there was loss of seed structures that attach to bird feathers, and in *Euphorbia*, there was an increase in fruit and seed size and loss of stickiness, both of which possibly reduced dispersibility (Wagner et al., 2005); in contrast, the mints (*Phyllostegia, Stenogyne*) and some lobeliads (*Clermontia, Delissea, Cyanea*) evolved fleshy fruits that attract birds (see Section 6), which likely increased dispersibility (Givnish et al., 2009; Lindqvist et al., 2003). Moreover, many of the largest-fruited (or –seeded) species are restricted to the oldest islands of Oʻahu and Kauaʻi (Carlquist, 1974), consistent with an evolutionary trend of increasing fruit size over time. Distributions of floral traits indicate evolutionary shifts as well, such as the evolution of moth pollination in *Brighamia* within the otherwise bird-pollinated lobeliads (Walsh et al., 2019).

Evolution of woodiness from herbaceous ancestors is common in Hawaiian angiosperms and has led to the highest global proportion of woody species of any flora in the world (Carlquist, 1974). An excellent example is the species-rich genus *Euphorbia*, with species transitions from sprawling and prostate plants in dry, coastal scrublands to tall trees in mid-elevation forests on Oʻahu (Yang and Berry, 2011). In *Plantago*, woodiness has evolved twice, alongside the incursion into forest and shrubland habitats from bogs (Dunbar-Co et al., 2008). The reasons underlying increased woodiness in Hawaiʻi's flora are unknown, but likely include the recurring evolution of wet-habitat forest species from coastal or dry habitat forest species, high rainfall in some forests favoring trees or shrubs, and the islands' relatively benign climate in some regions, which promotes continued growth year round and the perennial habit (Burns, 2019; Carlquist, 1974).

4.7. Effects of disharmony

Frontiers for future research involve understanding the effects of disharmony on forest community composition, functional composition and ecosystem functioning. For example, highly polymorphic species such as *M. polymorpha* are widespread and abundant in Hawaiian forests (e.g., present in 435/534 forest plots sampled across the islands (Craven et al., 2018)), whereas species from the diverse adaptive radiation of *Cyrtandra* are present in just two plots. Future examination of the interconnections among plant traits and the effects of disturbances on species, community, and ecosystem scale processes would provide new insights into the dynamics of a highly endemic biota to changing assembly and physical conditions, as has been shown elsewhere (Comita et al., 2018).

5. Demography, life history, and functional ecology

Research on the population dynamics and ecology of Hawaiian forest plants is heavily biased toward *M. polymorpha*, the most abundant and widespread tree species, and Hawaiʻi Island where the largest tracts of intact native forest remain (Jacobi et al., 2017). Less is known about the demography, functional ecology, and life history of Hawaiʻi's other forest trees and forests on the older islands.

5.1. Hawaiian tree demography

Studies of tree demography in Hawaiʻi are limited. Assessments of stage- and size-class distributions have been conducted for a few of Hawaiʻi's dominant species (Drake and Mueller-Dombois, 1993), but these data have rarely been used to quantify population growth rates and dynamics. Moreover, few studies have estimated growth and mortality rates across multiple ontogenetic stages or environments, instead providing snap-shots for a single ontogenetic stage and location. Recent demographic studies have revealed that consumption by non-native animals strongly influences the population dynamics of three endangered Hawaiian forest shrubs (Bialic-Murphy and Gaoue, 2018; Bialic-Murphy et al., 2017, 2018), but that each species is also affected by different environmental factors such as precipitation (Bialic-Murphy and Gaoue, 2018) and the availability of suitable germination sites (Bialic-Murphy et al., 2017). These studies showcase the value of long-term monitoring and demographic modeling for understanding the factors regulating Hawaiian forest plant population dynamics and for identifying key threats to endangered plant sustainability (Aguraiuja et al., 2008; Wong and Ticktin, 2015).

Growth rate estimates for Hawaiʻi's woody species reveal considerable variation among species. For example, for eight species on Hawaiʻi Island, annual increases in trunk diameter ranged from 0.5 mm/yr for *Vaccinium calycinum*, a understory shrub/small tree, to 4.0 mm/yr for the canopy dominant *A. koa*; *M. polymorpha* was close to the lower end of that range at 1.3 mm/yr (Hart, 2010). Faster growth rates have been reported for some forest trees in dry sites on Hawaiʻi Island, peaking with the shrub/small tree *Psydrax odorata* at 8.9 mm/yr (Sandquist and Cordell, 2007). In comparison, median growth rates of tropical tree species outside of Hawaiʻi range from 0.35 to 13.41 mm/yr in Costa Rica (Lieberman et al., 1985), from 6.0–75 mm/yr in Puerto Rico (Lugo et al., 1990), and 3.2–9.4 mm/yr in Venezuela (Worbes, 1999), indicating that Hawaiian species are within the range of growth rates reported for other topical forests, but may cluster at the slow end of the spectrum. Surprisingly few studies have compared growth rates of native and non-native forest species, with some evidence that non-native species have higher growth rates than native trees (Pattison et al., 1998; Stratton and Goldstein, 2001). Additional research comparing a diverse suite of growth metrics of native and non-native species throughout ontogeny could elucidate the stage at which non-native trees appear to out-compete native species, providing crucial insights into the displacement of native by non-native species in Hawaiian forests.

Apart from the well-documented episodic mortality of *M. polymorpha* (canopy dieback events), data on mortality rates are scarce for Hawaiian forest species. In montane wet sites on Hawaiʻi Island, annual mortality ranged from 0.98 % for *Ilex anomala* to 5.82 % for *Coprosma ochracea*, and annual mortality for *M. polymorpha* was 1.1 % (Hart, 2012). As expected, mortality rates varied across ontogenetic stages (not considering seed and seedling stages) for both *M. polymorpha* and *A. koa*, with the highest rates in the largest (oldest) trees (Hart, 2012). Mortality rates and sources of mortality across the archipelago and across gradients, including climate, disturbance, and species interactions (e.g. novel diseases and natural enemies), are needed to better understand how Hawaiʻi's plant populations may cope with future changes in the environment.

5.2. Seedling recruitment in Hawaiian forests

Seedlings growing in Hawaiʻi's forests experience environmental conditions that are distinct from other tropical forests for multiple reasons. First, owing to the relatively open canopy of Hawaiian forests, light levels in Hawaiian forest understories tend to be considerably higher, at 6.4 % transmitted irradiance (Inman-Narahari et al., 2013), than those of other evergreen rainforests, which typically range from 0.01–3.0% (Coomes and Grubb, 2000). In addition, Hawaiʻi's volcanic substrate presents several challenges for seedling establishment, including low nutrient availability and minimal water retention in young substrates. The substrate-age gradient leads to different recruitment dynamics across the archipelago, where young substrates are dominated by episodic recruitment leading to even-aged stands, and older substrates are dominated by gap-phase recruitment.

Seed dormancy, longevity (in storage), and germination patterns are well described for many Hawaiian plants due to a focus over the past 20 years on seed banking for conservation (Baskin and Baskin, 2014; Chau et al., 2019), although the extent to which these patterns reflect variation under natural conditions is unknown. Seed rain studies reveal dominance by *M. polymorpha*, which deposits thousands of minute, wind-dispersed seeds per m^2 per year (Cordell et al., 2009; Drake, 1992, 1998; Inman-Narahari et al., 2013). Typically, less than 20 % of these seeds are embryo-filled (Burton, 1982; Drake, 1992), at least partially due to pollen limitation (Stacy et al., 2017). Other native species may be seed-limited with exceptionally low germination rates (Cordell et al., 2009). Whether poor seed germination of Hawaiian forest plants is a characteristic of the flora or a consequence of altered pollinator and disperser communities is not known. Phenological patterns of flowering and seed production remain poorly described for Hawaiian forest trees, although many species are reported to have ripe fruits coinciding with the wet season (Wagner et al., 1999). Upon maturation, seed consumption by non-native rodents poses a serious threat to native plant regeneration (Chimera and Drake, 2010; Pender et al., 2013; Shiels and Drake, 2011). With the exception of species with physical dormancy such as *A. koa* and *Sophora chrysophylla*, and a few other exceptions such as *Pipturus albidus*, many native species do not form a persistent seed bank (Drake, 1998).

Regeneration of Hawaiian forest plants occurs in various ways, including seed germination on the ground and aerial substrates, sprouts of individual trees, and simultaneous recruitment of whole stands following periodic, widespread dieback. Coarse woody debris (CWD) colonized by mosses during decomposition has relatively high nutrient availability (Nadkarni and Matelson, 1992), and in montane wet sites on both well-drained and water-logged soils, bryophyte-covered CWD is a primary substrate for native seedling recruitment (Burton and Mueller-Dombois, 1984; Cooray, 1974; Iwashita et al., 2013;

Mueller-Dombois, 2000; Santiago, 2000). In water-logged soils, CWD may also alleviate anaerobic conditions by elevating seedlings off the substrate (Santiago, 2000). When CWD is far off the ground, as in nurse logs, seedlings also gain the advantage of reduced disturbance by non-native ungulates, such as feral pigs, or falling tree fern leaves (Busby et al., 2010; Drake and Pratt, 2001). Many seeds germinate on tree ferns (Cole et al., 2012; Drake and Pratt, 2001; Inman-Narahari et al., 2013), which presumably offer similar protection from disturbance. Because most previous seedling recruitment studies were conducted in unfenced areas where ground recruitment is limited by ungulate disturbance, it is likely that recruitment directly in the soil is more common than previously thought, as demonstrated by recruitment patterns in fenced areas (Cole and Litton, 2014).

Light quantity and quality are important factors in Hawaiian forest seedling recruitment. In general, seedling survival is higher under high-light conditions, although high conspecific seedling density can outweigh the benefits of high light (Inman-Narahari et al., 2016; Schulten et al., 2014). Although Hawaiian forests tend to have a relatively open canopy, understory light levels in Hawaiian montane wet forest sites can be quite low where tree and ground ferns such as *Dicranopteris linearis* form dense canopies (Russell et al., 1998), and the increased light provided by treefall gaps may be important for seedling recruitment in such forests, particularly for shade-intolerant canopy species like *A. koa* (Burton and Mueller-Dombois, 1984; Drake and Mueller-Dombois, 1993; Hart, 2010). Dry-adapted forest species likely recruit under relatively high light conditions, and non-native grasses constrain native recruitment in Hawaiian dry forests by reducing light and soil moisture (Thaxton et al., 2010, 2012). Where grass invasions have occurred, light levels have been reduced to the extent that native seedling recruitment is almost entirely absent (Cordell et al., 2009; Denslow et al., 2006). Weeding to remove the grasses can increase native seedling recruitment (Cordell et al., 2009; Denslow et al., 2006), but because it is highly labor-intensive, this is unlikely to be a viable long-term management strategy. Shading treatments that effectively limit grass growth while allowing recruitment of shade-tolerant native species (Funk and McDaniel, 2010; McDaniel and Ostertag, 2010) may be a more cost-effective plan. However, because many Hawaiian forest species are relatively shade intolerant, native species may be quickly displaced by more shade-tolerant invaders once there is canopy closure (McDaniel and Ostertag, 2010; Schulten et al., 2014). This pattern is in stark contrast to most native-invader dynamics in continental forests, and is driven by the high light availability that characterizes the understory of Hawaiian forests.

In general, non-native species are recruiting at high rates in Hawaiian forests (Cordell et al., 2009; Mascaro et al., 2008). While the forest canopy is still dominated by native trees, more successful recruitment by non-native than native seedlings could portend dramatic shifts in community composition to dominance by non-native species as the canopy trees die (Fig. 6). Persistent soil seed banks (Drake, 1998), high seed production (Cordell et al., 2009), preferential dispersal by non-native birds (Vizentin-Bugoni et al., 2021, 2019), vigorous seedling growth (Lurie et al., 2017), and low susceptibility to damage by non-native herbivores (Joe and Daehler, 2008; Shiels et al., 2014) likely all contribute to high seedling establishment of non-native plants in Hawaiian forests. Because our understanding of native species recruitment derives from studies on Hawaiʻi or Maui Islands, these results may not be representative of patterns on the older, more eroded (steeper) and species-rich islands of Oʻahu and Kauaʻi, where non-episodic gap phase recruitment is more likely. Additional research spanning more species, forest types, and substrate ages is thus needed to more broadly understand and identify the conditions optimal for recruitment. Because of ongoing changes to the substrate and overstory of many forests by non-native species (Box 5, Fig. 7), more information about recruitment requirements could shed light on factors constraining *in situ* germination rates of native forest species, and inform management efforts aimed at enhancing natural recruitment as a conservation goal (Chazdon and Guariguata, 2016).

Box 5
Novel and hybrid ecosystems

In this era of the Anthropocene (Braje and Erlandson, 2013), many of Hawaiʻi's landscapes are human-dominated and, due to global trade and transport, contain new mixes of species. Novel ecosystems were first defined as persistent new ecosystem configurations formed by introduced species (Hobbs et al., 2006). Hybrid ecosystems represent an intermediate condition where there are mixtures of native and introduced species (Hobbs et al., 2014). Disturbances and degradation can easily convert a historically native-dominated forest into a hybrid or novel ecosystem (Figure 7A, blue arrows). While restoration is possible (Figure 7A, red arrows), it is labor intensive and expensive, and arguably increasingly difficult to return from hybrid to historical, and perhaps no longer logistically feasible to return from novel to historical directly (Cordell et al., 2016; Ostertag et al., 2009; Suding et al., 2004). Thus, a strong argument can be made that the remaining mostly-native Hawaiian ecosystems should be prioritized for conservation. Acceptance of the idea that some environmental changes create hybrid and novel ecosystems that are irreversible is a paradigm shift (Hobbs et al., 2014).

Understanding the functioning of hybrid and novel ecosystems is vital. Critical questions that need to be addressed in Hawaiian forests relate to the beneficial functional roles that non-native species may play (Ewel and Putz, 2004). Introduced trees may serve as nurse plants, as perches for seed recruitment, as nitrogen-fixers, as phytoremediators, or as fuel for prescribed burns (Ewel and Putz, 2004). Introduced fauna may serve as seed dispersers for native species (Cole et al., 1995; Foster and Robinson, 2007), but are not always dispersing native seeds (Chimera and Drake, 2010; Pejchar, 2015). In addition, humans must make value judgments about the ecosystem properties most desired. For example, novel forests on Hawaiʻi Island had greater species richness, diversity, and rates of aboveground productivity and nutrient cycling than native forest sites (Mascaro et al., 2012), but are those conditions desirable on an island that has been constrained by low nutrients and limited long-distance dispersal for its evolutionary history? The ecosystem services being provided and the interactions occurring among species must be examined on a case-by-case basis in specific locations, because there is no common rulebook for these novel conditions.

One approach to evaluate the costs and benefits of novel and hybrid ecosystems is through deliberate construction of these ecosystems, either in the field or through modeling. Self-assembled vs. designed ecosystems can be distinguished, with that latter having a human-centered goal (Higgs, 2017). In a hybrid restoration experiment in Hilo, Hawaiʻi called Liko Nā Pilina (Figure 7B), four different mixes of native and non-native non-invasive species are being evaluated in terms of plant growth, survival, and reproduction, community assembly of leaf litter arthropods, and ecosystem properties (Ostertag et al., 2020; Ostertag et al., 2015). In a hypothetical study based on Kauaʻi, the relative costs of forest restored to pre-rat conditions (all native), pre-European (with Polynesian introductions), and a hybrid state were compared. The hybrid restoration stood out as moderate in cost, supportive of native plant regeneration and native insect abundance, cultural importance, and resilience to disturbance

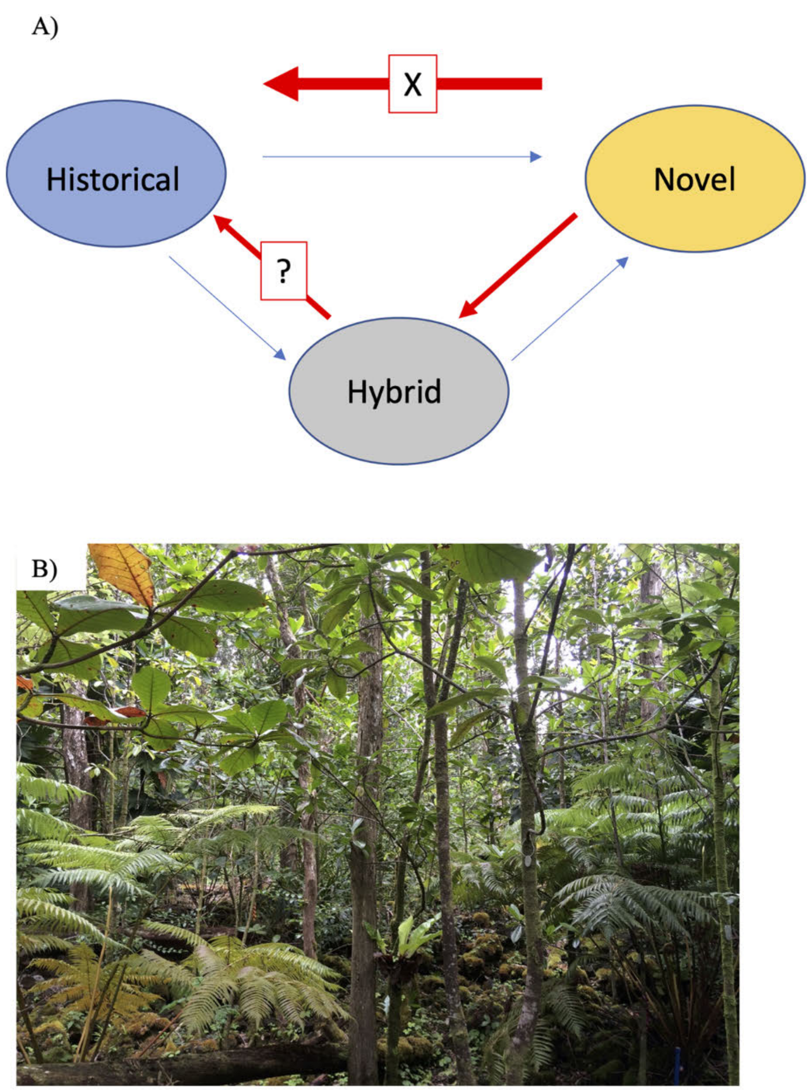

Fig. 7. Hawaiian forests include native-dominated communities that resemble historical pre-human contact assemblages as well as communities composed of a combination of native and introduced species, referred to as hybrids. Increasingly, species turn-over and modification of habitats and ecosystem dynamics are leading to novel ecosystems that are persistent and not easily converted back to historical conditions (A). Restoration efforts influence shifts between ecosystem types with variable success (Box 5). On Hawai'i Island, a hybrid restoration experiment called Liko Nā Pilina (B) investigates how four different mixes of native and non-native non-invasive species influence plant growth, survival, and reproduction, as well as community assembly of leaf litter arthropods, and ecosystem properties. Photo credit: Rebecca Ostertag.

5.3. *Tree physiology and morphology*

The dominance of *M. polymorpha* across such a broad range of environments coincides with remarkable genetic and phenotypic variation, as highlighted in the previous section. Less attention has been paid to intraspecific variation in traits of other native species, although this is changing in recent years (Givnish et al., 2004; Scoffoni et al., 2015; Waite and Sack, 2010). In general, plants in low-diversity forests such as those in Hawai'i are predicted to be slow-growing and conservative in their leaf economic traits (Wright et al., 2004), strategies thought to lead to weak competitive ability compared to continental plants (Simberloff, 1995). Consistent with these predictions, native species have been documented to have higher leaf mass per area, lower leaf nitrogen and phosphorus concentrations and photosynthetic rates, and higher leaf construction costs compared to non-native species in Hawai'i (Baruch and Goldstein, 1999; Funk et al., 2013; Gleason and Ares, 2004; Pattison et al., 1998). Native species also typically have low stomatal conductance and high water-use efficiency at the leaf and whole-tree levels (Cavaleri et al., 2014; Cordell et al., 2002; Kagawa et al., 2009; Santiago et al., 2000; Stratton et al., 2000), resulting in the now widely held claim that Hawai'i's native tree species are 'water savers' and non-natives are 'water spenders.' Most of these studies were restricted to relatively few species on Hawai'i Island, however, and differences in allocation strategies were often not considered. For example, photosynthetic rates in native species can be higher than those of non-native species when considered on an area rather than a mass basis (Funk et al., 2013), and when integrated over the total leaf lifespan, photosynthetic nitrogen-use efficiency is similar between native and non-native tree fern species (Durand and Goldstein, 2001). Considering the extensive environmental gradients that occur within Hawaiian forests, it is not surprising that climate contributes to leaf functional trait expression and adds complexities to these patterns. For example, an archipelago-wide study of 91 species found that non-native woody plants tend to be more resource acquisitive (higher photosynthetic rate, leaf N and P concentrations) in cool, wet habitats whereas native woody plants tend to be more acquisitive in hot, arid habitats (Westerband Knight and Barton, 2021). Other studies have similarly found that climate and resource availability can influence native versus non-native trait differences in Hawai'i (Funk and Vitousek, 2007; Henn et al., 2019), and in some instances, differences in functional trait space may be driven by shifts in community composition following invasion, from woody- to herbaceous-dominated communities. Clearly, the "syndrome" that island plants are more conservative in their leaf ecophysiology and economics has only partial support among studies on Hawaiian trees, and much of our current knowledge regarding trait differences stems from studies conducted primarily on Hawai'i Island (Funk and Vitousek, 2007; Henn et al., 2019). How these patterns of leaf ecophysiology influence plant performance and population dynamics are unclear but would benefit from additional research, particularly for rare species that may be vulnerable to extinction.

6. Positive interactions

Pollination and seed dispersal in Hawai'i's forests involve interactions with insects and birds. Birds are the only native vertebrate pollinators and frugivores in Hawai'i, which further distinguishes Hawai'i from other tropical islands, where bats and reptiles are also important pollinators and seed dispersers (Fleming and Kress, 2013). Because many birds went extinct before being studied by western scientists, much of what has been published regarding their roles as pollinators and frugivores has been inferred from the morphology of birds' bills and tongues, and from observations by early naturalists and descriptions in mo'olelo (Hawaiian oral histories); there has been surprisingly little effort to document the effectiveness of the remaining birds as pollinators. Given the limited number of extant native bird species that serve as pollinators, this task is tractable, and would be a valuable contribution to studies that compare the simplified pollination webs of Hawai'i to continental systems. In addition, recent research has documented climate-mediated decreases in the population sizes of Hawaiian forest birds that are likely pollinators and dispersers of many forest plant species (Benning et al., 2002; Paxton et al., 2016), which would contribute to an accelerated regime shift in Hawaiian forests.

6.1. Pollination

Information on specific plant-pollinator relationships in Hawai'i is fairly limited, but floral morphology suggests that 67 % of native plants are likely pollinated by insects, 19 % by birds, and 14 % by wind (Sakai et al., 2002). Although bees are most important pollinator group at the global scale, they are represented in Hawai'i by a single lineage of about 60 species in the genus *Hylaeus* (Colletidae) (Zimmerman, 1948), which occurs in virtually all habitat types, including forests (Daly and Magnacca, 2003). Although *Hylaeus* bees were among the most common native insects around the turn of the 20th century, today their populations are severely reduced, and many species are now rare or extinct owing to their heavy reliance on native plant resources and sensitivity to non-native insects (Magnacca, 2007; Miller et al., 2015; Wilson and Holway, 2010).

Hylaeus bees have been recorded on the flowers of over 60 native plant species, but they are thought to utilize community-dominant species most heavily (Daly and Magnacca, 2003; Magnacca, 2007). For example, these bees frequently visit and carry the pollen of *M. polymorpha* and *A. koa* flowers (Hanna et al., 2013; Koch and Sahli, 2013; Lach, 2008). *Hylaeus* may be important pollinators for other native plants that tend to receive few other regular visitors (Magnacca, 2007), especially species that, unlike *M. polymorpha*, are not also highly attractive to birds. Quantitative assessments of *Hylaeus* floral visitation rates and networks, however, are few and concentrated in coastal (Shay et al., 2016) and high-elevation ecosystems (Wilson et al., 2010). Interactions of *Hylaeus* with native plant communities in mid-elevation, closed-canopy forests in mesic to wet sites have yet to be characterized.

Even less is known about the roles of other insects in the pollination ecology of native Hawaiian plants. Many moths, for example, visit flowers nocturnally, and these interactions are not often observed. One recent series of studies discovered that two endangered *Schiedea* species occurring in forests with intermediate rainfall are pollinated only in the evening, and only by one to several species of small native moths, some of which remain undescribed (Weisenberger et al., 2014; Weller et al., 2017). Neither of the two native butterfly species (*Vanessa tameamea* and *Udara blackburnii*) has been confirmed to pollinate native trees, although adults of both species feed on *A. koa* nectar. One common conclusion to date is that native pollinating insects are strongly reliant on native plant resources, but whether the converse is equally true remains poorly understood. Floral visitation is now dominated by non-native insects in many Hawaiian ecosystems, and these insects tend to visit a wider range of native and non-native plants than native pollinators (Aslan et al., 2019; Kuppler et al., 2017). Whereas non-native species like European honey bees may be replacing lost pollination services in some cases (Hanna et al., 2013), their more generalist behavior may reduce pollination effectiveness in others via heterospecific pollen transfer (Miller et al., 2015).

Native flower-visiting birds are restricted to two monophyletic endemic lineages. The honeyeaters (Mohoidae) consist of five extinct species, all of which were specialist nectar feeders with relatively large, curved bills (Fleischer et al., 2008). The honeycreepers (Fringillidae, Drepanidini) consist of over 50 species, most of which are now extinct. At least five of these were specialist nectar feeders, and several others were generalists that occasionally consumed nectar (Banko and Banko, 2009; Pratt, 2005, 2009). The strongest inferences on bird pollination have been made for the lobeliads (Campanulaceae), a radiation of over 120 endemic species of shrubs and small trees (Givnish et al., 2009). Nearly all species in the lineage bear large, tubular flowers that appear adapted to pollination by birds, and all species examined produce the relatively dilute, hexose-dominated nectar commonly found in passerine-pollinated plants (Lammers and Freeman, 1986; Pender et al., 2014). Reproduction in some lobeliads may now be limited owing to the extinction of all honeyeaters and most honeycreepers (especially the nectar specialists with long, curved bills), and the decline of most remaining nectar-feeding honeycreepers. Native birds are increasingly infrequent visitors to lobeliads in many Hawaiian forests, especially at low and mid elevations where introduced avian malaria has decimated native bird populations (Cory et al., 2015). The introduced, generalist warbling white-eye (*Zosterops japonicus*) visits lobeliads, acting as an effective pollinator for species with small, accessible flowers, but species with deeper, more strongly curved flowers are either avoided or nectar-robbed by these birds (Aslan et al., 2014a, b). The role of self-pollination across lobeliad species remains unclear, but the decline of most species within this lineage suggests that a lack of pollinators may be one factor limiting regeneration, and that co-extinctions of plants and specialist pollinators have occurred and are in progress in Hawaiian forests.

6.2. Seed dispersal

Approximately 40–50 % of Hawaiian flowering plants produce fleshy fruits (Sakai et al., 2002), most of which are presumably adapted for dispersal by vertebrates. At least two major lineages of plants evolved fleshy-fruitedness after arriving in the islands: Campanulaceae and Lamiaceae. In addition to their roles as pollinators, birds are Hawai'i's only native vertebrate frugivores. This again distinguishes Hawai'i from most tropical islands, where seed-dispersing frugivores commonly include birds, bats, and reptiles (Fleming and Kress, 2013). The single native bat species, 'ōpe'ape'a (*Aeorestes semotus*), is insectivorous (Gorresen et al., 2018).

Birds that feed primarily on fruit include only two of the honeycreepers (though several generalist honeycreepers occasionally consume fruit), all five species of thrush (Turdidae), and all three crows (Corvidae) (Banko and Banko, 2009). Three of the five thrushes (*Myadestes*) are now extinct, and one rare species is restricted to montane rain forest on Kaua'i (Pratt, 2009). The single remaining common species (*M. obscurus*, 'ōma'o) occurs in montane forests on Hawai'i Island (Pejchar, 2015). Two of Hawai'i's three species of crows (*Corvus*) are known only from sub-fossil remains, and the remaining species (*C. hawaiiensis*) currently exists only in captivity. In addition to these frugivorous birds, which were almost certainly seed dispersers, at least six species of honeycreepers that consumed fruits and seeds had heavy bills specialized for crushing seeds and likely functioned more as seed predators than seed dispersers (Banko and Banko, 2009; Carpenter et al., 2020; Olson, 2014; Walther and Hume, 2016). Most of these species are extinct, and their effects on plant reproduction are unknown. The remaining species, *Loxioides bailleui* (palila), is now restricted to high-elevation forests on Mauna Kea, where it relies heavily on seeds of *Sophora chrysophylla* and the insect larvae they contain (Hess et al., 2014).

Inferences regarding the roles of extinct species in seed dispersal in Hawaiʻi are largely speculative, and even for the extant frugivores, little is known about dispersal beyond information on diets (Banko and Banko, 2009). The only published estimates of seed dispersal distances by native birds are for the ʻōmaʻo (Pejchar, 2015; Wu et al., 2014). Current frugivore communities also include several non-native birds that differ from native species in consuming smaller fruits, potentially driving selection for smaller fruits and thus a shift in community composition toward small-fruited species (Sperry et al., 2021). For example, the ʻōmaʻo inhabits montane forests on Hawaiʻi Island where it co-occurs with two generalist, non-native species: the warbling white-eye (*Zosterops japonicus*) and red-billed leiothrix (*Leiothrix lutea*) (Pejchar, 2015). The ʻōmaʻo consumes significantly larger fruits than either of the non-natives, and hence a greater range of species (Pejchar, 2015), but likely disperses them over shorter distances than the warbling white-eye (Wu et al., 2014). Similarly, the ʻalalā (*Corvus hawaiiensis*), extinct in the wild, is the largest remaining native forest bird and consumes larger seeds than all other extant birds (Culliney et al., 2012; Matsuoka, 2020). A more recent study that focused on diet diversity in the field found that plant species richness of ʻōmaʻo was significantly greater than leiothrix, and that the warbling white-eye had the lowest diet diversity and was the least frugivorous (Matsuoka, 2020).

There is increasing evidence that many introduced bird species, including at least 45 passerines and 12 gamebirds, may be at least partially filling the roles of extinct native dispersers (Foster, 2009), particularly for small-seeded native plants in the wet-montane (Foster and Robinson, 2007; Matsuoka, 2020) and dry-lowland (Chimera and Drake, 2010) forests. However, recent studies in seven forests on Oʻahu found that 93 % of seed dispersal events involved alien birds dispersing small-seeded alien plants (Vizentin-Bugoni et al., 2021, 2019), even in native-dominated forest. Matsuoka (2020) suggests that if the two native frugivores become extinct, the forest community would shift towards smaller-seeded species such as *Vaccinium* spp. and *R. hawaiensis*.

The recent, near-complete extinction of native fruit-eating birds has resulted in seed dispersal networks composed entirely of novel dispersers (Case and Tarwater, 2020; Vizentin-Bugoni et al., 2021, 2019), which are expected to result in altered patterns of seed dispersal for a majority of species. In particular, the Hawaiian flora includes several species with large ($\geq$ 5 cm diameter), fleshy fruits that have no known seed disperser, e.g., *Pritchardia martii* (Arecaceae), *Ochrosia* spp. (Apocynaceae), and *Alectryon macrococcus* (Sapindaceae) (Wagner et al., 1999). Potential dispersers in prehistoric times include the larger crows and possibly some species of moa-nalo, an extinct lineage of large, flightless waterfowl (Walther and Hume, 2016), though the latter might also have destroyed some of the seeds they ingested, if they consumed them at all (Carpenter et al., 2020). Research in montane mesic forest suggests that two of the four species examined were dispersal limited (Denslow et al., 2006). In Hawaiʻi's dry-habitat forests, where the fruits of native species tend to be larger, the effects of the loss of native seed dispersers are potentially even more severe. Whereas nearly 60 % of native forest tree species in a dry site had fleshy fruits, the predominant seed disperser of today, the warbling white-eye, overwhelmingly disperses non-native seeds (>92 % of seeds carried) rather than native seeds (<8% carried; Chimera and Drake, 2010), thereby contributing to the spread of nonnative plants in Hawaiian forests. The mismatch in size between historical native bird dispersers and extant non-native bird dispersers thus constrains dispersal for some large-seeded forest plants, likely contributing to a decline in recruitment and constriction in distribution. Whether plants can adapt to attract novel dispersers quickly enough to out-pace non-native species spread, or the confounding effects of other global threats such as global warming and habitat conversion, is unknown but relevant for conserving Hawaiian forests.

6.3. Plant-microbe interactions

Microbial diversity across Hawaiʻi's environmentally heterogeneous islands remains relatively uncharacterized, although previous studies have revealed interesting patterns. Contrary to predictions about limited fungal dispersal to the Hawaiian Islands, there is evidence for high mycorrhizal diversity and specialized interactions with mycoheterotrophic plants (Hayward and Hynson, 2014; Koske and Gemma, 1990). Most native and non-native Hawaiian plants form associations with mycorrhizal fungi (Koske et al., 1992), which enhance their performance (Gemma et al., 2002; Koske and Gemma, 2006; Miyasaka et al., 1993). Furthermore, there is evidence that mycorrhizae play a role in the establishment and spread of non-native plants (Allison et al., 2006; Hynson et al., 2013), although whether native mycorrhizae provide biotic resistance to the spread of non-native plants remains unclear. In addition to mycorrhizae, microbial interactions that improve nutrient access for host-plants include symbioses with *Rhizobium* bacteria for nitrogen. Although relatively few native trees have this symbiosis, a few common and widespread species, *A. koa*, *S. chrysophylla*, and *Erythrina sandwicensis*, develop nodules and likely play important roles in nutrient availability in Hawaiian forests (Pearson and Vitousek, 2001). Nitrogen fixation by non-native species, such as *Morella faya*, has been implicated in their successful establishment, with cascading effects on soil nitrogen and carbon cycling in Hawaiian forests (Asner et al., 2010; Vitousek et al., 1987).

Recent work has expanded from a focus on mycorrhizae and *Rhizobium* to demonstrate that soil fungal, bacterial, and archaeal diversity on Hawaiʻi Island co-vary in a complex and lineage-specific manner with precipitation and soil nutrient density (Peay et al., 2017), and that endophytic fungal communities within Hawaiian plants are highly diverse (Darcy et al., 2020; Datlof et al., 2017; Vega et al., 2010; Zimmerman and Vitousek, 2012). Microbial diversity can relate to the abiotic environment, as has been shown by the fungal endophyte communities within *M. polymorpha* with respect to rainfall and temperature (Zimmerman and Vitousek, 2012), and evapotranspiration (Darcy et al., 2020).

There are few functional studies of forest microbes, but they reveal that microbes have positive effects on forest plant species beyond their contributions to nutrient cycling. For example, the application of microbes extracted from healthy relatives to leaves of endangered *Phyllostegia kaalaensis* plants reduced the incidence of non-native powdery mildew and enhanced survival of out-plantings (Zahn and Amend, 2017). Forest microbes are also involved in food-web dynamics, as evidenced by epiphytic fungi on native Hawaiian trees serving as the primary food source for highly endangered tree snails in the genus *Achatinella* (O'Rorke et al., 2015; Price et al., 2017). Microbial ecology remains understudied in Hawaiian forests and is likely to be a fruitful area for future research.

7. Antagonistic interactions

The decline in Hawaiʻi's native fauna makes it difficult to characterize antagonistic species interactions in food webs or other interaction networks that are now dominated by non-native species. Nonetheless, there are still some native animals in Hawaiian forests, and insights can also be gained by examining interactions with novel natural enemies.

7.1. Herbivory

Native plant-herbivore interactions in Hawaiian forests are not well studied, and we know little about the specificity of interactions, temporal or spatial variability in those interactions, cascading consequences for upper trophic levels, effects on plant fitness, or the role of plant defenses in reducing or mitigating negative effects of herbivory. In part, this lack of research results from the pervasive assumption that island plants lack defenses due to a relaxation in selection pressure by (presumably absent) island herbivores (Bowen and VanVuren, 1997; Carlquist, 1974; Ziegler, 2002). Comparisons of native versus non-native plants in Hawaiʻi, however, have provided mixed or weak support for this idea. Although non-native species are reported to have higher levels of terpenes than native species (Sardans et al., 2010), concentrations of total phenolics are similar between native and non-native plants (Funk and Throop, 2010; Peñuelas et al., 2010), and leaf toughness (Funk and Throop, 2010) and prickle density (Hoan et al., 2014) are higher in native plants. Comparisons of herbivory as an indirect metric of defense (e.g., greater herbivory should reflect lower defense in focal plants) have similarly revealed mixed support, with no detectable difference between non-native and native Hawaiian plants in leaf damage by insects (Funk and Throop, 2010), and variable damage by non-native gastropods (Shiels et al., 2014).

Clearly, native Hawaiian plants are not uniformly less well defended than continental plants, a pattern corroborated by recent meta-analyses comparing defenses in island versus continental plants globally (Meredith et al., 2019; Moreira et al., 2021). Future research is needed to improve on previous methods and more robustly characterize the variation in defenses in the Hawaiian flora. For example, multiple defense types should be measured simultaneously (Barton, 2014), including resistance via chemical and physical traits, indirect defense via natural enemies, and tolerance to herbivory, the last of which is typically overlooked and has been shown to vary among native and non-native Hawaiian seedlings (Barton, 2016; Barton and Shiels, 2020; Lurie et al., 2017). Finally, specificity in plant defenses should be examined as this likely explains the variable results among previous studies. Most studies concluding that island plants lack defenses have focused on mammalian herbivory (Bowen and VanVuren, 1997; Burns, 2014; Moreira et al., 2021), but because defenses are usually highly specific (Ali and Agrawal, 2012; Tanentzap et al., 2011), island plants may be poorly defended against mammalian herbivores while simultaneously being well defended against other guilds, such as piercing-sucking insects or browsing birds, of which Hawai‘i had many (Walther and Hume, 2016).

The emphasis on weak defenses against mammalian herbivores in Hawaiian plants has unfortunately masked interesting interactions between plants and native invertebrate herbivores, which are highly diverse but taxonomically disharmonic in intriguing ways. For example, large leaf-chewing beetles are principally represented by a single possibly monophyletic group of weevils in the genus *Rhyncogonus* (Samuelson, 2003). Lepidoptera are a major member of the leaf-chewing guild in most tropical forests, and these too exhibit idiosyncratic representation; of the ~1000 known species in Hawai‘i, only two are butterflies, and many groups of moths common in other tropical forests are absent (Nishida, 2002; Rubinoff, 2017). The piercing-sucking insect fauna is well developed in Hawai‘i, and is similarly dominated by relatively few lineages that have diversified after arrival. As an example, the >80 species of delphacid planthoppers in the genus *Nesosydne* have evolved to utilize 28 plant families as hosts, but each species typically feeds on a single plant species (Bennett and O’Grady, 2012; Roderick and Percy, 2008). Conversely, all 35 species within a monophyletic radiation of gall-forming and free-living psyllids in the genus *Pariaconus* partition resource space within a single host plant species, *M. polymorpha* (Amada et al., 2019; Percy, 2017).

The community of endemic invertebrates that feeds on Hawai‘i’s forest plants also engages in a range of microbial symbioses. For example, the leaf- and sap-feeding insects (e.g., endemic planthoppers and leafhoppers) have intimate symbioses with bacteria and fungi that provide essential nutrients that may be missing in their phloem- and xylem-sourced diets (Baumann, 2005). A recent survey of several Hawaiian endemic insect species revealed that they maintained similar bacterial symbiotic interactions as their continental relatives (Poff et al., 2017), despite their long-term geographic and temporal isolation.

Despite declines in native insects, both *A. koa* and *M. polymorpha* currently experience high levels of native insect herbivory. The specialist koa moth, *Scotorythra paludicola* (Geometridae, Lepidoptera), undergoes periodic outbreaks that can defoliate tens of thousands of hectares of *A. koa* forest within a matter of months (Banko et al., 2014; Haines et al., 2009). With caterpillar abundances as high as 250,000 per tree during outbreaks, there is nonetheless variation in the intensity of defoliation among trees, and also variation among trees in their compensatory growth responses following defoliation (Banko et al., 2014). More research is needed to identify the factors that precipitate koa moth outbreaks and determine their severity and longevity, as well as the traits underlying variation in *A. koa* defenses. Like *A. koa*, *M. polymorpha* hosts abundant native arthropod communities, which are also species-rich (Gagne, 1979; Gruner, 2007). For example, Gruner (2007) collected 423 native arthropod species at five mesic forest sites across the archipelago chronosequence. Approximately 15–20 % of these species were herbivorous, and the abundance and biomass of herbivores were highest in intermediate-aged sites (5,000–150,000 years old), which were also the most productive, with the highest levels of foliar and litter nutrients. Considering that the greatest genetic diversity and taxonomic richness within the *Metrosideros* species complex is found on O‘ahu (Stacy and Sakishima, 2019; Sur et al., 2018), the full diversity of arthropods associated with this landscape-dominant group remains unexplored. Arthropod diversity associated with other Hawaiian plants is even less well known.

Non-native insects are abundant in Hawaiian forests, are constantly being introduced through horticultural and agronomic activities, and cause severe damage to native plants. A wide range of common and rare trees are attacked by generalist herbivores, such as the black twig borer (*Xylosandrus compactus*) and lobate lac scale (*Paratachardina pseudolobata*). In addition, some native tree hosts have been decimated by highly specialized species, such as the Erythina gall wasp (*Quadrastichus erythrinae*) and Naio thrips (*Klambothrips myopori*) (Conant et al., 2009; Hara and Beardsley, 1979; Kaufman and Higashi, 2015; Rubinoff et al., 2010). The effects of these new herbivores range from stunting of trees to stand-level dieback. Non-native ants frequently increase abundances of phloem-feeding insects on plants by protecting them, but may also reduce densities of leaf-chewing herbivores (Krushelnycky, 2015).

Grazing by native birds was possibly an important source of herbivory on Hawaiian plants before these species went extinct. The endangered nene, *Branta sandwicensis*, currently feeds on native plants within its reduced distribution (Baldwin, 1947; Black et al., 1998). The now-extinct flightless moa-nalo and nene-nui likely caused even greater plant defoliation owing to their large size. It has been suggested that selection imposed by these extinct browsers led to the independent evolution of prickles in four lineages of the endemic genus *Cyanea* (Givnish et al., 1994). Even Hawaiian honeycreepers can act as herbivores in addition to their roles as pollinators and seed dispersers. For example, the endangered palila, *Loxioides bailleui* (Fringillidae, Drepanidinae) most commonly consumes immature seeds of *Sophora chrysophylla*, but also consumes leaves and flowers of six Hawaiian plant species from diverse families (Hess et al., 2014). Unfortunately, due to declines and extirpations, it is impossible to know the extent of native bird browsing or its effect on native plant fitness.

7.2. Pathogens

Effects of pathogens in Hawaiian forests are not well documented. It has been suggested that they may have played a role in the periodic forest diebacks that have been documented throughout the history of the islands (Anderson et al., 2002; Clarke, 1875; Forbes, 1918; Gardner, 1980; Hodges et al., 1986; Mortenson et al., 2016; Mueller-Dombois, 1987). The role of tree pathogens in these episodes is not clear, highlighting the inherent challenges of identifying the drivers of tree mortality, particularly when microbes may be involved. For example, *M. polymorpha* dieback observed in the 1960–70’s was initially attributed to a widespread, soil-borne fungal pathogen (Burgan and Nelson, 1972), but it was later concluded that dieback was due to cyclical forest dynamics, possibly in combination with climatic conditions (Hodges et al., 1986; Jacobi, 1993; Mueller-Dombois, 1985). In contrast, recent declines of *A. koa* and *M. polymorpha* have more definitively been linked

Table 3
Tools and actions to promote conservation and restoration of Hawaiian forests, organized by focal outcome – enhance biodiversity, maintain suitable habitat, and protect ecosystem function. Some actions and tools have featured more commonly than others, and the ones marked with an asterisk have received relatively little attention and are fruitful areas for future research. Information about the natural history and biology of Hawaiian forest species from ecological and evolutionary research can enhance and improve conservation. Relevant theories and fields of study are identified for each conservation tool/action.

Theme	Classification	Tool/Action	Insights from Ecology & Evolution Research
Biodiversity	Conservation	Species discovery and taxonomy	Next-gen tools provide precision for recent lineages
		Living Collections: Seed banking	Seed storage behavior, longevity, and dormancy
		Living Collections: Tissue culture	
		Living Collections: seed orchards	Variation in phenology and seed production
		Living collections: nurseries, gardens	Seed and seedling ecology - germination and establishment behavior
		*Disease control	Novel diseases; evolution of defense of island plants
		*Predator/herbivore control	Novel predators and herbivores; evolution in defense of island plants
		*Mutualist protection (e.g. pollinators, seed dispersers)	Species networks and specificity of island plant-animal interactions
		Early detection of threats (non-native plants, enemies)	Invasion stages
		Protective designation: conservation priorities (e.g. endangered species, high biodiversity)	Ecosystem services, species network; diversity theory
	Restoration	*Cross breeding (e.g., between populations)	Inbreeding vs. outbreeding consequences (especially in low population sizes)
Habitat	Conservation	*In situ* outplanting (species scale)	Plant establishment; niche theory; priority effects
		Inter situ outplanting (species scale)	Plant establishment; niche theory; priority effects
		Ungulate control (fencing, hunting)	Ungulate behavior; population ecology
		*Outreach/service learning	Biocultural conservation
		Protective designation: habitat suitability	Niche theory
	Restoration	*In situ* outplanting (habitat scale)	Plant establishment; niche theory; priority effects
		Inter situ outplanting (habitat scale)	Plant establishment; niche theory; priority effects
		*Climate change mitigation: assisted migration	Plant stress tolerance; niche theory; intraspecific variation
		Non-native plant control (detection, removal, reduction)	Invasion stages; plant population dynamics and controls
Ecosystem function	Conservation	Protective designations (e.g., forest reserves)	Biodiversity; ecosystem services
		Biosecurity (early detection of threats)	Dispersal; invasion stages
		*Fire control (suppression, break establishment)	Disturbance ecology; plant fire tolerance
	Restoration	Conversion of fallow agriculture lands into novel forests (e.g., timber and agroforestry)	Succession
		*Hybrid forests (native and non-native)	Community assembly; ecosystem services; species interactions
		*Post-disturbance seed sowing	Plant recruitment; niche theory; priority effects

to introduced pathogenic fungi.

The disease Koa Wilt was first observed in 1980 in greenhouse *A. koa* saplings, which rapidly wilted and senesced (Gardner, 1980). Since then, stand-level diebacks have occurred across Hawaiʻi Island, particularly at elevations below 2500 feet, and sporadic tree mortality has been observed on the other main islands (Gardner, 1996). *Fusarium oxysporum* f. sp. *koae* was consistently isolated from infected trees, and it is now known to kill trees of all sizes and ages (Anderson et al., 2002; James et al., 2006). Mortality tends to radiate from a centrally infected tree, indicating transmission between root systems via soil and water (Anderson et al., 2002; Dudley et al., 2007). This epidemiological pattern has made it challenging to cultivate *A. koa* in plantations and to reestablish it in affected areas (Anderson et al., 2002; Gardner, 1980). Encouragingly, variation in mortality among trees suggests some natural resistance exists (Dudley et al., 2015).

Within the last 15 years, *M. polymorpha* trees have suffered two widespread outbreaks of fungal pathogens. In 2005, a seedling on Oʻahu was observed to have fungal rust that was isolated and identified as *Austropuccinia psidii* (Beenken, 2017; Uchida et al., 2006); the disease has since spread throughout the archipelago. The *Austropuccinia* rust has had a relatively minor impact on *M. polymorpha* trees, infecting up to 5% of trees in areas where the disease is known to occur (Loope, 2010). However, *A. psidii* has also infected at least five other native trees and shrubs, with significant impact on the endangered *Eugenia koolauensis* (Zablan, 2007). Spores occur on the leaves of infected plants and can be spread via wind, or direct contact with humans, birds, and bees (Carnegie and Cooper, 2011).

Since 2010, rapid, stand-level mortality events commonly known as rapid ʻōhiʻa death (ROD) have emerged as a serious threat to *M. polymorpha*, first on Hawaiʻi Island, and more recently, on Kauaʻi, Maui, and Oʻahu (Brill et al., 2019; Keith et al., 2015; Mortenson et al., 2016). Recently, ROD has been primarily attributed to a new fungal vascular pathogen, *Ceratocystis lukuohia* (Barnes et al., 2018) that leads to a swift decline in performance and mortality of trees within weeks following the onset of symptoms. The mechanisms of transmission for *C. lukuohia* likely involve a combination of local and long-range wind dispersal, non-native insects (Roy et al., 2019), humans, and ungulates, but further research in this area is needed. ROD is highly virulent, leading to >20 % annual mortality in infected stands, with several of the earliest impacted stands exhibiting almost 100 % mortality (Mortenson et al., 2016). Preliminary screening of young *M. polymorpha* plants on Hawaiʻi Island revealed variation in mortality rates and suggested the presence of some form of resistance in at least one variety (Luiz et al., 2021). At the time of this writing, ROD has spread throughout Hawaiʻi Island, impacting over 70,000 ha, and has dispersed to Kauaʻi, Maui, and Oʻahu as well. Given the role of *M. polymorpha* in shaping native forest structure, and the numerous rare understory species that are restricted to *M. polymorpha*-dominated forests, the further spread of the pathogen is likely to have wide ranging ecological effects beyond *M. polymorpha* mortality (Fortini et al., 2019).

8. Living in today's world – conservation challenges

Hawaiian forests are threatened by the same anthropogenic factors that are acting worldwide, including habitat loss, non-native species, and climate change. Island floras are particularly vulnerable to these threats due to their restricted species distributions, relatively low genetic diversity, and high rates of endemism (Caujapé-Castells et al., 2010). As home to a unique endemic biodiversity, Hawaiʻi receives considerable attention with respect to managing these threats (Friday et al., 2015). There are many approaches to forest conservation and restoration around the world, and the same is true of Hawai'i (Gillespie et al., 2014; Jones, 2017; Kawelo et al., 2012). Forest restoration goals include, but are not limited to, increasing and restoring ecosystem services such as carbon sequestration and watershed function (Goldstein et al., 2008; Rayome et al., 2018; Strommer and Conant, 2018), increasing native species diversity, restoring habitat for native animals including birds, bats, snails, and insects (Pejchar et al., 2018), restoring resiliency and sustainability (Ostertag et al., 2015), restoring the Indigenous cultural landscapes (Box 3, Fig. 3) (Burnett et al., 2019; Pascua et al., 2017; Winter and Lucas, 2017; Winter et al., 2020b, c), educating the public about native forests, and benefiting from commercial timber operations (Harrington and Ewel, 1997; Ostertag et al., 2008) and integrated agroforestry (Friday et al., 2015). Meeting these goals depends on combined approaches to mitigate threats, proactively protect healthy forests, and restore lost functions or interactions, all of which benefit from an understanding of the complex ecological and evolutionary dynamics of Hawaiian forests.

8.1. New forest regime

Hawaiian forest assembly has been completely altered by non-native plants, animals, and microbes, and these non-native species have disrupted ecosystem dynamics (Box 5, Fig. 7). For example, in dry areas, fire-promoting C4 grasses from Africa now typically dominate the understory, resulting in the almost complete loss of native seedling recruitment, with cascading losses of forest structure (Litton et al., 2006). These changes in community structure and composition result in fuel and microclimate conditions that increase the likelihood of subsequent fires (D'Antonio and Vitousek, 1992; Freifelder et al., 1998). This cycle is now considered the primary agent in conversion of forest to grassland in dry and mesic ecosystems in Hawai'i and elsewhere in the tropics (Mack and D'Antonio, 1998). The transformation of a forest to a grassland yields a substantial loss of aboveground carbon and significantly alters nutrient cycling (Litton et al., 2006; Mack and D'Antonio, 2003). This is a radical shift from the pre-human contact period when grasslands were a small component of Hawaiian landscapes (Rollins, 2009).

Forest ecosystem dynamics have been profoundly altered by invasions as well. For example, in mesic and wet forest sites, dominance by nitrogen-fixing species, such as *Morella faya* and *Falcataria moluccana*, alters nutrient availability and reduces above-ground carbon stocks, facilitating further invasion by species that can take advantage of high soil nitrogen availability (Allison and Vitousek, 2004; Hughes et al., 2017; Hughes and Denslow, 2005; Vitousek and Walker, 1989). In dry forest sites, *Prosopis pallida* not only influences nitrogen-cycling, but also has deep roots that are able to tap into groundwater sources at the local (Dudley et al., 2014) and landscape levels (Dudley et al., 2020). *Morella faya* also alters the light environment, shading out light-dependent native under- and mid-story species (Asner et al., 2008). These altered biogeochemical cycles, coupled with reductions in light availability, ultimately shift these systems to entirely novel ecosystems (Mascaro et al., 2012). Among forest survey plots, *Psidium cattleyanum* is now the second most abundant tree (after *M. polymorpha*) across all islands (Table 1), and its continued spread is a major threat to Hawaiian forests. In addition to interactions with other non-native species, such as pigs that disperse their seeds, *P. cattleyanum* alters soil carbon and nutrient cycling (Barbosa et al., 2017; Enoki and Drake, 2017; Strauch et al., 2016).

Hawai'i's native trees and forests are at continued risk due to the arrival and spread of non-native microbial pathogens (DeNitto et al., 2015). The U.S. Department of Agriculture, Forest Service recently reported that given Hawai'i's central location in the Pacific and reliance on an import economy, the regions that pose the greatest pathogen risk to the archipelago are the continental United States and Asia-Pacific (DeNitto et al., 2015). Unfortunately, awareness of pathogens in Hawai'i generally arises only after pathogen-plant-vector links are established and disease has occurred. Considerable time is then required to identify etiological agents and transmission mechanisms (Fletcher et al., 2010). Travelers leaving Hawai'i undergo strict inspections to prevent the spread of pests to mainland agriculture, but there are no inspections for travelers coming to Hawai'i, which could offer a beneficial strategy to protect native biodiversity in the islands. Given the limited screening of incoming biota and the lack of information on both the susceptibility of local plants to these threats and the importance of endemic and introduced animals as vectors, it is incredibly difficult to manage this threat. Unfortunately, this scenario leaves no opportunity for prevention, and limited knowledge to swiftly implement mitigation efforts (Fletcher et al., 2010).

Ongoing climate change may introduce yet further regime shifts in Hawaiian forests owing to differences between native and non-native trees in their ecohydrology. Differences in canopy structure and epiphyte abundance between native and non-native species cause differences in cloud water interception (Juvik and Nullet, 1995; Takahashi et al., 2011), further exacerbating drought effects. Several studies have shown lower water-use efficiency of non-native plants (see Section 5), with higher transpiration rates reducing local soil moisture (Michaud et al., 2015) and downstream watershed yields (Strauch et al., 2017). These complex threat interactions are challenging to explore, and may quickly become intractable as additional threats are considered (e.g., land-use and climate influencing fire risk, which in turn influences disturbance and consequently invasion risk).

The effects of climate change on non-native animals are important for the conservation of Hawai'i's forests and, in at least some cases, are being carefully monitored. There is perhaps no clearer global example than the warming-driven spread of avian malaria into high-elevation forests that threatens Hawaiian forest bird species (Benning et al., 2002). The high susceptibility of most native forest birds to avian malaria and the known temperature constraints to disease and vector development explain ongoing forest bird population declines and are expected to lead several species towards extinction with additional warming (Fortini et al., 2015; Liao et al., 2017; Paxton et al., 2016).

8.2. Conservation philosophies

There is a broad range of initiatives and entities involved in the conservation of Hawai'i's forests, including Federal and State agencies, watershed alliances that include both government and private lands, and non-profit organizations, each with their own missions that work independently or collaboratively with community groups towards forest conservation and restoration. Conflicts between hunters and conservationists and Indigenous cultural practitioners over natural resource management have been a major challenge since at least the 1990s (Adler, 1995; Kueffer and Kinney, 2017). In some cases, the conflicts arise due to different cultural priorities between conservation managers and natural resource users, as illustrated by demands to maintain non-native vertebrates for hunting. In other cases, the source of contention concerns approaches to conservation and how and where particular conservation tools (e.g., biocontrols versus chemical controls versus mechanical controls) should be used. Such challenges are not insurmountable, however, and more collaborative approaches to conservation are currently being pursued. A final major limitation concerns support for conservation efforts in terms of funding, personnel, and public perception, none of which are sufficient for conservation to be successful (Leonard, 2008).

There is a spectrum of philosophical foundations and goals to forest restoration projects in Hawai'i. Some aim to restore altered forests to a historical pre-contact state (Jones, 2017). However, the long history of non-native species in Hawai'i (since Polynesian arrival) makes it difficult to identify the target "native" communities for this goal. Moreover, the loss of native species that performed key ecosystem services, such as pollination and seed dispersal, make many native forest species now dependent on non-native animals to fulfill those roles. As a consequence, conservation practitioners have increasingly developed strategies that combine native and non-native species into hybrid communities (Box 5, Fig. 7) for restoration in order to fulfill the goals of ecosystem services while maintaining at least some native biodiversity (Burnett et al., 2019; Cordell et al., 2016; Ewel and Putz, 2004; Ostertag et al., 2015; Ross et al., 2015). Often, the non-native species incorporated with this hybrid ecosystem approach are Polynesian introductions, thereby using this era as the target goal (Burney and Burney, 2016; Campbell and Campbell, 2017; Dietl et al., 2015). Although the hybrid ecosystem restoration approach is somewhat controversial (Murcia et al., 2014) and many restoration projects still focus exclusively on native species, this paradigm acknowledges that Hawaiian forests are in a new regime, one that cannot be feasibly returned to earlier states, at least not in all areas.

The human dimension is inextricably connected to conservation efforts. Humans may be the source of the problems—either directly or indirectly—but humanity is the solution. In efforts to restore biodiversity, ecological health, and ecosystem services, managers have a broad range of knowledge to draw upon from various scientific disciplines and cultural traditions, of ancient and modern tools and technologies to implement solutions, and of financial models to design sustainable programs that can last long into the future. Approaches that capitalize on shared cultural foundations of the intrinsic connection between humanity and nature are likely to be the most fruitful (Chang et al., 2019; Kueffer and Kinney, 2017; Pascua et al., 2017; Winter and Lucas, 2017). The efficacy of certain approaches has been studied (Burnett et al., 2019), but a comprehensive analysis of these approaches has yet to be undertaken in Hawaiʻi. New research could provide valuable insight in this area.

8.3. *Common conservation practices*

Based on the state of the ecosystem, management approaches can utilize restoration techniques that range from active to passive (Bechara et al., 2016; Burnett et al., 2019; Meli et al., 2017; Zahawi et al., 2014). Conservation and restoration of native forests benefits from a deep understanding of the ecology and evolution that underpins native forest dynamics, and thus practices that are guided by basic scientific principles are most likely to be successful (Table 3). Common conservation practices in Hawaiian forests include ungulate exclusion, non-native weed control, and out-planting, among others (Table 3).

Given the severe negative effects of non-native ungulates on Hawaiian plants, it is common management practice to exclude them from managed sites using fences, which in most cases results in positive gains for native vegetation, but in some cases may also increase abundances of non-native species. Removal of pigs leads to increases in cover and species richness of common native species in wet forest (Cole and Litton, 2014; Cole et al., 2012; Hughes et al., 2014; Loh and Tunison, 1999). Similarly, exclusion of goats (Scowcroft and Hobdy, 1987) and sheep (Scowcroft and Giffin, 1983) from dry forest sites results in greater establishment of common native woody species. Rare native species can also recover after ungulate removal, although this primarily depends on the presence of rare species at the time of ungulate removal (Cole and Litton, 2014). Recovery can be extremely slow or non-existent in some ecosystems as a consequence of dispersal limitation or habitat fragmentation, and a major concern surrounding non-native ungulate removal is the potential for rapid proliferation of non-native plants released from top-down control, as well as increased fire risk (Blackmore and Vitousek, 2000; Cole et al., 2012; Scowcroft and Conrad, 1992; Zavaleta et al., 2001). A nine-year study in dry forest sites on Hawaiʻi Island showed no change in the abundance of native vegetation following removal of a suite of non-native ungulates (Kellner et al., 2011), and native woody species declined following exclusion of deer, pigs and goats from forests in mesic habitats on Kauaʻi (Weller et al., 2011). Because ungulates are known to enhance non-native, but not native, plant dispersal (Diong, 1982; Nogueira-Filho et al., 2009; Warshauer et al., 1983), this result reveals the complexity of ungulate effects on native-non-native plant dynamics and highlights the need for additional research to refine predictions for how fencing can influence native diversity across the Hawaiian Islands.

Non-native plant control is a major focus of forest conservation and restoration in Hawaiʻi. In addition to manual removal and herbicide application, practitioners are experimenting with indirect control methods such as shading and biocontrol agents. As mentioned above with unintended positive effects of ungulate control on non-native plant proliferation, climate-related disturbances and change may also enhance the establishment and spread of non-native species. Of particular concern are shifts in native species ranges in high-priority management areas such as Hawaiʻi Volcanoes National Park, which are expected to experience substantial losses in native species of conservation interest (Camp et al., 2018). These examples of complexities involving non-native plants and climate change align with similar interactions observed elsewhere (Hellmann et al., 2008; Petitpierre et al., 2016; Ziska and Dukes, 2014).

9. Conclusions and future directions

Hawaiian forests are home to a unique endemic biota that has inspired people since the Polynesians first arrived. Due to its isolation and volcanic origin, the Hawaiian archipelago offers unparalleled opportunities to investigate adaptive radiations, the evolution of trait syndromes, and community assembly; as a result, Hawaiian forests are renowned among biologists worldwide. Our review of this extensive body of research has revealed several key generalities. First, despite the flora harboring considerable phenotypic variation and spanning wide distributions across extensive environmental gradients, only a few lineages have undergone explosive adaptive radiations. Second, among tropical forests of comparable mean annual rainfall and temperature, Hawaiʻi is relatively species-poor, and the dominance of forests by a few lineages is not well explained by morphological or physiological plant traits. Third, despite support for a few island syndrome predictions, there are exceptions to them all. Hawaiian plants on the whole are not less defended against herbivores, less dispersible, more conservative in their leaf economics, or more slow-growing than their continental relatives. Our synthesis suggests that despite the considerable body of work conducted across Hawaiian forests, greater synthesis is still needed to understand the complexities and subtleties that underlie the observed patterns. In particular, more work is needed to understand the drivers, sources, and constraints on phenotypic variation among Hawaiian species, and to understand the role of species interactions in mediating these patterns.

We still know remarkably little about interactions among forest plants, animals, and microbes, despite our deep understanding of the physical underpinnings that have created Hawaiʻi's forests (e.g., volcanic eruptions, tradewinds, orographic effects). Unfortunately, native species interactions are nearly impossible to characterize in Hawaiʻi's contemporary forests due to the dramatic regime shifts caused by human colonization and the spread of non-native species. Nearly all contemporary species interactions, among competing plants, between plant and herbivores, pollinators, seed dispersers, and diseases, now involve non-native species. Novel species interactions may provide hints regarding historical native community dynamics, but unraveling these mysteries may no longer be possible given the scale of disruption. As a consequence of the regime shifts, most Hawaiian forests are now hybrids of native and non-native species or novel communities completely dominated by non-native species. An increasing number of restoration efforts are leveraging hybrid communities for conservation of target native species and restoration of ecosystem services. Conservation and restoration of Hawaiian forests depend on diverse tools and strategies grounded in basic ecological, evolutionary, and biocultural principles with the goals of mitigating the most pervasive threats (e.g., non-native ungulates, fire-prone grasses, and pathogens) to maximize native biodiversity and function. In turn, much can be learned regarding the ecology and evolution of Hawaiian forest species while simultaneously taking steps to conserve and restore native forests. The future of Hawaiian forests thus depends on explicit integration of ecological and evolutionary research with conservation and restoration activities.

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Declaration of Competing Interest

The authors report no declarations of interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ppees.2021.125631.

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Removal of non-native trees fosters but alone is insufficient for forest regeneration in Hawai'i

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ABSTRACT

Across the globe, non-native plant species have become abundant in many tropical forests, resulting in altered patterns of biological diversity and species composition, and impacting important ecosystem functions. However, long-term experimental research on the efficacy of non-native tree removal for tropical forest restoration remains limited. We investigated the removal of non-native tree species in a mesic tropical forest in Hawai'i, where rates of endemism and endangerment of plant species is high and multiple non-native tree species are abundant. As a collaboration between resource managers and researchers, we tested the effects of non-native tree removal on overstory and understory metrics of restoration using three restoration approaches: "total cut" (cutting all non-native trees); "girdle" (girdle of all non-native trees); and "selective cut" (cutting approximately 50% of non-native trees). Prior to removal, we established permanent plots (four 10 × 10 m plots per restoration treatment, with 10 1 × 1 m subplots in each), then monitored them over 10 years. Across all treatments, canopy openness increased significantly post restoration, peaked after three years, then decreased to pre-treatment levels or lower. The increase was largest for the total cut treatment, but there was large variation within treatments. By the end of the experiment, the total cut and girdle treatments performed similarly for all our metrics of restoration, including survival, growth, density, and basal area of native trees; density and richness of native species in the understory; and total weed biomass. The selective treatment performed worse, showing lower relative gains in basal area of native trees and density of native understory individuals. Overall, tree removal was effective in restoring a native canopy. However, understory native species richness and density remained at pre-treatment levels, likely due to limited seed dispersal, seed predation by non-native rodents, and continued competition from non-native herbaceous species. Nonetheless, subplots with the best starting conditions performed the best. More intensive and longer-term weeding of non-native species in the understory, focused on areas with the best starting conditions and combined with out-planting of native seeds, seedlings and/or saplings, is likely necessary to foster effective native species regeneration. Overall, our research shows that removal of non-native trees using the total cut and girdle techniques can foster native forest restoration in the mesic forests of Hawai'i, but that ongoing long-term management in the understory is critical.

1. Introduction

1.1. Background

Amidst global anthropogenic changes to ecosystems, non-native plant species have become abundant in many tropical forests, resulting in altered patterns of biological diversity and species composition, and impacting important ecosystem functions (Vitousek et al., 1997; Levine et al., 2003; Wright, 2005; Castro-Díez et al., 2019). Numerous studies have demonstrated the impacts of non-native plants on forest ecosystems, including on light levels and light acquisition (Reinhart et al., 2006; Cordell et al., 2009; Schulten et al., 2014), carbon

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and nutrient cycling (D'Antonio and Corbin, 2003; Vilà et al., 2011), seed dynamics (Holmes and Cowling, 1997; Holl, 1999), and soil processes (Dassonville et al., 2008; Gómez-Aparicio and Canham, 2008; Weidenhamer and Callaway, 2010). In particular, light is one of the most important limiting factors of plant growth in tropical forests (Chazdon and Pearcy, 1991; Hubbell, 1999), and the presence of non-native trees may cause substantial reductions in light levels, which can be detrimental to the survival and growth of native species (Asner et al., 2008; Ostertag et al., 2009).

Given the prevalence of non-native canopy species in tropical forests and their potentially detrimental impacts, investigating approaches to their removal is important for understanding effective methods to restore native tropical forest ecosystems (Ostertag et al., 2009; Kandert et al., 2021). Experimental research on non-native woody plant removal remains relatively limited (but see: Wakibara and Mnaya, 2002; Yelenik et al., 2004; Loh and Daehler, 2008) compared to research on removal of grasses or herbaceous species (e.g., Zavaleta et al., 2001; Díaz et al., 2003; Adams and Galatowitsch, 2008), and is especially limited regarding the removal of multiple woody species within a single stand (Kandert et al., 2021). Additionally, existing research on non-native plant removal has focused on particular ecosystem types including grasslands and wetlands, whereas tropical forests remain understudied (Kettenring and Adams, 2011). Studies to date on removal of non-native woody species have shown increases in species richness of native seedlings compared to sites without removal (Wakibara and Mnaya, 2002; Loh and Daehler, 2008; Kandert et al., 2021). Removal of woody species alone, however, may not support the return to native species composition, due to the presence of non-native seeds in the seed bank and their potential competitive advantages over native seedlings (Loh and Daehler, 2008; Ostertag et al., 2009). For example, in one removal study, density of native stems was similar between removal and control plots (Cavaleri et al., 2014).

There are multiple possible approaches to non-native tree removal. One widely used removal technique is girdling, where a ring of bark (including the cork, cork cambium and phelloderm together known as the outer bark, and the secondary phloem or inner bark) is removed from the stem, also disrupting the vascular cambium and secondary xylem in some cases (Huberman and Goldschmidt, 2003). The girdling technique immediately blocks the transport of photosynthates from the canopy to the roots, and causes a slow death of the trees (Högberg et al., 2001). Two other approaches to removal include total cut (all non-native trees removed), and selective cut (non-native trees systematically selected for removal, leaving some non-natives in the stand). The key difference between these three removal techniques is the increase in light availability (both the amount and rate of increase). With the total cut approach, large gaps are created immediately, which supports species that require high light levels for establishment (Brokaw, 1985; Loh and Daehler, 2008). By selectively removing non-natives, smaller gaps in the canopy and a lower increase in light occurs, providing a narrower opportunity for light demanding species to establish and favouring shade-tolerant species (Denslow, 1987). It is important, however, to consider changes in photosynthetically active radiation (PAR) in the forest gaps that result from the different methods of non-native tree removal. In small gaps, PAR can still be high and allow for rapid regeneration of light demanding species, but the distribution of PAR is highly variable across a closed canopy stand in tropical forests (Torquebiau, 1988). Nonetheless, the spatial extent of PAR in the selective cut approach will be reduced compared to the total cut approach. Girdling, on the other hand, creates no immediate increase in light availability, but over time, and depending on whether all non-native trees or only select few non-natives are girdled, an increase in light availability will occur (Loh and Daehler, 2008).

The methods by which non-native trees are removed may impact the outcomes for native forest restoration, particularly in terms of differences in regeneration of native seedlings (Wakibara and Mnaya, 2002; Loh and Daehler, 2008; Flory and Clay, 2009). Some studies in tropical forests have shown that full removal of non-native trees enhanced native species diversity, for instance in wet forests in Brazil (Podadera et al., 2015), yet there are few existing studies that have compared the impacts of the different removal techniques. The studies that exist have shown that girdling may allow for greater species richness of regenerating native seedlings than the total cut approach, for example in forests in Hawaiʻi (Loh and Daehler, 2008) and Tanzania (Wakibara and Mnaya, 2002). The trend of enhanced native species regeneration in girdled versus total cut plots may be due to non-native, opportunistic seedlings outcompeting native seedlings under high light levels in the total cut plots (Loh and Daehler, 2008). One caveat to the results of these studies, however, is that monitoring took place over a relatively short period of time (3–4 years). Longer-term studies are important for understanding effects of removal techniques on native forest regeneration, as many native species are slow-growing and non-native plants may return over time (Kettenring and Adams, 2011). Additionally, the studies described above focused on the removal of a single non-native, invasive tree species, whereas investigating the efficacy of removing multiple species is important in many tropical forest contexts where there are a suite of non-native trees impacting the native ecosystem (Ostertag et al., 2009).

The removal of non-native species is a critical conservation issue in Hawaiʻi, which hosts exceptionally high levels of endemism and endangerment; roughly 90% of native plants are endemic and over 50% are at risk of extinction (Stone, 1967; Wagner et al., 1999; Sakai et al., 2002). Hawaiʻi's wet and mesic forests have been the focus of many restoration efforts over the past several decades (e.g., Scowcroft and Jeffrey, 1999; Scowcroft et al., 2008; Friday et al., 2015, Trauernicht et al. 2018). Despite the economic costs and labor dedicated to these efforts (Burnett et al., 2019), there is surprisingly little information on their success. The few existing studies, which have focused on lowland wet forests, demonstrate that removal of non-native trees affects microclimatic conditions for native saplings and can increase regeneration over the short term (Ostertag et al., 2009; Schulten et al., 2014). One ecologically important native, disturbance-adapted tree in Hawaiʻi, *Acacia koa* (*koa*), is fast-growing and can provide suitable habitat for the establishment of native understory species following the removal of non-native plants (McDaniel and Ostertag, 2010). *Koa* forms a persistent seedbank and can also spread vegetatively using root suckers, and it persists as a dominant component of old growth mesic forests. Hence, it is important to explore the impact of restoration on *A. koa* populations (Spatz and Mueller-Dombois, 1973; McDaniel and Ostertag, 2010).

1.2. Objectives

We tested the effects of different approaches to removing non-native trees on the long-term (10-year) regeneration of native species in a Hawaiian mesic forest. We focused on three restoration approaches or treatments: "total cut" (cutting all non-native trees); "girdle" (girdling all non-native trees); and "selective cut" (cutting approximately 50% of non-native trees) to ask how restoration treatment affects: 1) canopy openness, and metrics of 2) overstory and 3) understory restoration success (Table 1). We hypothesized that higher canopy openness in the total cut approach would initially lead to higher recruitment of both native and non-native understory species. We also expected that over time the girdle and selective cut treatments would reach similar densities of native understory species and recruitment into the overstory as the total cut treatment, but that they would have lower understory density of non-native species.

2. Materials and methods

2.1. Field methods

To test the effects of restoration approach, we (researchers at the University of Hawaiʻi at Mānoa and resource managers at the Army Natural Resources Program-Oʻahu (ANRPO) and Honolulu Board of

Table 1
Metrics of forest restoration assessed over 10 years at Makaha, Oʻahu.

Forest level	Metric	Level of analysis		
		Plot	Sub-plot	Individual tree
Canopy	Canopy openness		√	
Overstory	Native tree survival			√
	Native tree growth (change in basal area)			√
	Size (basal area) of *Acacia koa* recruits			√
	Density of native trees	√		
	Basal area of native trees	√		
	Density of *Acacia koa* recruits	√		
	Basal area of *Acacia koa* recruits	√		
Understory	Native species richness		√	
	Density of native understory individuals		√	
	Weed (non-native) biomass		√	

Water Supply) established a collaborative restoration experiment in Makaha Valley, a mesic forest site in the northern Waiʻanae Mountains of Oʻahu. ANRPO carries out restoration across the island of Oʻahu, and was interested in identifying effective restoration techniques. The Makaha Valley site is part of the area managed by ANRPO and had a canopy consisting of both native and non-native trees, and thus was a priority for restoration. The broader region of Makaha Valley was historically managed by Native Hawaiians, but since it was purchased from a Hawaiian chief in 1885, it has undergone major changes in vegetation as a result of initiatives to grow sugar, coffee, and rice (Green, 1969). The Honolulu Board of Water supply gained control of water and management of the valley in 1987 and ANRPO began resource management in 1999. In 2007, a fence to exclude feral pigs was built in the subunit where the restoration site was located, and the pigs remaining inside the fence were removed. With the exception of one species of bat, Hawaiʻi has no native land mammals. Exclusion of feral pigs can increase cover of both native and non-native plant species (Cole et al., 2012). The fence does not exclude introduced rodents or ground birds.

The restoration site is located on a north-facing ridge at 1600–1800 m elevation, within fenced subunit. At the start of the experiment in 2005, the native trees dominant in the canopy were *Acacia koa* (*koa*), *Metrosideros sandwicensis* (*ʻōhiʻa lehua*), and *Psydrax odorata* (*alaheʻe*); the dominant non-native trees were *Aleurites moluccanus* (*kukui*, a Polynesian introduction to Hawaiʻi), *Psidium cattleianum* (strawberry guava), and *Schinus teribinthifolia* (Christmas berry). In 2005, we randomly established 12, 20x20 m permanent plots along the length of the ridge, which was not wide enough to support more than two adjacent plots. In each plot we identified and measured all trees > 5 cm DBH, and tagged all the native trees. Eight of the plots were similar in terms of the proportion of native to non-native trees: 32 ± 12% of the trees/plot were native and native trees made up 56 ± 22% of the total basal area per plot. We randomly assigned one of two treatments (total cut, girdle) to each plot for a total of four plots of each treatment. The remaining four plots had higher density and basal area of non-native trees than in the other plots (only 7 ± 5% of the trees/plot were native and native trees contributed to 22 ± 34% of the total basal area per plot). In three of these plots, native basal area ranged from 2 − 8% of the total, and in the fourth plot, a single large *Acacia koa* tree made up the native basal area, hence the large SD. We assigned these remaining four plots to the selective cut treatment (50% of non-native trees removed) since the large amount of light opened up by a total cut or girdle in this context would have likely led to a proliferation of non-native plants that would require too much weeding to manage. Although we searched for other potential sites to increase our sample size for the girdle and cut treatments, we could not find other comparable plots. Most of the lower valley was composed entirely of non-native plant species, as is the case across the mesic forests of much of the region. In all our analyses we controlled for differences in initial density and/or basal area of non-native trees. We could not include a "control" treatment (no restoration interventions), since ANRPO's mandate is to restore the forest area by removing all invasive species. Leaving large areas of non-native invasive species within the project area would allow for continued spread into restored plots and our goal was to compare across treatments in the context in which ANRPO carries out restoration.

In the center of each 20x20 m plot, we established a permanent 10x10 m plot for monitoring, such that each plot had at least a 10 m buffer around it. In each of the twelve 10x10 m plots, we tagged, identified, and measured each tree > 1 cm DBH. To monitor the process of regeneration, we randomly placed 10 permanent 1x1 m subplots within each 10x10 m plot (total of 120 subplots). In each subplot, we tagged, identified to species and measured the height of all native plants (>10 cm in height), and recorded the species identity, number, and size of all non-natives. Plots were adjusted for slope following standard procedures using a clinometer, to ensure that the size of all plots was equal.

Non-native tree removal was carried out in October 2005. For the selective cut treatment, on the day of tree removal, we randomly selected half of the non-native trees in each plot to be removed. Trees were cut with a chainsaw and the wood was moved to the perimeter of the plots in slash piles. Following the cut or girdle treatment, herbicide (Garlon 4 in a 20% dilution with Forestry Crop Oil) was applied to each non-native tree. We monitored all plots and subplots in the two weeks prior to removal and then post-treatment at different periods for 10 years (Appendix B, Table S1). At each re-monitor period, we tagged and measured all new native individuals and recorded survival status and growth of previously tagged individuals. For the first four years, we also weeded all non-natives from the understory of each subplot every six months and obtained their biomass (wet and dry weights). Over the 10-year period, ANRPO periodically removed non-native trees that had grown to the mid or overstory within the plots, as well as non-native shrubs, herbs and grasses.

To assess differences in canopy openness across treatments and over time, we took photos using a 180-degree hemispheric lens at the center of each subplot, 0.5 m above the ground, at each census post-treatment for 10 years. This allowed us to link canopy openness directly to seedling regeneration in the subplots, and gave us 10 random samples of canopy openness within each plot. We analyzed photos for canopy openness using Gap Light Analyzer Version 2.0 (Frazer et al., 1999). All photos were taken before sunrise or on cloudy days to avoid calculation errors caused by sunlight reflecting off vegetation.

2.2. Analysis

We tested the effects of restoration approach (treatment) on canopy openness and metrics of overstory and understory restoration success using linear mixed effects models (LMEs, using lme4, v.1.1–23), and generalized linear mixed effects models (GLMMs, using the package glmmTMB, v.1.0.2) in R Studio version 1.3.1073 (R Core Team, 2021). For each response variable (metric of restoration success), we started with a full model and conducted backwards selection by sequentially removing predictor variables with the highest p-value and assessing model fit based on AIC values (Zuur et al., 2009). We checked model assumptions by visually inspecting the residual and QQ plots. All full models and final best fit models are presented in Appendix A.

To test the effects of restoration treatment on canopy openness (measured at the subplot level), we included the interactive effects of treatment and time, and included plot as a random factor (Appendix A, Table S1). To test the effects of restoration treatment on overstory metrics, we focused on survival and growth of native trees and size of *Acacia koa* recruits (individual tree level measures), and native tree density and basal area (plot level measures) as response variables (Table 1). For the growth and survival models, we tested the effect of treatment, with initial basal area (log) as a covariable, and plot and species as random factors. For survival, we used a binomial (logit) model (Appendix A, Table S2). To test the effects of treatment and time on native tree density and basal area, and account for differences in pre-treatment conditions across plots, we included initial density/basal area of native or non-native trees as a co-variable in the models and plot as a random factor. Both density and basal area were log-transformed to meet model assumptions. We also tested the effects of treatment on density and basal area of *Acacia koa* at the plot level (Appendix A, Table S3C).

We tested the effect of restoration treatment on three metrics of understory restoration success: native species richness, density of native understory individuals (of all life forms, e.g., woody, herbaceous, sedges, ferns), and biomass of non-natives, including plot as a random factor (Appendix A, Table S4). For the first two metrics, we included only individuals > 10 cm in height. To test the effects of treatment and time on the density of native understory individuals, we used a zero-inflated negative binomial model and included initial basal area of native trees as a covariate. All predictor variables were log transformed. For biomass we ran two models. First, we tested the effects of treatment and time on the annual biomass (dry weight) of non-natives removed from the understory through 2009. Second, we tested the effects of treatment on total weed biomass removed over the study, using initial (pre-treatment biomass) as a covariable. For both models, the residuals were heterogenous. We therefore included variance covariates that increased exponentially with weed biomass and varied across plots (Zuur et al., 2009) for the annual biomass model, and a variance covariate that varied across plots for the total biomass model. Finally, one plot was an outlier in the models, so we ran them with and without it. The model results did not change in terms of which terms were significant, but the model without the outlier had a better fit so we present those results here.

3. Results

3.1. Changes in light conditions

Across all treatments, canopy openness increased significantly post-treatment (estimate = 13.58; $p < 2.00\text{E-}16$; Appendix A, Table S1), peaked in the 2008 census, then decreased through 2016 (Fig. 1). However, the increase in canopy openness was greater for the total cut treatment than for either the girdle or selective cut treatments (Appendix A, Table S1). By 2016, canopy openness did not differ significantly from pre-treatment levels in the total cut treatment; however, it was lower than pre-treatment levels in the girdle (estimate = −4.14, $p < 0.001$) and selective cut (estimate = −2.01, $p < 0.001$) treatments (post-hoc test). Within both the total cut and girdle treatments, there was very large variability in canopy openness (Fig. 1).

3.2. Overstory metrics of restoration success

Survival of native trees (>1 cm DBH) ranged from 62.7% ± 0.16 in the total cut treatment, to 73.9% ± 0.13 in the girdle, and 73.8% ± 0.21 in the selective cut treatment. Survival did not vary as a function of tree size (initial basal area) (Appendix A, Table S2a). There were no significant differences across restoration treatments in native tree survival nor in size-specific growth (measured by change in basal area) of native trees (Appendix A, Table S2b).

At the plot level, native tree density increased significantly from pre-treatment levels (2005) to 2016 (estimate = 0.33, p = 0.034; Fig. 2A; Appendix A, Table S3a). Change in native tree density over this period did not differ across treatments. However, the change was significantly lower in plots with higher initial density of non-native trees (estimate = −1.21, p = 0.011). Change in basal area of native trees over the same period did not differ between total cut and girdle treatments, but it was significantly lower in the selective cut treatment (estimate = −2.56, p = 0.039; Fig. 2b; Appendix A, Table S3b).

Only two species, *Acacia koa* and *Dodonea viscosa* (ʻaʻaliʻi), had individuals that germinated post-treatment and grew into the canopy (to a DBH > 1 cm) by the end of the study. For *D. viscosa,* no individuals were present pre-treatment, and the two individuals that recruited into the canopy were both in the cut treatment. For *A. koa*, the restoration site had three individuals pre-treatment, one in each treatment and each large (41–85 cm DBH). In 2016, basal area and density of *A. koa* recruits into the canopy were not significantly different between the cut treatment and the girdle treatments (Appendix A, Table S3c).

The number of *A. koa* recruits into the canopy varied across plots within treatments. In 2016 there were 33 new *A. koa* recruits into the canopy in the cut treatment, but 30 were in one plot and the other three plots had only one recruit each. The girdle treatment had eight new *A. koa* recruits into the canopy, all in one plot. There were no *A. koa* recruits into the canopy in the selective cut plots. Neither of the two plots with many *A. koa* recruits had *A. koa* trees pre-treatment. As such, initial *A. koa* density was not a significant predictor for either variable. The size of *A. koa* recruits (measured as basal area) did not vary

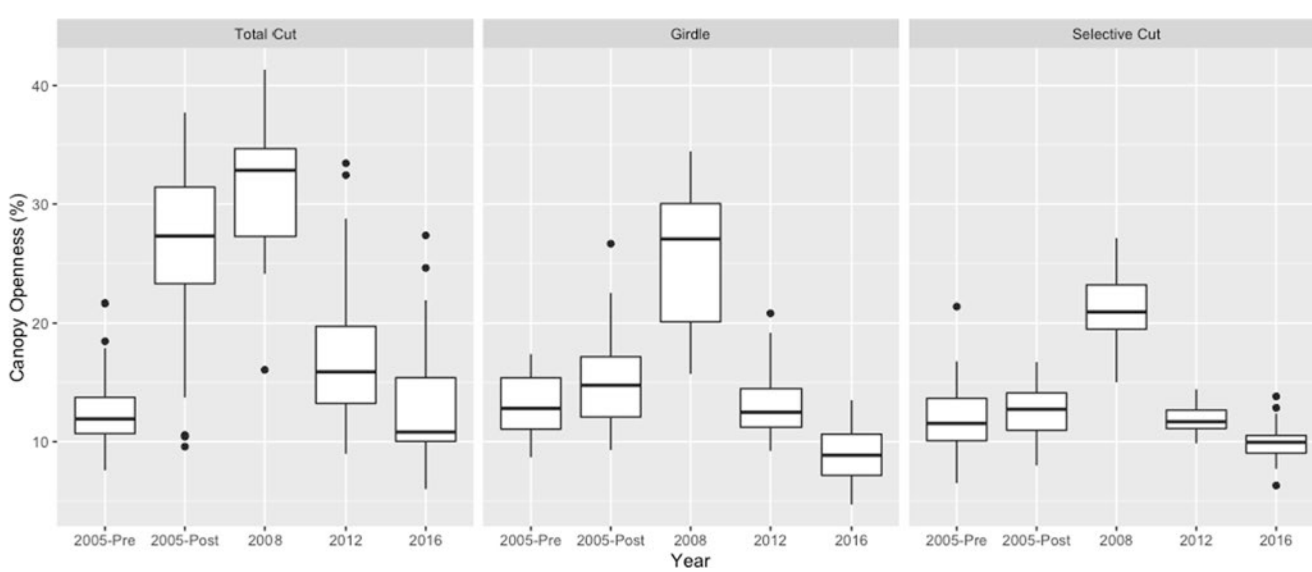

Fig. 1. Change in canopy openness from before non-native tree removal (2005-Pre) to 2016 at a restoration site in Makaha, Oʻahu across the three restoration approaches to removing non-native trees: total cut, girdle, and selective cut.

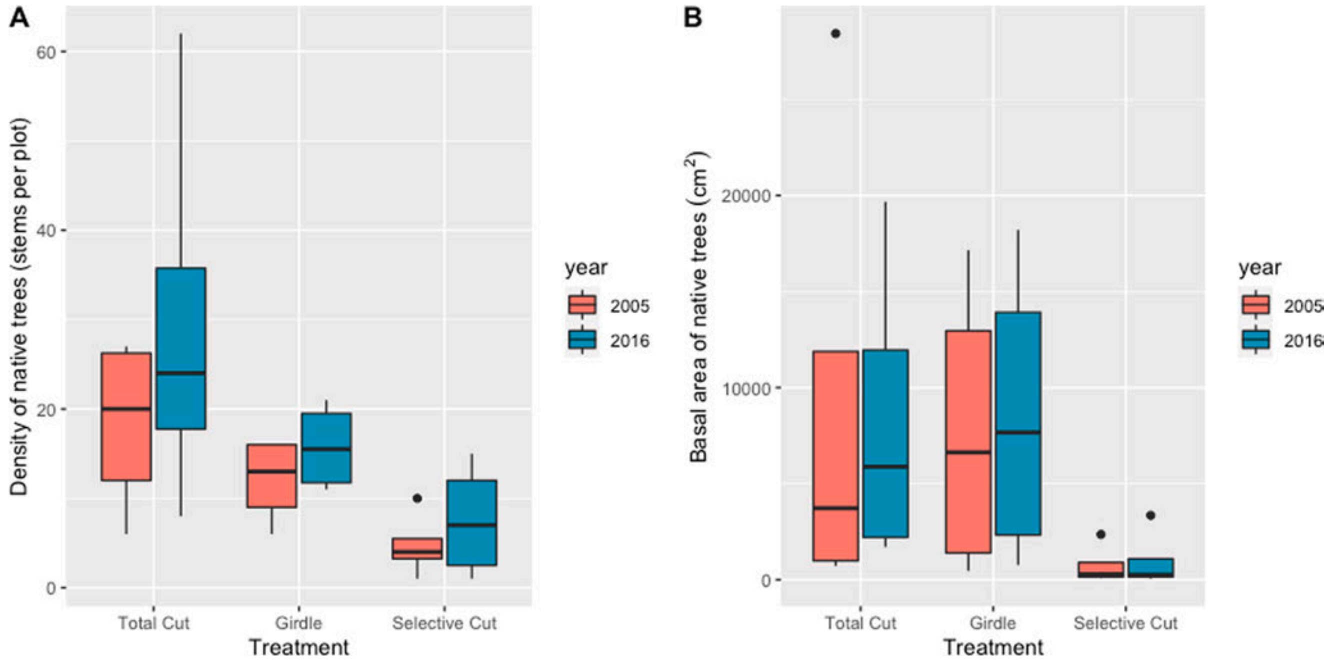

Fig. 2. Native tree density (A) and basal area (B) for the total cut, girdle, and selective cut restoration treatments prior to removal of non-native trees (2005) and in 2016 at the end of the experiment.

significantly across treatments (Appendix A, Table S2A). All of the new *koa* recruits that we documented over time emerged from seeds, as opposed to suckers.

Aside from *A. koa*, pre-treatment there were eight other native tree species in plots, but only one species, *Psydrax odorata*, had saplings present (individuals 1–5 cm DBH). This was the only species to recruit into the canopy, and it did so across all treatments, including the selective treatment.

3.3. Understory metrics of restoration success

Of the nine native overstory species present in the plots, seedling recruitment was only observed for three species: *A. koa*, *P. odorata* (both seedlings and root suckers), and *Diospyros sandwicensis* (*lama*) (only 1 seedling) over the study period. In contrast, new recruits were observed for all of the eight non-native overstory species, with six of the eight still present in 2016 (Table 2a).

Across all plots, there were 12 native understory species present in 2005. This dropped to nine in 2016 (Table 2b). Restoration treatment did not have a significant effect on native understory species richness per plot (Fig. 3a, Appendix A, Table S4a). There were significantly fewer species in the understory three months post-treatment (estimate = −0.28, p = 0.002) and in 2008 (estimate = −0.21, p = 0.021). However, species richness per plot in the end of the experiment was not significantly different (Appendix A, Table S4a).

Density of native understory plants was significantly lower in the selective treatment than in the total cut treatment (estimate = −0.86, p = 0.009; Fig. 3b, Appendix A, Table S4b); this model controlled for differences in pre-treatment basal area of native canopy trees. Across treatments, native seedling density was significantly higher in 2008 than pre-treatment (estimate = 0.63, p = 0.001). However, by 2016 native seedling density did not differ from pre-treatment levels.

The effect of treatment on annual weed biomass removed varied over time (Fig. 4). In the first few years, there were no differences across treatments. However, by 2008, weed biomass increased in the total cut treatment, and by 2009, weed biomass was significantly higher than pre-treatment levels in the total cut plots (estimate = 1.87, p = 0.001; Appendix B, Table S4c), but were lower in the girdle and selective cut plots

Table 2a
Overstory species present pre-treatment and observed recruitment over study period (2005–2016) at a restoration site in Makaha, Oʻahu. One new native species not present pre-treatment recruited into the overstory in 2016: *Dodonea viscosa.*

Species Latin name (Hawaiian name)	Seedling recruitment observed
Native species	
Acacia koa (*koa*)	√
Antidesma platyphyllum (*hame*)	
Bobea sp. (*ʻahakea*)	
Diospyros sandwicensis (*lama*)	√
Dodonaea viscosa (*ʻaʻaliʻi*)	
Eleocarpus bifidus (*kalia*)	
Metrosideros polymorpha (*ʻōhiʻa lehua*)	
Nestegis sandwicensis (*olopua*)	
Psychotria mariniana (*kōpiko*)	
Psydrax odorata (*alaheʻe*)	√
Non-native species	
Aleurites moluccanus (*kukui*)[1]	√
Cordyline fruticosa (*kī*)[1]	√
Coffea arabica	√
Psidium cattleianum	√
Psidium guava	√
Schinus terebinthifolia	√
Syzygium cumini	√
Toona ciliata	√

[1] Polynesian introduction.

(treatment*2009 estimate = −1.64, p = 0.021; estimate = −1.83, p = 0.002 respectively). Nonetheless, total weed biomass (summed over the first four years of the experiment) did not vary across treatments, but increased significantly as a function of pre-treatment weed biomass (estimate = 0.63, p < 0.001; Appendix A, Table S4d). The overall richness of non-native species increased over time (Table 2b).

4. Discussion

Our research investigated the effects of different approaches to removing non-native trees on metrics of forest restoration. Overall, outcomes of total cut and girdle treatments were similar, with few

Table 2b
Species present in the understory or as epiphytes in restoration plots at a site in Makaha, Oʻahu.

Species	Life form	Pre-treatment (2005)	2016
Native species			
Acacia koa (*koa*)	Woody seedling	√	√
Alyxia stellata (*maile*)	Liana	√	√
Asplenium nidus (*ʻēkaha*)	Epiphytic fern	√	
Carex wahuensis	Sedge	√	√
Coprosma foliosa (*pilo*)	Woody seedling	√	
Diospyros sandwicensis (*lama*)	Woody seedling	√	
Dodonaea viscosa (*ʻaʻaliʻi*)	Woody seedling		√
Doodia kunthiana (*ōʻkupukupu*)	Fern	√	√
Elaphoglossum sp. (*ʻēkaha*)	Epiphytic fern		√
Lepisorus thunbergianus (*pākahakaha*)	Epiphytic fern	√	√
Microlepia strigosa (*palapalai*)	Fern	√	√
Pepperomia spp. (*ʻalaʻala wai nui*)	Herb	√	
Psydrax odorata (*alaheʻe*)	Woody seedling	√	√
Non-native species			
Ageratum conyzoides	Herb		√
Ageratum houstonianum	Herb		√
Ageratina riparia	Herb		√
Aleurites moluccana	Woody seedling	√	√
Blechnum appendiculatum	Fern	√	√
Clidemia hirta	Herb		√
Conyza bonariensis	Herb		√
Coffea arabica	Woody seedling	√	√
Cordyline fruticosa	Monocot shrub	√	√
Cyanthillium cinereum	Herb	√	√
Kalanchoe pinnata	Herb	√	
Melinis minutiflora	Grass		√
Nephrolepis exaltata	Fern	√	√
Oplismenus hirtellus	Grass	√	√
Paspalum conjudatum	Grass	√	√
Pityrogramma austroamericana	Fern		√
Psidium cattleianum	Woody seedling	√	√
Rubus argutus	Woody/sprawling		√
Schinus terebinthifolia	Woody seedling	√	√
Sonchus oleraceus	Herb		√
Syzygium cumini	Woody seedling	√	
Toona ciliata	Woody seedling	√	√

differences in overstory or understory metrics. The selective cut treatment, however, performed worse than both of the other approaches.

4.1. Lack of differences in outcomes of total cut versus girdle approaches

The lack of differences in outcomes between the total cut and girdle treatment may be due to several factors, including our study design and the duration of our experiment. Any differences observed across treatments in the density and basal area of overstory native trees would be due to differential rates of recruitment, survival and/or growth of native species. Although our study lasted 10 years, this is likely not long enough to observe large differences in recruitment into the overstory. With the exception of *Acacia koa*, the native mesic forest trees present at our site pre-treatment were all slow-growing species, and unless individuals were already present as saplings, they would not be expected to germinate and reach 1 cm DBH within the study period. In addition, our sample size was low for our plot-level metrics.

However, we found no differences between treatments even for metrics where our sample sizes were large and where changes are expected to be clearly detectable over a 10-year period. This includes size-specific survival and growth of individual trees (total cut treatment n = 73; girdle treatment n = 48; selective treatment n = 19); and density and richness of native seedlings (n = 40 plots/treatment, 120 total). The lack of differences across treatment is likely due to the fact that these variables are strongly influenced by microhabitat conditions, such as light, wind, humidity, seed rain, and cover of non-native species (Guariguata et al., 1995; Holl, 1999; Kandert et al., 2021) which varied significantly within treatments and plots. For example, even though the treatments showed different light trajectories, there was large variation across subplots within treatments (Fig. 1). Similarly, while the total cut treatment produced more weed biomass in some years than the other treatments, there was large variation across subplots within treatments in terms of weed biomass (Fig. 4). Ultimately, this variation appears to have overridden any larger differences in treatment. We may, however, have detected more differences if we had been able to establish control plots with similar initial conditions to the treatment plots.

Our finding that conditions pre-treatment at the subplot level significantly predicted conditions 10-years post-treatment further supports this interpretation. For example, although there was high turnover of individuals in the understory over the study period (few native individuals survived the 10-year period), initial density and richness of understory plants were both significant predictors of the final density and richness. Similarly, although plots were weeded consistently over the first four years, initial weed biomass was a strong predictor of final weed biomass (at the end of four years). From a management perspective, this suggests that the best areas for native forest restoration are those that already have the highest density and richness of native species (Holl et al., 2000; Loo et al., 2017; Kandert et al., 2021). This is consistent with ANRPOs observations from their restoration sites elsewhere, where the poorer the starting conditions, the greater the input necessary; and their strategy to start with restoring the best areas, and then focus on reconnecting them.

4.2. Lower performance of selective cut approach

Our results show that the selective cut treatment performed worse than both the girdle and total cut treatments, with significantly lower increases in basal area of native trees and density of understory seedlings at the end of the experiment, and no *Acacia koa* recruits into the canopy. The selective cut treatment plots had a lower proportion of native species (in terms of both density and basal area) than the other two treatments at the start of the experiment. It was for this reason that we included selective cut as a treatment—the large canopy gaps from either of the other two treatments would likely have led to very high regeneration of weeds, which has been shown by numerous studies (e.g., Loh and Daehler, 2007; West et al., 2014; Song et al., 2017). However, our statistical models accounted for differences in pre-treatment conditions, meaning that the increase in native tree basal area and understory native seedlings *relative* to starting conditions was lower in the selective cut plots. Indeed, despite having the largest *A. koa* tree at the site, and recruitment of *A. koa* seedlings over the study period, not a single individual reached 1 cm DBH and survived by the end of the study. In contrast, other studies in mesic and wet forests in Hawaiʻi showed that restoration treatment was less important than the initial location of mature *A. koa* trees for determining recruitment (McDaniel et al., 2011).

The lower light conditions and the characteristics of the remaining non-native trees in the selective cut plots may be at least partially responsible for the selective cut plots having lower performance in native overstory and understory regeneration than the other two treatments. The fact that canopy openness was lower at the end of the study than at the start, combined with the low recruitment of native trees, indicates that the gaps left from selectively removing non-native trees were filled by the expanding non-native canopy. This can occur quickly for species like *Psidium cattleainum*, which reproduce clonally. Darker conditions limit recruitment (Drake and Mueller-Dombois, 1993; Cordell et al., 2009) and relative growth rates (McDaniel and Ostertag, 2010) of native tree species in mesic and wet Hawaiian forests. For example, *A. koa* can regenerate very quickly, but only in high light situations, such as after fire, bulldozing, or in pastures (McDaniel et al., 2011; Scowcroft, 2013; Trauernicht et al., 2018). In addition, the leaf litter from the non-native species that remained in the canopy, including *Psidium guava* and *Syzgium cumini,* may be allelopathic (Chapla and

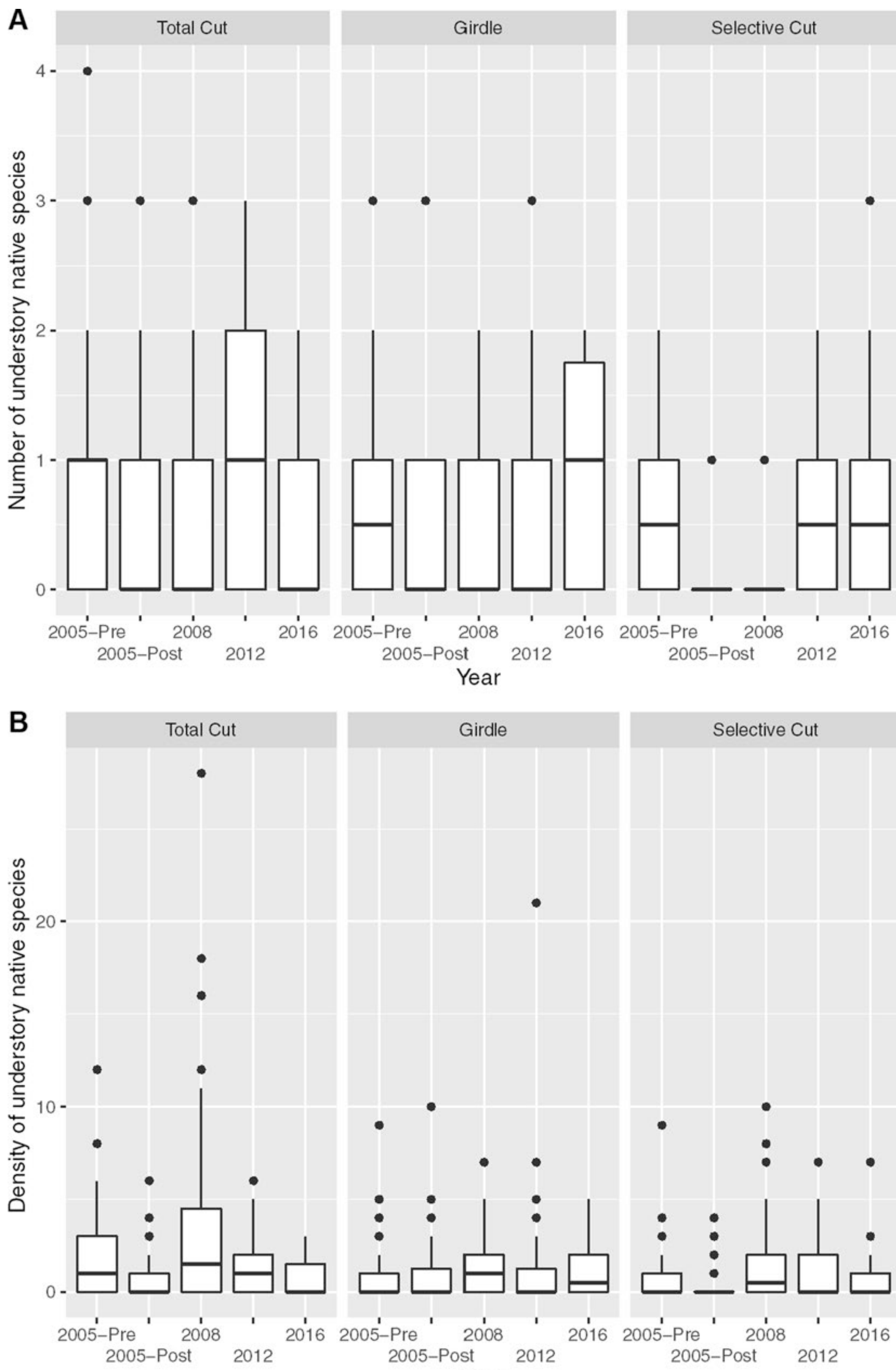

Fig. 3. Richness (A) and density (B) per subplot of native species in the understory from 2005 pre-treatment to 2016 at the end of the experiment, across all restoration treatments at a site in Makaha, O'ahu.

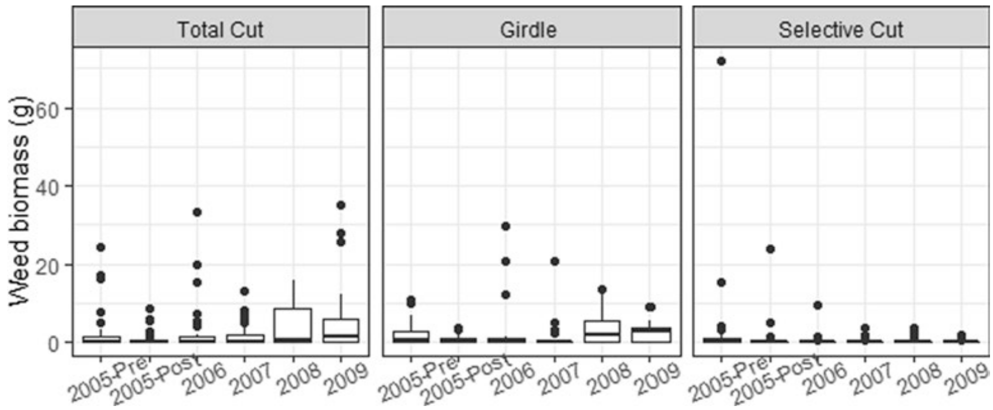

Fig. 4. Mean biomass per subplot of non-native plants removed annually for each restoration treatment at a site in Makaha, Oʻahu.

Campos, 2010; Tewari et al., 2017; Ooka and Owens, 2018) and as such may prevent or reduce seed germination. Given that it is technically more difficult to selectively cut trees because it requires untangling and carefully removing them, the lower yielded benefits suggest this approach is not worth the effort.

4.3. Effects of restoration on overstory metrics

Our results show that both the girdle and total cut treatments were highly effective at restoring native forest canopy. Overstory density of native trees increased significantly relative to starting conditions, and since the plots were periodically weeded for non-native overstory species, the gaps in the canopy left by the removal of non-native species were filled by recruitment and/or expansion of the existing native tree canopy (Fig. 1). Our finding that canopy openness in the cut treatment was higher three years post-treatment (2008) than immediately post-treatment can be explained by the death of a few of the large trees in the plots. Future research on the effects of wind on trees that become isolated post-treatment is needed.

It is not unexpected that only three native species recruited into the canopy. *Acacia koa* and *D. viscosa* are two of the few disturbance-adapted Hawaiian mesic forest trees, and the remaining native tree species present in the plots are considered shade tolerant species, typically regenerating under more shaded conditions. *Pipturus albidus* (*māmaki*), another disturbance-adapted species, was an early pioneer that disappeared by the end of the study, which may be both because they tend to be short-lived and because the closed canopy prevented them from meeting their high light requirements (Pattison et al., 1998), or because the conditions were too dry. These three species have quickly colonized other mesic restoration sites (Loh and Daehler, 2007; McDaniel and Ostertag, 2010; Trauernicht et al., 2018). This was the only tree species observed to colonize the plots and disappear before the end of the experiment.

Pysdrax odorata was the only canopy species with saplings (1–5 cm DBH) present in our plots pre-treatment, hence it is not surprising that it was the only other species to recruit into the canopy. This species reproduces by root suckers and therefore has the ability to regenerate even when conditions for seed germination are lacking. Other studies have shown that the new canopy formed by early colonizers such as *A. koa* can provide the habitat conditions for recruitment of the shade-adapted species (Denslow et al., 2006; McDaniel and Ostertag, 2010). However, as described below, this was not the case in our experiment.

4.4. Effects of restoration on understory metrics

In contrast to the success of the overstory, restoration did not lead to regeneration of native species in the understory. Across treatments, recruitment was highly limited and although the density of understory species increased significantly by 2008, by the end of the experiment it did not differ significantly from the start. In a global review of studies on invasive plant removal, the majority of experiments showed that native plant species richness did not increase without additional intervention (Kettenring and Adams, 2011). A key issue is the success of non-native species recruitment in the understory. Although we did not measure weed biomass at the end of the 10 years, the richness of non-native species was higher than at the start. Other studies in Hawaiian forests have also shown that despite a return to full canopy coverage or dominance by native species, non-native recruitment in the understory is often high and prevents recruitment of native species (Yelenik, 2017). In mesic Hawaiian forests, secondary invasion can be worse than in dry or wet forests, due to the wider range of climatic conditions supporting a higher variety of non-native species, and the resulting communities of invaders can be more difficult to manage than the initial non-native community (D'Antonio et al., 2017). It will be important for future research on non-native species removal treatments to examine management strategies for secondary invader communities and their interactions with native seedlings (Pearson et al., 2016).

The low recruitment and/or survival of native seedlings is likely due to the factors that commonly limit recruitment across Hawaiian mesic forests: lack of seed dispersal (Denslow et al., 2006), predation of seeds by introduced rodents (Shiels and Drake, 2011), and competition from non-native species (D'Antonio et al., 2017). At our site, the latter were gap-colonizing, fast-growing species, most of which have reproductive traits such as small seed size and/or clonal growth that provide advantages over the native species. We observed consistent fruiting of eight of the nine canopy species in our plots (the one exception was *Bobea* sp. which had only one individual in the plots). However, most of these species produce large seeds that, in contrast to many of the non-native canopy species at the site, do not form a soil seedbank. In addition, due to the decline and extinction of Hawaiʻi's native birds (Burney et al., 2001; Boyer, 2008), and the inability of the introduced bird species present to disperse large seeds (Chimera and Drake, 2010), these species have no known dispersers. Undispersed seeds may have lower chances of germination and survival (Caughlin et al., 2015) and may also suffer higher rates of seed predation (Chimera and Drake, 2011). Previous research has documented both the abundance of introduced rodents in Makaha (Shiels, 2010) and the predation of seeds of most of the canopy species by rodents (Shiels and Drake, 2011). While ANRPO has since installed rat traps throughout the study site, during our study period there was no trapping in the area.

The understory at the study site in Makaha pre-treatment was dominated by seedlings and saplings of coffee (*Coffea arabica*) and guava (*Psidium cattleianum*) (including suckers), with some plots dominated by basket grass (*Oplismenus hirtellus*). These fast-growing species easily outcompete native seedlings, providing dense shade and little space and resources for seeds to germinate (Kandert et al., 2021). The significant increase in the density of native understory plants during the period of weeding (2005–2009) highlights the potential for restoration success. The subsequent decrease by the next census (2012) and through the end of the study was due to mortality of existing individuals and a lack of further recruitment. This is likely due to the increase in density of non-native plants, though we are unable to confirm this as we did not measure weed biomass after 2009, but visually it clearly appeared to be the case. The fact that light conditions when we stopped weeding in 2009 were higher than pre-treatment suggests that light-loving, non-native species had the continued opportunity to proliferate. This increased light also is likely responsible for the addition of new non-native species, as has been observed in other Hawaiian mesic forests after disturbance (Loh and Daehler, 2008; Trauernicht et al., 2018) and by ANRPO in other restoration sites. However, a confounding factor in our experiment is the fencing established in 2007. Exclusion of feral pigs can increase cover of both native and non-native species (Cole et al., 2012), and a post-fencing increase in non-native understory cover was documented by ANRPO in other transects in the valley. Nonetheless, had the 2008 increase in native understory plants been solely the result of fencing, we would expect it to have continued through to the end of the experiment.

5. Conclusions

Overall, our research demonstrated few differences in metrics of restoration success between the total cut and girdle approaches to removing non-native trees in a mesic forest. A total cut approach is preferable from an economic perspective, since all trees are removed and/or chipped at one time, allowing for more efficient use of time and resources. In addition, it eliminates the hazard of later treefalls that occur in the girdle approach, which can also destroy regenerating vegetation. As such, it appears to be a preferable choice for overstory restoration, at least under the starting conditions of our study (about 50% non-native basal area).

Our research also shows that even when restored areas are managed for introduced animals (feral pigs, introduced rodent seed predators), recruitment of native species will not be successful without the addition of consistent and long-term weed control in the understory. This is likely needed at least until the canopy fills in, which took about six years in our study, and probably well beyond that—until the native canopy species can grow larger than the weedy species. Given the massive effort that understory weeding involves over time and space, the care needed to avoid removing native seedlings, and the long-term management period this would entail, one alternative to promote recruitment in native forest restoration projects would be to focus management on a series of small plots (approximately 2×2 m or 3×3 m may be manageable, though the optimal size would need to be tested) throughout the restoration area. Our finding that the relative increase in understory forest restoration was higher in areas where native species abundance and/or richness was higher, combined with the patchiness we found of native and non-native understory vegetation and of microhabitat conditions, also point to the value of focusing on a series of carefully selected understory plots to manage.

Moreover, given that a lack of seed dispersal will continue to limit seed germination, and the slow growth rate of many native woody species, understory restoration needs to be substantially jump-started by out-planting (seeds, seedlings and/or saplings) of those overstory species present, as well as others) (Friday et al., 2015; Trauernicht et al., 2018). This type of 'ecosystem restoration approach' is precisely one that ANRPO has been taking now, with much success. Future research on which species and/or functional traits may provide the best outcomes, the timing of planting in the successional trajectory, and how this might vary across patches with different compositions of non-native species, will provide more insight still. If costs prohibit extensive planting throughout the restoration site, a nucleation technique of planting in smaller patches that will ultimately expand has been shown to be effective in enhancing understory species diversity (Bechara et al., 2021; Corbin and Holl, 2012). Overall, our study suggests great potential for mesic forest restoration in Hawai'i but underscores the need for more intensive and sustained understory management for it to be effective over the long-term.

CRediT authorship contribution statement

Lauren Nerfa: Formal analysis, Validation, Writing – original draft, Visualization. **Zoe Hastings:** Investigation, Writing – review & editing. **Amy Tsuneyoshi:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Kapua Kawelo:** Funding acquisition, Conceptualization, Methodology, Investigation, Writing – review & editing. **Jane Beachy:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Tamara Ticktin:** Funding acquisition, Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foreco.2022.120267.

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KIA HAWAII

01/24/22

Tyler Bogardus
Animal Program Coordinator
RCUH / OANRP

Via Email: tyler.bogardus@gmail.com

Subject: FLIR SURVEY REPORT OANRP

Aloha Tyler**,**

On Jan 18th & 19th we successfully completed the planned FLIR flights in the Makua and Lihue area as planned.

In Makua we detected 13 pigs and 14 goats and in Lihue we detected 9 pigs, please see the attached map.

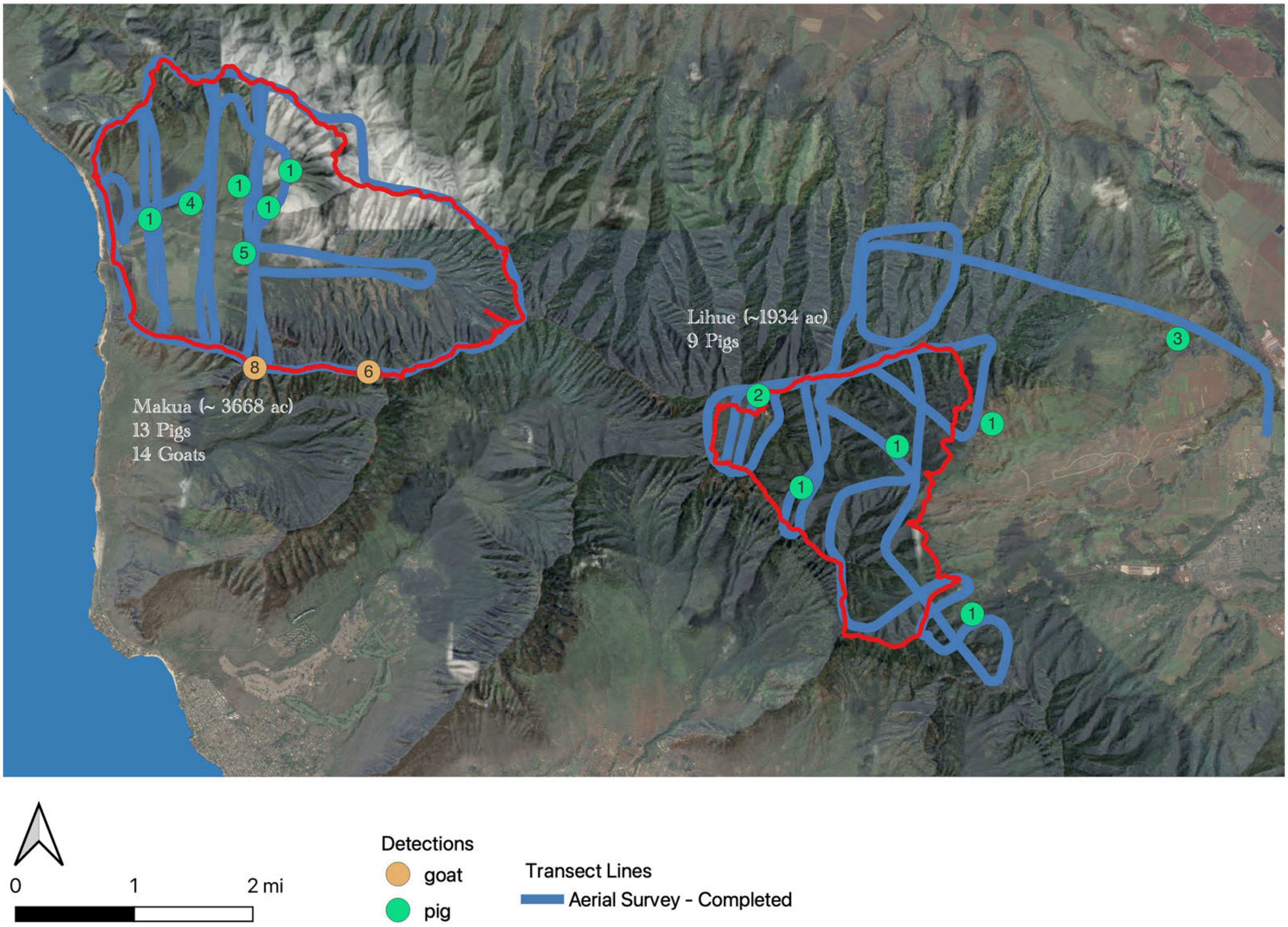
Please also find attached via email raw data for all locations and track logs.

We appreciate the opportunity to be of service and look forward to working together again in the future.

Please don't hesitate to reach out to myself or Jared with any questions or concerns.

Mahalo,

Jake Muise



Lihue (~1934 ac)
9 Pigs
Makua (~ 3668 ac)
13 Pigs
14 Goats
0
1
2 mi
Detections
goat
pig
Transect Lines
Aerial Survey - Completed

Ecosystem Restoration Management Plan

MIP Year 19-23, Oct. 2022 – Sept. 2027
OIP Year 16-20, Oct. 2022 – Sept. 2027

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: ANRPO, DOFAW (State Forest Reserve)

Acreage: 216 Acres

Elevation Range: 1800-3127 ft

Description: Ekahanui MU is located in the Southern Windward Waianae Mountains. Puu Kaua is at the apex of the 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 worth intensive management. The alien dominated areas were included in the MU boundary to ensure management options for the Oahu elepaio, *Chasiempis ibidis*. The majority of this alien dominated area fenced for *C. ibidis* management falls into the Subunit II fence. The MU is accessed via the Kunia road through the Kunia Loa Farm Lots 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. 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 MU is most easily accessed from the Wiliwili Ridge Trail to the north of the main Ekahanui access trail.

Native Vegetation Types

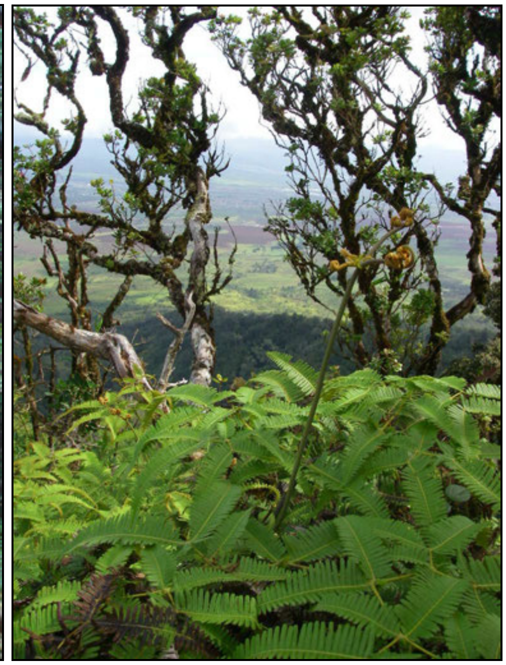
<table>
<tr><th colspan="2">Waianae Vegetation Types</th></tr>
<tr><td>Mesic mixed forest</td><td><u>Canopy includes:</u> Acacia koa, Metrosideros polymorpha, Nestegis sandwicensis, Diospyros spp., Planchonella sandwicensis, Charpentiera spp., Pisonia spp., Psychotria spp., Antidesma platyphylum, Bobea spp., Sapindus oahuensis, and Santalum freycinetianum.

<u>Understory includes</u>: Alyxia oliviformis, Bidens torta, Coprosma spp., and Microlepia strigosa</td></tr>
<tr><td>Mesic-Wet forest</td><td><u>Canopy includes</u>: Metrosideros polymorpha Cheirodendron trigynum, Cibotium spp., Melicope spp., Antidesma platyphyllum, and Ilex anomala.

<u>Understory includes:</u> Cibotium chamissoi, Broussasia arguta, Dianella sandwicensis, Dubautia spp. Less common subcanopy components of this zone include Clermontia spp. and Cyanea spp.</td></tr>
<tr><td colspan="2">NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted.</td></tr>
</table>

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	N/A	Wild
Plant	*Cenchrus agrimonioides* var. *agrimonioides*	EKA-A, B, C, D	Central Ekahanui	MFS	Both
Plant	*Cyanea grimesiana* subsp. *obatae*	EKA-A*	North Branch of South Ekahanui	N/A	Wild
Plant	*Cyanea grimesiana* subsp. *obatae*	EKA-B*, C	North Branch of South Ekahanui	GSC	Reintroduction
Plant	*Delissea waianaeensis*	EKA-A, B*, C*, D	Ekahanui	MFS	Both
Plant	*Euphorbia herbstii*	EKA-A*	Ekahanui	GSC	Wild
Plant	*Kadua parvula*	EKA-A	Ekahanui	MFS	Reintroduction
Plant	*Phyllostegia hirsuta*	EKA-A*	Ekahanui	None	Wild
Plant	*Phyllostegia kaalaensis*	EKA-A*	Ekahanui	None	Wild
Plant	*Phyllostegia mollis*	EKA-A*, B*	Ekahanui	N/A	Wild
Plant	*Phyllostegia mollis*	EKA-C, D	Ekahanui	MFS (OIP)	Reintroduction
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	Both
Snail	*Achatinella mustelina*	EKA-A, B, C,D,E,F,G	ESU-E	MFS	Wild
Bird	*Chasiempis ibidis*	N/A	Ekahanui	None	Wild
Arthropod	*Drosophila montgomeryi*	N/A	Ekahanui	None	Wild

MFS= Manage for Stability *= Population Dead #is 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	*Bobea sandwichensis*	Endangered
Plant	*Dracaena forbesii*	Endangered
Plant	*Cyanea pinnatifida*	Endangered
Plant	*Dissochondrus biflorus*	Species of Concern
Plant	*Geniostoma kaalae*	Endangered
Plant	*Pteralyxia macrocarpa*	Endangered
Plant	*Melicope christophersonii*	Endangered
Plant	*Melicope cornuta* var *decurrens*	Endangered
Plant	*Neraudia melastomifolia*	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
Bird	*Asio flammeus sandwichensis*	State 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

Delissea waianaeensis recruitment at reintrodution

Abutilon sandwicense flower

Wild *Schiedea kaalae* patch

Plantago princeps var. *princeps* with infructescense

Locations of rare resources at Ekahanui

Image Redacted
Sensitive Information
Available Upon Request

MU Threats to MIP/OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2022
Pigs	All	Across MU	No animals within fence
Goats	All	Across MU	No animals within fence
Rats	All	Across MU	MU-wide A-24 grid of 306 traps running since Sept. 2017.
Cats	*Chasiempis ibidis*	Across MU	4 AT220 traps across lower extent of unit.
Predatory snails *Euglandina rosea*	*Achatinella mustelina*	Predator-proof snail enclosure offsite (Palikea North)	Limited to hand-removal. All *A. mustelina* in MU have been moved into Palikea North enclosure.
Slugs	*C. grimesiana* subsp. *obatae, D. waianaensis, S.kaalae, P. mollis,* seedlings of several other species may be affected	Localized Control	Slug control toxicant applied every 6 weeks. *No current slug control at *P.mollis* site, prioritized for resumption of treatment
Ants	Potential threat to *Drosophila montgomeryi*	Localized toxicants	No current control: toxicants may pose threat to managed fly taxa.

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2022
Weeds	All	Rare taxa sites primarily, across MU secondarily	Regular maintenance required several times per year
Fire	All	Target *Megathrysus maxima*	Regular grass control within the MU and along fence line as needed.
Black Twig Borer *Xylosandrus compactus*	*Alectryon macrococcus* var. *macrococcus*,	None	No known control
Coconut Rhinoceros Beetle *Oryctes rhinoceros*	Unknown, possible threat to *D. forbesii*	Currently limited to detection: pheromone panel traps spaced along access trail	Multiple *O. rhinoceros* detected in traps, first detection late 2021
Jackson's Chameleons	*A. mustelina*	None	All *A. mustelina* translocated to Palikea North. Any finds with in unit will be noted for threat assessment for other managed taxa.

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 continues 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 Honouliuli.
- 1972: One individual of *Drosophila montgomeryi* was recorded from Kaluaa Gulch.
- 1990-2009: Honouliuli Preserve managed by The Nature Conservancy (TNC).
- 1998-2002: Biological surveys by TNC Staff and Joel Lau.
- 1999: *C. ibidis* management begins with banding and rodent control of about 6 pairs. 2000: Subunit I fence completed (40 acres). TNC eradicated the last pigs through the use of volunteer and staff hunters.
- 2001-2006: Catchment tanks and field nursery installed. Other common native restoration efforts done by TNC/Army staff.
- 2002: *Achatinella mustelina* surveys by Army Staff and Joel Lau.
- 2004: ANRPO 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.
- 2006: Number of *C. ibidis* pairs with rodent control increases to 20.
- 2007: Active management by TNC stops due to staff reductions.
- 2007: Pigs breached Unit I fence, removed by hunting and snaring.
- 2008: Subunit II/III fence completed.

- 2009: James Campbell Co. sells Honouliuli Preserve to the State of Hawaii/TNC transfers lease.]
- 2009: Over 25 *C. ibidis* pairs known and protected by localized rodent control.
- 2010: The last pig removed from subunit II fence.
- 2010: Vandalism to perimeter fence observed at Cyanea gulch crossover, hole cut in fence repaired with no ungulate breach.
- 2010-2011: Large-scale rodent trapping grid system installed using 512 Victor snap traps throughout the whole MU.
- 2011: Stream in airplane gulch breaches fence, repaired.
- 2011: Slug c
- 2011: One hundred and two Victor snap traps are added to existing rodent trapping grid. A total of 667 traps now protects 30 *C. ibidis* pairs, *A. mustelina*, and managed rare plants.
- 2012: Subunit IV fence completed, pig ingress in Subunit I, hunted out.
- 2013: Thirty-four Goodnature A24 Rat Trap- Automatic & Self-Resetting are added to trapping grid to assist rodent control surrounding the *A. mustelina* and *Plantago priceps var. priceps* populations at the top crestline of MU.
- 2013: Huliwai fence completed around in-situ *A. sandwicense* population.
- 2014: Pig ingress in Ekahanui subunit II, hunted out
- 2016: Strategic area above Subunit I enclosed, mauka line of Subunit I repaired, no further sign detected
- 2016: Two temporary enclosures for *A. mustelina* were built around populations that were rapidly declining in order to protect the remaining *A. mustelina* until the Palikea North enclosure is complete.
- 2016: *Kadua parvula* representing Halona PU planted on rappel off of Crest Line LZ
- 2017: One hundred and two *A. mustelina* were collected and brought to the Snail Extinction Prevention Program's housing and rearing facility.
- 2017: All Victor snap traps were replaced with Goodnature A24 Rat Traps. A total of 306 A24 traps were added. The number of *C. ibidis* pairs benefiting from rodent control increases to 42.
- 2018: All ESU-E *A. mustelina* were translocated to the Palikea North enclosure.
- 2017: Temporary snail enclosure at "mamane site" dismantled and flown out.
- 2018: Temporary snail enclosure at "Amastra site" dismantled and flown out.
- 2019: Landslide damages section of interior fence (EKA-C) above former "mamane site" snail enclosure, new 50m section of fence constructed to replace demolished portion.
- 2020: Additional *K. parvula* planting conducted off-rappel, one utilizing former PlaPriPri.EKA-D reintro site, the other in a small area of upper slope habitat ~100m down ridge from the Crest Line LZ.
- 2020: Pig sign detected during rat trail clearing in Unit II, one pig observed during setting of snares, 2 pigs subsequently snared in Cyanea gulch. No breach detected in fence, pigs may have entered as piglets and remained undetected in Unit II.

- 2020: Number of *C. ibidis* pairs protected with rodent control reaches 52.
- 2021: South Line Ekahanui #223 LZ, originally used for snap grid installation, reopened on south fence line above Unit III
- 2021: Additional *K. parvula* planted into off-rappel sites.
- 2021: 3 panel traps for *Oryctes rhinoceros* deployed along access trail (by early 2022, *O. rhinoceros* detected in all three traps)
- November 2021: DOFAW/Oahu Plant Extinction Prevention Program (OPEPP) plant 500 *Urera kaalae* into 2-D gulch
- 2022: Targeted feral cat (*Felis catus*) control begins in Airplane and Cyanea gulches to reduce impact to ANRPO tracking tunnel data. Four (4) NZ AutoTraps AT-220 traps and two (2) Timms traps are installed in Airplane and Cyanea gulches. Three (3) Steve Allan Kat Traps are installed within the Huliwai gulch system for targeted *F. catus* control.
- 2022: During rare plant monitoring in Ekahanui-05, one *A. mustelina* was found within an SLCA. Ferroxx was not applied at location and has been suspended pending surveys for additional *A. mustelina.*

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 2008
  - Subunit IV (Bump Out) completed 2011
  - Huliwai *A. sandwicense* fence completed 2013
- Conduct quarterly fence checks.
- Conduct quarterly Subunit fence checks.
- Note any pig sign while conducting day-to-day actions within fenced MU.
- If any pig activity is detected, work with Ungulate Biologist to implement control.

Discussion:

There is a perimeter fence around the entire Ekahanui MU (EKA-A) encompassing four subunits. The Huliwai *A. sandwicense* fence (HUL-A) will also be included in this discussion. The EKA-C fence separates units 1 and 2. The EKA-D fence separates units 1 and 3 where the *A. sandwicense* EKA- A and C populations are. There are two small PU fences the EKA- G that surrounds a wild *S. kaalae* and the EKA- F which encompassed the *D. waianaensis* EKA-B population. The EKA-H fence, known as the "Bumpout", is built around a wild and reintroduced population of *C. agrimonioides var. agrimonioides*, the EKA-D and E.

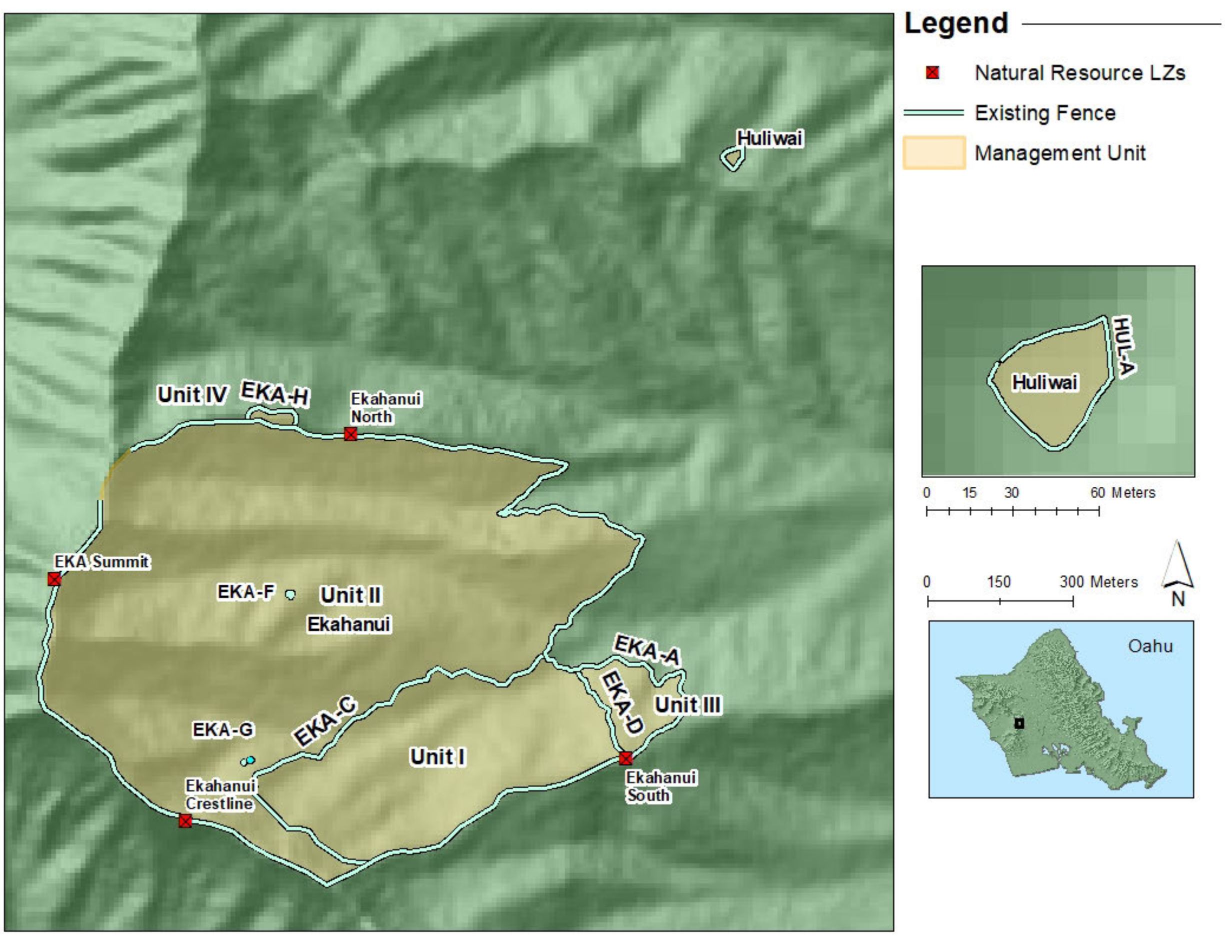
The major threats to perimeter fences include fallen trees, vandalism, rock fall, and high water events. There are no "major" gulch crossings of the EKA-A fence, but rather three smaller crossings that have potential to carry a large amount of debris in flash floods. Special emphasis will be placed on checking the fence after extreme weather events, such as in 2011 when a stream breached the unit II part of the perimeter. Additional fencing panels have been flown in and staged at the bottom of the unit in the event that flooding or tree-fall cause a breach. There have been few incidences of vandalism to the fence in the past. A hole cut in the perimeter fence at the bottom of Cyanea gulch was noted and fixed on a fence check in 2010. The EKA-C is threatened by landslides from the cliffs above. In 2019, staff fixed nearly 55 meters of fence due to a large landslide that occurred. Falling trees and erosion threaten the EKA-D and H fences. The small PU fences are threatened by tree falls and landslides.

Since the construction of the second fence unit, encompassing largely unmanaged area, pig sign has mainly been detected in Unit II. The large area of the unit combined with limited work conducted there, may allow pigs that enter the fence as piglets to go undetected. This is likely the case with the two pigs snared in 2020, sign was detected during the six month servicing of the A24 grid. While skirting is present along the fence in areas where erosion could cause a breach, adding fickle fence to the bottom of the unit especially, may reduce the ability of "squeezers" to access the unit.

Goat pressure has also fluctuated with increased presence along the southern fence line in 2020/21 noted during fence checks. Significant browsing of grass outside and within reach inside the fence has been ongoing along the southern fence line. Activity along the summit and crest line portions of the fence has been more limited. Domestic goats may be moving into the forest reserve from Kunia Loa Farm Lots and mixing with feral herds.

The Huliwai *A. sandwicense* fence is along the Honouliuli Contour Trail and was constructed in 2013. The most persistent issue with this small fence has been tree fall and debris build up on the upslope portion of the fence. There have been breaches caused by tree fall but no ungulates have entered the fence. Debris on the topside of the fence has been cleared periodically during fence checks and baffles have been installed up slope to reduce the buildup.

Ungulate Management Map



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

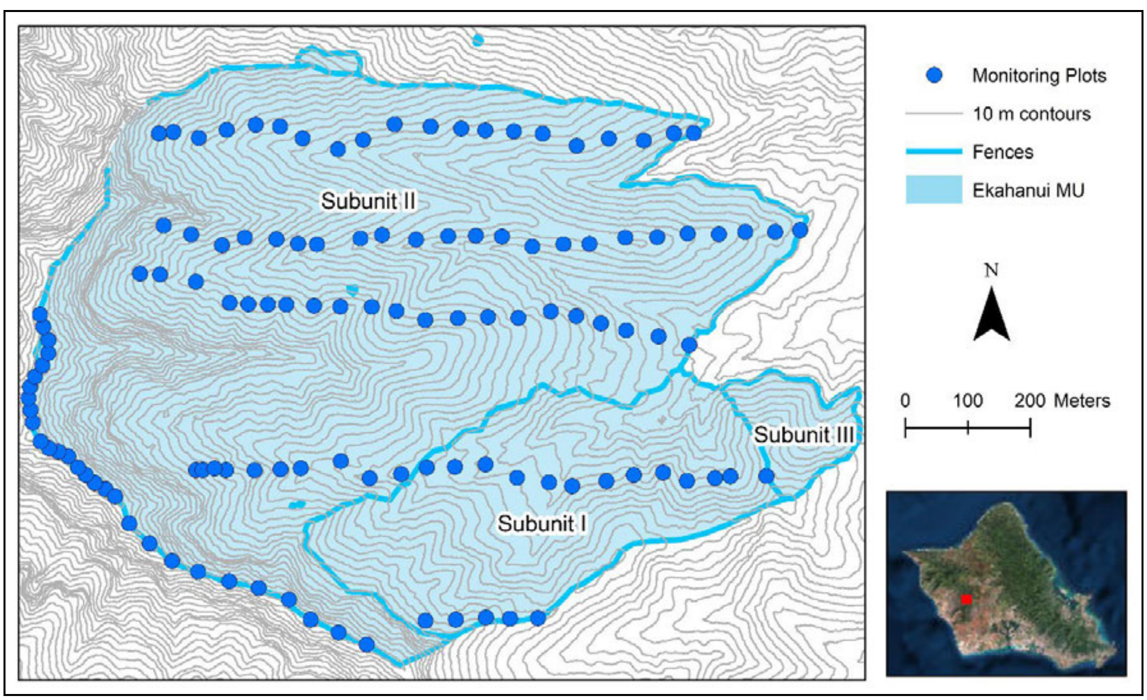
Background

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

Methods

Monitoring was conducted in 2008 and 2018 in 121 plots, with plots generally located every 20-50 m along transects (ANRPO 2009 and 2019). Transects were spaced approximately 200 m apart within accessible portions of the MU. 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 above ground level), were also documented. Monitoring will continue on the same interval, next occurring in 2028.

Ekahanui MU Vegetation Monitoring Plot Locations



Summary results

Management goals were met for non-native understory in both of the years monitored. Goals were not met for native understory, native canopy and non-native canopy in either year.

Median cover (%) of vegetation in plots at Ekahanui MU from 2008 to 2018

	2008	2018
Native understory	3.0	3.0
Non-native understory	25.0	35.0
Native canopy	0.5	0.5
Non-native canopy	75	95

There were a number of noteworthy significant differences in vegetation between the years monitored including:

- **Categorical cover**
  - Increased
    - Non-native understory
    - Non-native canopy
- **Richness**
  - Increased (within plots)
    - Non-native understory
    - Native canopy
    - Non-native canopy
  - Decreased (across MU)
    - Native understory
- **Frequency**
  - Increased
    - Non-native understory
      - *C. hirta*
    - Non-native canopy
      - *P. suberosa*
- **Species cover**
  - Increased:
    - Non-native understory
      - *B. appendiculatum*
      - *C. hirta*
      - *M. minutiflora*
      - *P. cattleianum*
    - Non-native canopy
      - *P. cattleianum*
      - *S. terebinthifolius*
    - Native canopy
      - *M. polymorpha*
- **Target weed taxa**
  - *D. cordata* var. *pacifica* less prevalent
  - *P. dioica* more prevalent

- *C. arabica* encroaching

Aside from the increase in native canopy richness and *M. polymorpha* canopy cover, and the reduction in *D. cordata* var. *pacifica* prevalence along the upper crest line, changes generally reflected worsening conditions, particularly for non-native components. Non-native canopy cover, already prevalent in 2008, now predominates, and the two most prevalent canopy taxa for the MU, *P. cattleianum* and *S. terebinthifolius*, expanded in cover, and had the most prevalent recruitment by far in comparison with other species. Though non-native understory cover continued to meet the management goal, it is getting worse, with a number of problematic species expanding in frequency and/or cover. Most concerning is the decrease in overall MU native diversity in the understory, and the encroachment of *C. arabica*. The trails associated with the rodent control grid present a potential risk for spread of problematic weeds. Also of concern, *Abutilon grandifolium* was anecdotally observed in a few locations (outside of plots) during monitoring in 2018. With respect to safeguarding rare plant genetic integrity, the presence of *A. grandifolium* poses a potential risk to *Abutilon sandwicense* populations in Ekahanui. Seedlings grown from seeds collected from *A. sandwicense* in Waianae growing adjacent to *A. grandifolium* appeared to be hybrids between the two species, suggesting crossing is possible between the two. In sites where *A. sandwicense* is managed in Ekahanui and Huliwai, special care will be taken to note and control *A. grandifolium* to help mitigate the potential for hybridization.

These monitoring results were not surprising, given the degraded nature of much the MU, and the limited weed control that occurs here. Areas with remaining native habitat are primarily limited to the uppermost elevations and are otherwise patchily distributed throughout non-native dominated forest. Much of the management that occurs on an MU scale is associated with *C. ibidis*, with an emphasis on rodent control rather than weed control, as *C. ibidis* indiscriminately utilize non-native habitat, but are vulnerable to rodent predation. While rodent control may result in less native seed predation, there will likely be less non-native seed predation as well, and any resulting increased recruitment will likely be dominated by non-natives. Areas around rare plants that receive consistent weeding efforts have been anecdotally observed as being successful in transitioning from mixed native and non-native habitat into native dominated habitat. Changes in these areas cannot be assessed from the MU-scale monitoring and would require smaller-scale monitoring methods targeting those specific areas.

<u>Recommendations</u>

Based on the results of vegetation monitoring, several recommendations were made with the goal of maintaining remaining native habitat, protecting rare plants, and preventing the spread or incursion of problematic weeds not currently dominant in the MU, rather than making progress towards meeting unrealistic management objectives:

- Continued general ecosystem weed control in the vicinity of rare plant resources, expanding to include more area as feasible
- Continued control for existing ICAs
- Vigilance to prevent incursion or spread of problematic weeds along rodent control grid (continue to maintain sanitation protocols for gear, watch out for new and or problematic weeds along trails, and control weeds as necessary)
- Add *A. grandifolium* to the limited distribution taxa target list, with special emphasis for control in areas near *A. sandwicense* populations
- Conduct targeted sweeps every five years for all *C. arabica*, *H. popayanensis*, *P. dioica*, and *T. ciliata*, and mature individuals of *F. uhdei* and *S. campanulata,* focusing on known infestations first. Solicit help from other field teams as area is large.
- Consider possible weed control efforts along the upper crestline and its utility for rare plant reintroductions.

- Consider the need for an alternate form of vegetation monitoring (such as point-intercept) in 2-D, Palai, Unit III, the Bump Out, and other areas that are actively weeded to assess change in vegetation in response to active management efforts.

Surveys

Potential Vectors: ANRPO 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, campsites, fence lines, trails, and other high traffic areas.

Strategy and Control Methods:

- Note unusual, significant or incipient alien taxa during the course of regular fieldwork. Map and complete Target Species form to document sighting.
- Survey LZs and Campsites used in the course of fieldwork, not to exceed once per quarter.
- Survey the access trail annually and note any novel/potentially incipient taxa.
- Quarterly surveys of LZs (if used).
- Annual Weed Transect Survey (WT-Ekahanui-01)
- Note unusual, significant or incipient alien taxa during the course of regular fieldwork.
- Any significant alien taxa found will be researched and evaluated for distribution and life history. If found to pose a major threat, control will begin and will be tracked via Incipient Control Areas (ICAs)

Discussion:

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

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, 136 Ekahanui North. LZ and the South Line LZ that was reopened in 2021. There is a weed transect along the access trail from the trailhead to the fence. There are currently no road surveys for the 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:

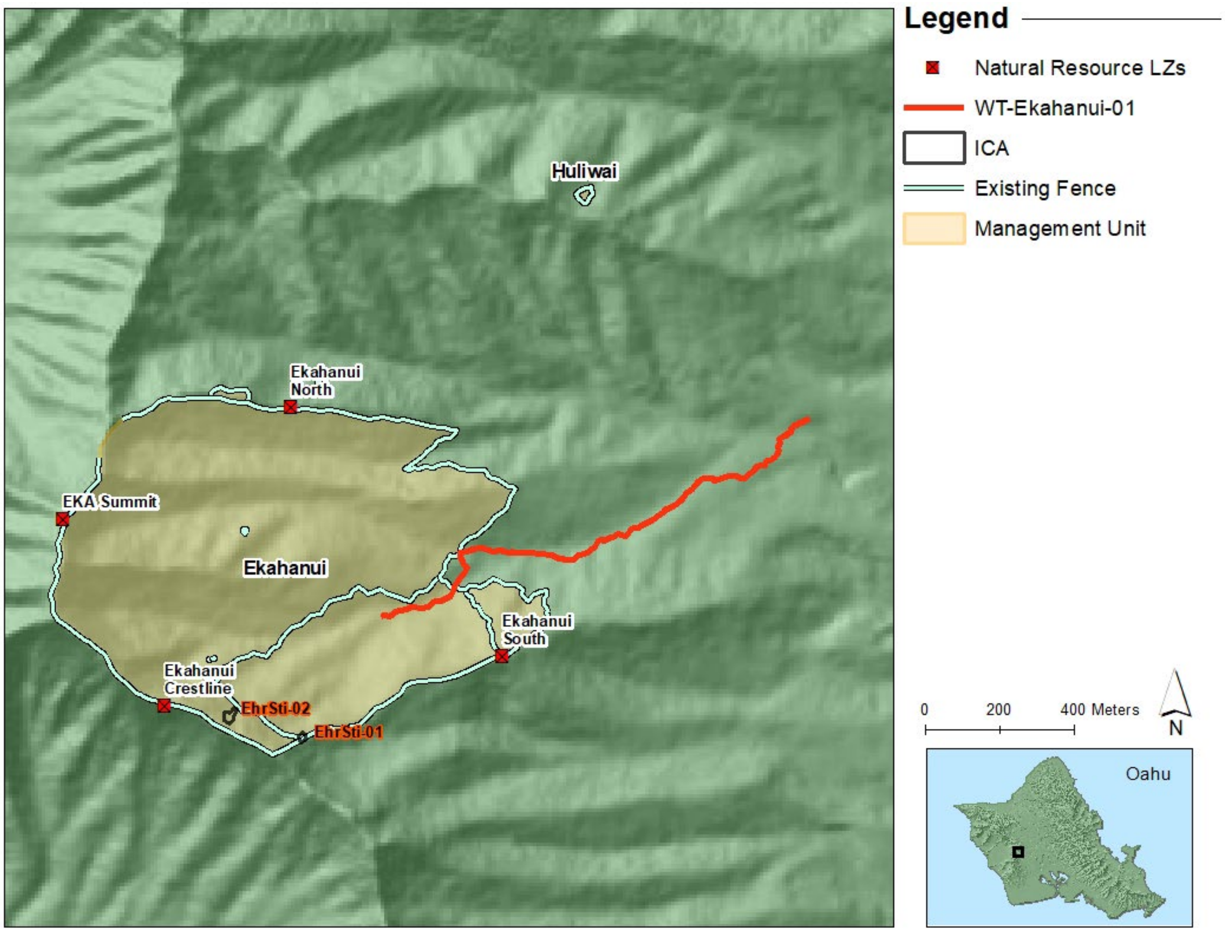
- Eradicate ICAs through regular and thorough monitoring and treatment. In the absence of any information about seed bank longevity for a particular species, eradication is defined as 10 years of consistent monitoring with no target plants found.

- 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, locations, 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 and many incipient taxa's seed longevity is not well understood. 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



ICAs are drawn around each discrete infestation of an incipient invasive weed. ICAs are designed to facilitate data gathering and control. For each ICA, the management goal is to achieve complete eradication of the invasive taxa. Frequent visitation is often necessary to achieve eradication. Seed bed life/dormancy and life cycle information is important in determining when eradication may be reached; much of this information needs to be researched and parameters for determining eradication defined. Staff will compile this information for each ICA species.

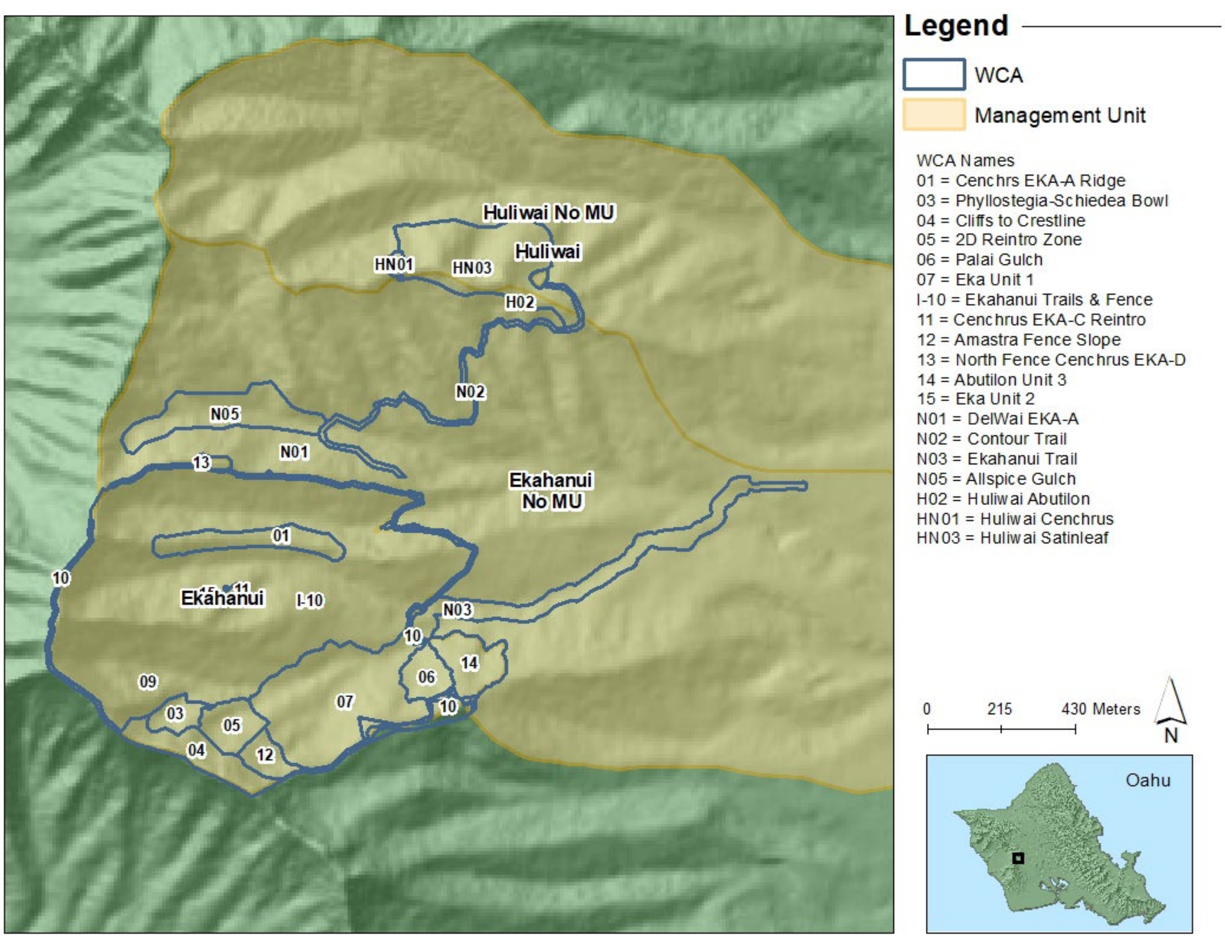
Two incipient species have been identified by ANRPO in the MU, *Ehrharta stipoides* and *Acacia mearnsii*. Return visits will be scheduled in order to prevent immature individuals from reaching maturity and to eradicate these species from the MU. Other taxa described in the target taxa table below are targeted within the WCAs.

Summary of ICAs

Taxon	ICA Code	Control Discussion
Ehrharta stipoides	Ekahanui-EhrSti-01	Checked quarterly, last mature observed in 2018, last immature in 2019 with no plants observed since. Candidate ICA for "eradicated" status.
	Ekahanui-EhrSti-02	Checked quarterly, plants consistently found. Eradication difficult due to steep terrain and potential for non-target damage caused by pre-emergent herbicides.

<u>ICAs Eradicated at MU:</u> *E. stipoides* (HuliwaiNoMU-EhrSti-01)

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 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:

- 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 The Nature Conservancy (TNC). Most of this effort has taken place within the unit 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 Army Natural Resources Staff. Reintroductions of common natives have also been conducted by TNC and continued by ANRPO to restore habitat within the MU. Much of the weed control conducted by NRS in Subunit I follows the actions set-forth by TNC staff, however, current work is more focused on WCAs and sites within them containing MFS reintroductions.

The Ekahanui Subunit II fence was completed in 2009. There are a few WCAs within this subunit, and for the most part, they are small and are for weed control only as needed around managed rare plant species. Most of Subunit II is highly degraded (see monitoring data). While not widely used in Ekahanui, Incision Point Application (IPA) of concentrated herbicide may prove useful in limiting spread of target weedy canopy species in Unit II.

The Unit III fence was completed in 2009 to protect a wild population of *Abutilon sandwicense* (EKA-A). After the completion of the fence, an augmentation (EKA-C) to the wild *A. sandwicense* was conducted. Unit III has also had several rounds of common native reintroductions to improve habitat for managed taxa and reduce weeding effort required over time.

A large concern with weed control in Ekahanui MU is its potential impacts on Oahu *C. ibidis*. The MU has the largest breeding population of *C. ibidis* managed by ANRPO, 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 *C. ibidis* have evolved with native forest components and would persist better within restored habitat.

C. ibidis 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 Rare Vertebrate Conservation Specialist.

Weed control in Huliwai is restricted to within the HUL-A fence around in-situ *A. snadwicense* and around the *C. agrimonioides* var. *agrimonioides* on the ridge above. The habitat in the Huliwai fence and the ridge are highly degraded and weeding efforts coincide with annual monitoring of the rare plants.

The table below summarizes invasive weeds found at Ekahanui and Huliwai, 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
Abutilon grandifolium	Scattered	Control within WCAs, target for complete removal from MFS/GSC *A. sandwicense* sites
Achyranthes aspera	Restricted	Found infrequently along access trail. Note and control any additional infestations along access trail and within unit.
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.
Ardesia eliptica	Restricted	Immatures observed along north fence line of Ekahanui, likely dispersed by birds from adjacent unmanaged areas.
Acacia mearnsii	Restricted	Found to the North of Ekahanui, above Jeep Trail and on lower portion of Kaua Access trail within fence. Matures and significant numbers of immatures within the fence should be targeted and any observation of spread within the MU should be noted and controled.
Casuarina glauca	Scattered	Found on lower Airplane Ridge and along ridgeline near CenAgrAgr.HUL-A.
Chrysophyllum oliviforme	Scattered	In Huliwai. Targeted for control within WCAs
Clidemia hirta	Widespread	Found throughout MU, control within WCAs dueing ecosystem weeding.
Coffea arabica	Widespread	Found throughout gulches below the MU. Targeted for control within WCAs, large defoliation event observed late 2021/early 2022 possibly attributed to fungal pathogen.
Drymaria cordata	Scattered	Observed in limited areas in Ekahanui-05. Note any additional infestations, especially on trails to prevent spread.
Ficus macrophylla	Widespread	Targeted for control within WCAs. Map individuals/groups of plants within the MU.
Fraxinus uhdei	Widespread	Target for control within WCAs. Dominant tree in gulches below fence, wind dispersed
Heliocarpus popayanensis	Widespread	Targeted for control within WCAs. Effective IPA control method known.
Megathrysus maximus	Scattered	*M. maximus* is widespread in the disturbed habitats that surround the MUs. *M. maximus* 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.
Mallotus philippensis	Restricted	Huliwai area, target for control in Huliwai-02. Note and control where ever found in Ekahanui to prevent establishment in unit, problematic in Kaluaa.
Oplismenus hirtellus	Widespread	Shade tolerant grass, found throughout MU, target with grass-specific herbicide.
Pimenta dioca	Restricted	Found in gulch to the North of Ekahanui fence. Plants are localized and any spread out of this gulch into the MU will be noted and controlled.
Schefflera actinophylla	Widespread	Targeted for control whenever observed; map individuals/groups of plants within the MU.
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 within frequently managed sites.
Spathodea campanulata	Widespread	Kill when seen. Efficacy of IPA treatment poor for large trees.

Taxon	Distribution	Notes
Toona ciliata	Scattered	Problematic weed in many MUs, locations of mature trees within MU should be marked and trees controlled to slow ingress into unit.

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	Growth Habit	Outplant/SDT	Notes
Acacia koa	Tree	Outplant	Outplant if no mature trees on site. Recruits grow rapidly.
Antidesma platyphyllum	Tree	Outplant	Grow from seed. Seeds recalcitrant.
Bidens torta	Herb	Seedsow	Seed sows.
Carex meyenii	Sedge	Outplant	Groundcover species for shadier areas
Carex wahuensis	Sedge	Outplant	Good groundcover until larger canopy species can establish
Ceodes spp.	Tree	Outplant/ Seedsow/ Transplant	Grow from seed. Recalcitrant. Can seedsow or transplant.
Cibotium chamissoi	Fern	Outplant	Grow from spore. Tree fern.
Claoxylon sandwicensis	Tree	Outplant	Grow from seed. Tends to recruit well in gulch areas. Need collections of seed.
Coprosma foliosa	Shrub	Outplant	Grow from seed.
Cyperus polystachyos	Sedge	Seedsow	Excellent groundcover until larger canopy species can establish. Seedsows highly effective.
Dianella sandwicensis	Herb	Outplant/ Division	Good groundcover until larger canopy species can establish. Divisions possible in wetter areas.
Dodonaea viscosa	Shrub	Outplant	Grow from seed. Fast growing shrub/small tree.
Doodia kunthiana	Fern	Outplant	Grow from spore. Groundcover for shadier areas.
Eragrostis grandis	Grass	Outplant	Good groundcover until larger canopy species can establish
Hibiscus arnottianus	Tree	Outplant	Grow from seed. Need collections of seed.
Kadua affinis	Shrub	Outplant	Grow from seed.
Metrosideros polymorpha	Tree	Outplant	Grow from seed. Major component of forests.
Microlepia speluncae	Fern	Outplant	Grow from spore. Larger fern, but more delicate than *M. strigosa*. Plant in shade or moist soils.
Microlepia strigosa	Fern	Outplant/Division	Grow from spore. Good groundcover until larger canopy species can establish. Plant with 18” spacing or tighter for weed suppression.
Mysine lessertiana	Tree	Outplant	Grow from seed. Tends to recruit directly under mother tree.
Pipturus albidus	Tree	Seedsow	Known to grow from seed sows. Good early establishment. Trim around year two making gaps

Native Taxon	Growth Habit	Outplant/SDT	Notes
			for larger canopy species.
Pittosporum spp.	Shrub	Outplant	Grow from seed. Has established quickly in other restoration areas and fruits heavily.
Planchonella sandwicensis	Tree	Outplant/Seedsow	Grow from seed. Slow growing. Seeds recalcitrant.
Psydrax odorata	Tree	Outplant	Need to grab snatchlings if desired. Slow growing, but hardy. Fruit often bored.
Rockia sandwicensis	Tree	Outplant/Seedsow/ Transplant	Grow from seed. Recalcitrant. Can seedsow or transplant.
Santalum freycinetianum	Tree	Outplant	Grow from seed. Companion plant in container.
Sapindus oahuensis	Tree	Outplant, Seedsow	Grow from seed. Slow growing but has large footprint once established. Seedsows possible, especially if cleaned and soaked prior to sow.
Scaevola gaudichaudiana	Shrub	Outplant, Seedsow	Grow from seed. Tends to recruit in disturbed areas.
Sophora chrysophylla	Shrub	Outplant	Grow from seed. Need to collect seed.
Urera glabra	Tree	Outplant	Grow from seed if possible. Drosophila host plant.

WCA: Ekahanui-01 Airplane Ridge

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: *P. cattleianum* and *S. terebinthifolius* 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. Any *A. mearnsii* observed will also be targeted as this WCA overlaps with the former *A.mearnsii* ICA.

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 minimize drastic light level changes. 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 *Cenchrus* individuals. The goal of weed control in this WCA will be to join the patches of the managed taxa through gradual alien overstory removal and annual understory weeding directly around plants.

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 *C. parasiticus, B. appendiculatum*, and *R. rosifolius*

Notes: Originally this WCA was a very small area in Subunit II around a small population of *S. kaalae* individuals, but was expanded in size to include an area for reintroduction of *Phylostetgia mollis* in 2012. Currently, there are several *P. mollis* recruits from the EKA-D reintroduction. Management of this reintroduction area through time via weed control has improved the understory and canopy greatly, however the decline of the *P. mollis* population has led to the discontinuation of slug control in this WCA and less overall weeding effort. For the one remaining *S. kaalae* fence, around the sole survivor of the EKA-B population, *w*eed control is conducted directly around the rare plant, understory weeds being the prime target. The canopy is predominately *P. cattleianum* and has not been heavily weeded due to *C. ibidis* considerations and 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. Control grass, primarily *Melinus minutiflora* in exposed areas and *Paspalum conjugatum* in more covered sites around rare taxa.

Notes: Weed control in this WCA has become less focused around *in-situ* rare plant sites with the decline of wild *P. princeps* var. *princeps.* With the failure of the *P. princeps* var. *princeps* EKA-D planting, it was decided the site would be suitable for the expansion of *Kadua parvula* plantings. This area was also home to many *A. mustelina*, which have been translocated to the Palikea North enclosure. The area is steep, and weed control is therefore conducted in smaller patches between cliff areas. Removal of alien vegetation must be gradual as there is a mix of native and non-native plants throughout the WCA. In the past, because there were snails in the area, alien trees and shrubs were girdled, and not cut down. Staff should continue to exercise caution in clearing during weeding, as there is always a possibility that snails are still present. However, leaving standing treated alien trees is no longer necessary. Grass control is important in maintaining native habitat for the cliff-dwelling rare plants. However, grass sprays are difficult given the steep terrain and exposure to wind. Grass control is conducted during the course of regular weeding, any large patches of grass will be noted and more extensive control will be performed as needed.

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 diverse native forest that has a long history of weeding by TNC and later by NRS staff 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*, *C. grimesiana* subsp. *obatae*, *D. waianaensis*, *S. kaalae*, *S. hookerii* (TNC reintroduction), and *Urera kaalae* (TNC/DOFAW reintroductions). There are also several wild *S. kaalae* and *A. dielfalcatum* within the WCA.

The habitat quality and presence of plantings of both listed and non-listed *Urera*, hosts species for *Drosophila montgomeryi,* this area has been chosen as a future release site for lab reared flies. *U. glabra* will continue to be incorporated in common reintroductions carried out in the future to increase the number of potential host plants.

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 *C. ibidis*, as there are several breeding pairs in this area. No canopy *P. cattleianum* will be treated during breeding season, but a removal effort with follow-up common native planting is being planned for the section of *P. cattleianum* between the gulch rare plant sites and the *C. agrimoniodes* var. *agrimoniodes* to the north.

Large-scale grass control has not yet been necessary in this WCA, as most of it is gulch terrain. There is a fair amount of *M. minutiflora* growing in the *C. agrimonioides* var. *agrimonioides* reintroduction zone. Grass is hand pulled directly around the *C. agrimonioides* var. *agrimonioides* prior to any grass spray due to the use of a grass specific 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 is in need of common native outplantings to reduce light levels in the understory and reduce competition from alien grasses with *C. agrimonioides* var. *agrimonioides*. Plantings of *Acacia koa* and *D. viscosa* at a relatively high density may help and will be considered as part of future restoration efforts.

WCA: Ekahanui -06 Palai Gulch

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

Targets: Understory weeds include *R. rosifolius*, *Oplismenus hirtellius,* and *Christella parasiticus*. *P. suberosa* is also controlled. *A. grandifolium* will also be targeted because of the concern of hybridization with planted *A. sandwicense.*

Notes: Nicknamed Palai Gulch for its many native ferns, this WCA encompasses a small gulch with a native forest patch and includes reintroduced *A. sandwicense*, *C. grimesiana* subsp. *obatae, C. pinatifida* (TNC planting), *U. kaalae* (TNC planting) and *S. kaalae*. Understory weeds such as *R. rosifolius* and *C. parasiticus* 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 a *C. ibidis* territory. Canopy weed control will not be conducted during *C. ibidis* breeding season to avoid disrupting foraging and nesting behavior. Canopy weed control, if any, will only be conducted outside of *C. ibidis* breeding season, and in consultation with the Rare Vertebrate Conservation 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*. *S. kaalae* have also been observed recruiting and F1s have persisted, making it a candidate site for further rare plant reintroductions. This WCA could also be another potential release site for *D. montgomeryi* and any future common native plantings should include more *U. glabra.*

Due to the shady canopy, the weedy grass *O. hirtellius*, thrives in the gulch and throughout the WCA. Annual grass sprays will be conducted to control this grass.

WCA: Ekahanui -07 Unit I

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 50% non-native cover

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

Notes: This WCA includes the majority of the Subunit I fence, including a ridge that was forested with *G. robusta*, known as silky oak ridge. Due to the abundance of *C. ibidis* pairs in the area, and no IP plant populations, no work in the WCA aside from trail clearing/maintenance was conducted in the previous five-year period. In years prior, TNC staff planted hundreds of small *A. koa*, with mixed results. Most of the saplings did not do well under the *G. robusta* canopy. Like its predecessor, this expanded WCA is comprised of alien dominated forest, with no actively managed rare plant populations. *C. ibidis* pairs inhabit the majority of this WCA, therefore no control of any canopy weeds will be conducted during *C. ibidis* breeding season, if at all. The focus of weed control in this WCA will be on maintaining the trails that service the rat-trapping grid. Given proximity to other more heavily managed areas in Ekahanui, this WCA may be a good place to conduct limited distribution taxa sweeps to limit weed inputs to those adjacent areas.

WCA: Ekahanui -10 Fenceline/trails

Veg Type: Mesic Mixed Forest

MIP Goal: N/A

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

Notes: This WCA is focused on infrastructure maintenance, and accounts for all weed control that takes place in order to maintain rat trapping trails and the fence line. WCA Ekahanui-08 has been incorporated into this WCA as it fell along the fence line and had overlapping targets and goals. *M. maximus* 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 include removing downed trees, treating thick understory, spraying other grass as needed along the perimeter fences of subunit I and II, and maintaining rat-trapping trails annually.

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 planting has all but failed with only one plant remaining and there are dense patches of *P. cattelanum* on either side of the planting. The site has been determined to be unsuitable and no more plants will be planted there, the amount of effort required to make the site suitable for other rare plant reintroductions is untenable at this time. Understory weed control will continue directly around the remaining plant but greater habitat restoration here will not be conducted. Once this last plant dies work in this WCA will be discontinued.

WCA: Ekahanui -12

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 50% non-native cover

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

Notes: Formerly, *A. mustelina, Amastra* sp. and several TNC rare plant reintroductions occurred 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 still has quite a few weedier patches. Weed efforts will be two fold; focus on maintaining 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 “The Bump-Out”

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native cover

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 more aggressively within the past four years to open up room for common restoration actions. Since 2019, over 900 common natives have been planted in this WCA to replace the *P. cattleianum* that has been removed from the northeast corner of the fence. Restoration actions will continue until all stands of *P. cattleianum* are removed from the fence extension. The continued observation of positive results may make this WCA suitable for future rare plant reintroductions. The response of this WCA to restoration efforts could be a blue print to larger restoration efforts in other ridgetop sites in Ekahanui MU.

Grasses and other understory weeds will also continue to be targeted by general weeding actions to maintain the rare plant reintroduction. While many of the outplanted *C. agrimonioides* var. *agrimonioides* have died, many have reproduced and some of those F1s have matured.

WCA: Ekahanui -14 Abutilon

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 25% non-native

Targets: Understory weeds such as *A. grandifolium, Lantana camara*, *O. hirtellius, Setaria palmiflora, and M. maximus*

Notes: This WCA includes the entire Subunit III fence, and includes a small gulch. Most of this WCA is highly degraded, and weed control is primarily 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. *Grevillea robusta* were targeted via incision point application (IPA) in this WCA with limited success. The IPA treatment has been discontinued due to the destruction caused by dead trees falling onto the rare plants and perimeter fence. Alien canopy is still targeted, however the very large *G. robusta* have proven to be difficult to address. To improve the habitat for the *A. sandwicense,* over 850 common native trees, shrubs, and groundcovers have been planted since 2019 to aid in stabilization of soil, reduce weeding efforts, and to improve overall habitat.

WCA: Ekahanui-15 "The Wild West"

Veg Type: Mesic Mixed Forest

MIP Goal: Less than 50% non-native

Notes: This WCA encompasses most of the Unit II fence and is highly degraded aside from isolated patches of native vegetation. There are no active rare plant sites within this WCA therefore, meaningful weed control is not currently conducted. This WCA is mainly managed for *C. ibidis* nesting sites and territories adding another layer of limits to aggressive restoration efforts. Sweeps for limited distribution taxa and other alien canopy using IPA could prevent the further degradation if this unit and limit the spread of target taxa. The Ekahanui-AcaMea-01 ICA also overlaps with this WCA. There are no plans for rare plant reintroductions or restoration in this WCA.

WCA: Ekahanui NoMU-01 (Inactive)

Veg Type: Mesic Mixed Forest

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

Targets: *S. terebinthifolius.*

Notes: This WCA was established around a small population of *D. waianaensis* and occurs outside of the MU. The last time live *D. waianaensis* were observed in this WCA was 2015. Since then, no plants have been observed and as a result weeding at the site has been discontinued. Return visits to the site have not resulted in any additional plants so it is likely that the poor habitat quality and lack of ability to seedbank has extirpated *D. waianaensis* from this WCA.

WCA: Ekahanui NoMU-02

Veg Type: N/A

MIP Goal: N/A

Targets: Tree fall/obstructions to Honouliuli contour trail between Ekahanui and Huliwai

Notes: This WCA was created to track any trail maintenance done on the Honouliuli contour trail including clearing downed trees and grass control. The Friends of Honouliuli also maintain this section of the contour trail to maintain access to their sites.

WCA: Ekahanui NoMU-03

Veg Type: N/A

MIP Goal: N/A

Targets: *Achyranthes aspera, M. maximus,* 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 *Achyranthes aspera*, *M. maximus* 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. Other actions in this WCA include the Ekahanui-WT-01 to monitor the spread pf novel taxa into the MU and clearing fallen trees from the access trail. The Friends of Honouliuli volunteer group regularly maintain the trail.

WCA: Huliwai-02 Abutilon

Veg Type: Mesic Mixed forest

MIP Goal: Less than 25% non-native

Targets: Understory weeds such as *A. grandifolium, O. hirtellius*, *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. cuminii* 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 been observed recruiting within a thick *O. hirtellius* understory and staff noticed an increase in seedling mortality once *O. hirtellius* was removed. Allowing the *A. sandwicense* to be established before *O. hirtellius* control seems beneficial but replacing it with *C. oahuensis*

WCA: HuilwaiNoMU-01 Cenchrus

Veg Type: Mesic Mixed forest

MIP Goal: Less than 25% non-native

Targets: Understory weeds such as *Melinis minutiflora*, *Paspalum conjugatum*, *P. cattelianum*

Notes: This WCA is highly degraded, and minimal weed control is conducted around a wild population of *C. agrimonioides* var. *agrimonioides*. Keeping non-native grasses and fast growing understory weeds out of area is a priority; however, weeding is infrequent and limited to visits for monitoring and collection of GSC taxa.

Small Vertebrate Control

Species: *Rattus rattus* (black rat, roof rat), *Rattus exulans* (polynesian rat, kiore), *Rattus norvegicus* (Norway rat), *Mus musculus* (House mouse), *Lophora leucamelanos* (Kalij pheasant), *Pternistis erckelii* (Erckel's francolin), *Pavo cristatus* (Indian peafowl), *Felis catus* (house cat), and *Herpestes auropunctatus* (small Indian mongoose)

Threat level: High

Seasonality/Relevant Species Biology: Year round *C. ibidis* breeding has been observed at Ekahanui. The A24 trap grid provides year-round protection to *C. ibidis* and rare plant taxa threatened by rodent predation.

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.
- Control feral cats and mongoose in the area to ensure accurate tracking of rodents via tracking tunnels.

Strategy and Control Methods

- Control rodents annually across the entire MU with Goodnature A24 trap grid.
- Quarterly tracking data collected using tracking tunnels.
- Note small vertebrate damage to rare plants during monitoring/in the course of regular fieldwork.
- Control feral cats in Huliwai as well as Ekahanui to reduce this taxa's impact on rodent tracking data.

Discussion:

In Ekahanui, ANRPO staff continue to maintain MU-wide grid of 306 Goodnature A24 traps to protect *C. ibidis* and several other MIP/OIP species year round. The grid is maintained every 5-6 months and faulty traps are replaced regularly to ensure protection for rare taxa. Tracking tunnels are set on quarterly intervals across the MU to monitor rat and other small vertebrate activity.

In 2021 an ANRPO study began a study comparing *C. ibidis* nest success and nest height in areas with and without year-round rat control. For this study, a new group of 24 tracking tunnels were installed in Huliwai for comparison with Ekahanui.

These tracking tunnels, as well as the tunnels from Cyanea and Airplane gulches in Ekahanui have been increasingly tracking feral cats. In 2017 and 2018, cat tracking was observed in 9% and 18% of EKA-B tracking tunnels respectively. In 2019 tracking increased to 42%, 2020 to 44%, 2021 averaged 38%, and through the first quarter of 2022 tracking for cats averaged 40% of tracking tunnels. There have been single observation dates (3/21/2022) that have had tracking approaching 90% of tunnels registering cat activity. The result has been that it is difficult to accurately determine rat activity in these areas. To address this problem, Three Steve Allan SA2 Traps were installed in Huliwai. Four NZ Auto Traps AT-220s and two Timms traps were installed in Ekahanui. All trap installation occurred on March 1, 2022. All three types of traps are also able to kill mongoose, which have also been known to skew rat-tracking data. Additional traps may be installed around the unit for more complete small vertebrate control. The Huliwai traps may be discontinued upon the completion of the research project employing them currently. The Ekahanui traps may be incorporated into the small vertebrate control regime for *C. ibidis* in that MU.

Game birds are also a potential threat to managed rare plant taxa. *L. leucamelanos* have been documented breaking the stems of *D. waianaensis* by while feeding on fruit and *P. erckelii* are suspected in disturbing plantings of other species while dust bathing. Any damage potentially caused by game birds will be noted during monitoring or in the course of normal fieldwork. There have also been anecdotal observations of game birds eating Ferroxx AQ and Sluggo immediately after application in SLCAs. No game bird control is currently employed but damage to managed taxa should be noted and may raise the need for control.

Small Vertebrate Control/Tracking Map

Image Redacted
Sensitive Information
Available Upon Request

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Steve Allan SA2 Trap in Huliwai

NZ Auto Trap AT-220 in Ekahanui

Image Redacted
Sensitive Information
Available Upon Request

Timms Trap in Ekahanui

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 *C. grimesiana* subsp. *obatae*, *D. waianaeensis,* and *S. kaalae*.
- Conduct annual census monitoring of rare plant taxa to look for seedling recruitment and slug herbivory. Note any slug herbivory to managed taxa observed in the course of other actions in the SLCA.
- Avoid potential impacts to rare snails.

Strategy and Control Methods:

- Define Slug Control Areas (SLCAs) around rare plant locations. Prior to any control, complete the Pre-Application Survey Protocol; see below. A buffer of at least 5 meters from vulnerable plants is recommended. 10 meters is optimal.
- Calculate amount of Ferroxx needed to treat SLCA. Orient staff to SLCA and train applicators.
- Apply Ferroxx at interval determined by forest type (dry,mesic,wet), seasonality of slugs at site, risk to rare taxa, accessibility. Highest frequency is every 6 weeks, however, this may be lengthened based on the factors listed.
- If rare snails are found in an established SLCA, treatment will be halted. Rare snails will be relocated to the MU snail enclosure, and the Pre-Application Survey Protocol will resume.

Slug Control Area Locations Table

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

Discussion:

Slug control in Ekahanui began in early 2011 after it was determined that slugs can cause dramatic declines in the survival of rare native Hawaiian plants (Joe & Daehler 2008). Control of slugs using the organic molluscicide Sluggo® (trademark omitted from the rest of this document) (Neudorff, Germany) was shown to encourage seedling germination and recruitment of certain rare plant species (Kawelo *et al*. 2012) in particular those within the Campanulaceae and Caryophyllaceae. In 2017, Sluggo was replaced by Ferroxx AQ® (trademark omitted from the rest of this document), a longer lasting bait with the same active ingredient. Since alien invertebrate control is ongoing in known former habitat of *A. mustelina,* rare snails encountered in SLCAs during the course of regular fieldwork will cause the application to be suspended and trigger resurvey protocol of the area of the find as noted above.

Two sites in Ekahanui-03 and 06 with rare plant reintroductions susceptible to slug damage are candidate sites for Ferroxx AQ application. The *P. mollis* reintroduction in Ekahanui-03 had Sluggo application halted due to poor survivorship, but there has been consistent recruitment from the seedbank. Palai Gulch in Ekahanui-06 is home to a *S. kaalae* reintroduction (EKA-E) that has had recruitment without slug control and could benefit from application.

At the time of the update to this MU plan, five *A. mustelina* have been found within the EKA-A-1 SLCA. One was discovered during rare plant monitoring and triggered a halt to Ferrox AQ application within 20 meters of the find. A subsequent day survey found an additional five *A. mustelina* in the immediate vicinity of the previous find. Of the five snails found, three were relocated to the Palikea North snail enclosure while the other two were out of reach for removal. A night survey is scheduled and surveys will continue until zero are found during at least one survey per survey protocol.

Slug Control Area Map

Image Redacted
Sensitive Information
Available Upon Request

Pre-Application Survey Protocol:

For control only of slugs and non-native snails via listed, approved molluscicide application in forests, on offshore islands, and in other natural areas to protect threatened and endangered Hawaiian plants. Only Ferroxx AQ® Slug and Snail Bait is approved for use in forest areas in Hawaii. Area must be thoroughly searched by experienced malacologists prior to application of Ferroxx AQ® granules to ensure that non-target native Hawaiian snail species are not impacted. Do not apply in areas where it may come into contact with known populations of endemic Hawaiian snail species from the following rare families or subfamilies: Amastridae, Achatinellinae and Endodontidae. Bait cannot be applied within 20 m of any tree known to harbor endangered Hawaiian tree snails (*Achatinella* spp.).

1. Conduct thorough day survey of proposed treatment area to include searching trees and all understory vegetation. The ground and rock talus areas will also be search. An effort to identify other snails found and their rarity will be made prior to Ferroxx use.
2. If proposed treatment area is known *Achatinella* spp. site or if *Achatinella* spp. is observed during day survey, then must conduct night survey and remove all *Achatinella* spp. to a snail enclosure/protected area prior to bait use.
3. Area will continue to be surveyed and *Achatinella* spp. translocated to enclosures until all *Achatinella* spp. are removed from the area and at least one survey is conducted where 0 snails are found within area.
4. If *Achatinella* spp. are abundant in large numbers or are found on multiple trips, use of Ferroxx will not be allowed in area.
5. If *Achatinella* spp. are located in the area in the course of other field work, then surveys and relocation efforts will resume.
6. An effort to identify other snails found and determine their rarity will be made prior to Ferroxx use.

Ant Control

Species: *Solenopsis papuana*

Threat Level: Low

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

Management Objectives:

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

Strategy and Control Methods:

- Sample ants at human entry points using the standard survey protocol (Plentovich and Krushelnycky 2009) and *Drosophila* sites once a year. Use samples to track changes in existing ant densities and to alert ANRPO 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 conservation management 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	Low risk of accidental ant introduction, possible *D. montgomeryi* release site.
Palai Gulch (proposed)	Low risk of accidental ant introduction, possible *D. montgomeryi* release site. No current monitoring.

Discussion:

Ants have been documented to pose threats to a variety of resources, including native arthropods, native insects (*D. montgomeryi*), 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, ants are sampled in high-risk areas using the following method:

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

Standardized surveys have been conducted annually at the 2D reintroduction site listed in the table above. 2D has become a Manage For Stability (MFS) site for *D. montgomeryi* pending release of flies by the DOFAW insectary due to the concentration of host plants (*Urera* sp.) within the site. Surveys will be implemented in Palai Gulch if it is also deemed suitable by DOFAW insectary staff for additional *D. montgomeryi* releases. If surveys reveal the presence of ant species known to be a threat to *D. montgomeryi,* control will be implemented.

Ant Management Map

Image Redacted
Sensitive Information
Available Upon Request

Predatory Snail Control

Species: *Euglandina rosea* (rosy wolf snail), *Oxychilus alliarus* (garlic snail)

Threat level: High

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

Management Objectives:

- Maintain an offsite population of Ekahanui ESU snails at the Palikea MU.
- For management of Ekahanui ESU snails, see Palikea MU plan.

Discussion:

E. rosea and *O. alliarus* have been present in this Management Unit for some time; predation by *E. rosea* in this MU has caused a precipitous decline in *A. mustelina*. No baits have been developed for the control of *E. rosea*. While most remaining *A. mustelina* from Ekahanui have been translocated to the Palikea North exclosure some may remain. *E. rosea* encountered in the course of regular field work in known *A. mustelina* areas should be mapped and controlled, no other predatory snail efforts will be scheduled.

Jackson's Chameleon Control

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

Threat Level: High (for *Achatinella*)

Seasonality/Relevant Species Biology: Unknown

Management Objectives:

- No current survey actions scheduled for Jackson's chameleons.
- Map and remove any chameleons during the course of normal fieldwork.

Strategy and Control Methods:

- While surveying for native snails or conducting any other field work in the MU, note, GPS and remove any chameleons

Discussion: Any chameleons found in the MU will be mapped and removed from the field. While ANRPO no longer actively manages rare snails in Ekahanui, A. *mustelina* are still occasionally encountered. Since most *A. mustelina* from Ekahanui have been translocated to the Palikea North enclosure, search protocols for chameleons have been suspended in Ekahanui MU.

Coconut Rhinoceros Beetle

Species: *Oryctes rhinoceros*

Threat Level: Unknown

Seasonality/Relevant Species Biology: Unknown

Management Objectives:

- Survey for presence within MU.

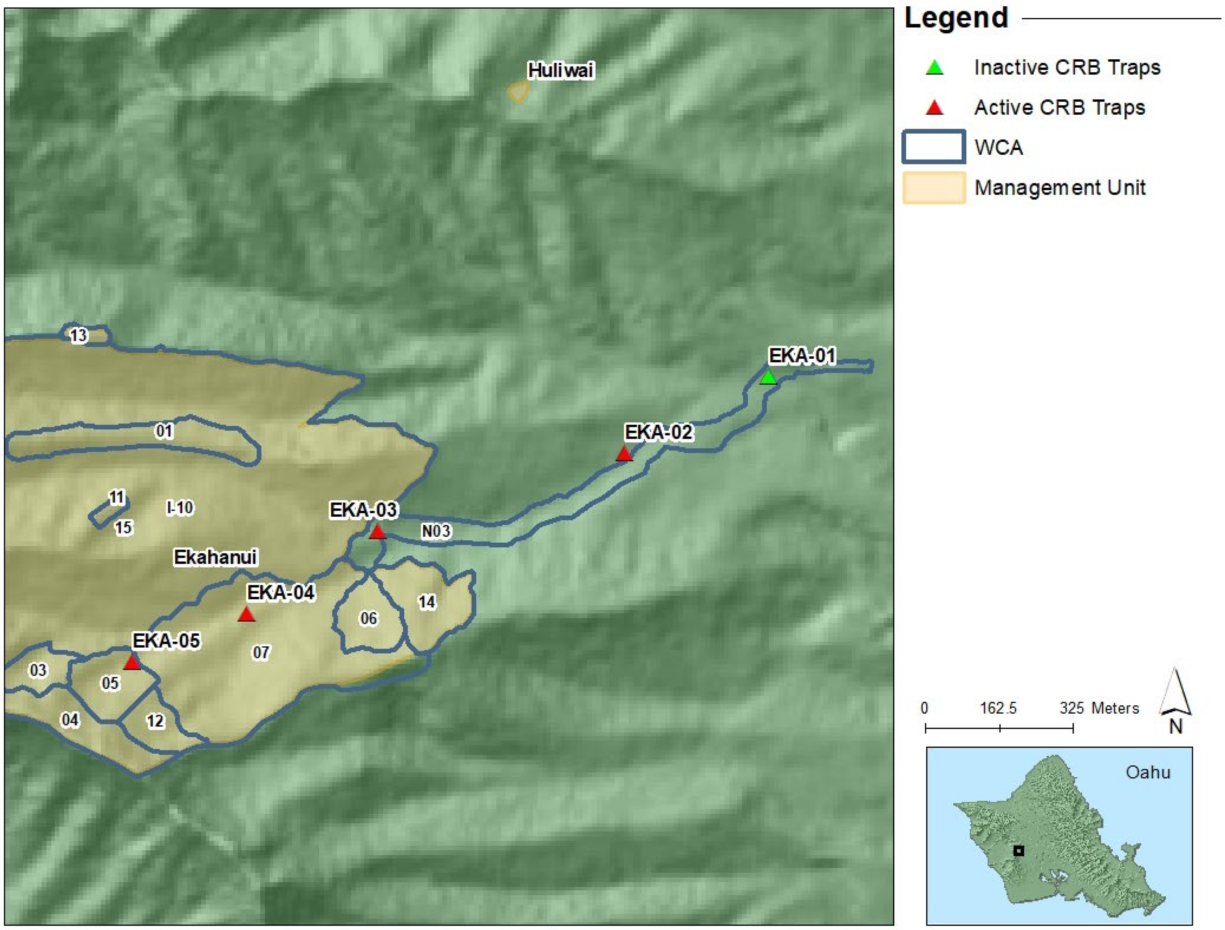
Strategy and Control Methods:

- Deploy panel traps with solar lights and pheromone lure along access trail and into MU.
- Change/monitor lure at six-week interval (note observations at scheduled trap monitoring and in the course of other visits to MU).

Discussion:

O. rhinoceros are known to be well established in numerous sites on Oahu, including the Kunia Loa Farm Lots. Ekahanui does not contain managed taxa known to be effected by CRB but monitoring has been established to determine their expansion into the MU.

Ekahanui CRB Traps Map



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 patterns. *Megathrysus 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 from Kunia Road.

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:

- Communications through fire meetings between landowners and local agencies to, access to forest reserve areas and water sources.
- A plan for coordination of chain of command between Hawaii Fire Department and Federal Fire Department, and other ground crews involved.

- Army biologist 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. Honouliuli contour trail serves both as an access trail and as a fuel break.
- 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.

Discussion:

In 2016, a fire burned inside the Forest Reserve boundary through moist, heavy fuels mostly dominated by iron wood trees (*Causarina* sp.), with some *Grevillea robusta, Acacia confusa, Schinus terebinthifolius,* and *Fraxinus uhdei* (see Fire Management Map). 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 ignition is believed to have been caused by a campfire near the contour trail, which was not sufficiently extinguished.

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

In 2005, a fire on two ridges South of Ekahanui (see Figure1) burned 170 acres, five of which were in the Honouliuli Forest Reserve. This fire started in the pineapple fields burning heavy fuels dominated by *M. maxima* grass, with some *Grevillea robusta, Acacia confusa,* and *S. 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 the Oahu *C. ibidis* nesting habitat territories.

Historically, numerous fires were ignited and burned along Kunia rd. Though Ekahanui MU is ~2.5 km from Kunia road, ongoing development in Kunia Loa Farm Lots adds many potential ignition points much nearer to the Honouliuli Forest Reserve. Further development of the Kunia Loa area will create a buffer from any roadside fires but may also create many new ignition sources from the farm lots themselves. The network of roads created within the Kunia Loa development has also created greater accessibility for City and County fire crews to access potential fires before they pose a threat to the Ekahanui and Huliwai Management Units.

Most of Ekahanui's rare and endangered taxa are in non-fire threatened areas. They persist in areas that are higher in elevation where the moisture regime is more wet-mesic than dry-mesic as in the lower elevations. 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.

Should a fire enter the Priority Response Zone and threaten these Resources, DOFAW wildlands fire response staff will be deployed supported by HFD. ANRPO staff familiar with the resource locations to will assist in coordinating efforts and not direct fire suppression response.

Ekahanui Fire Management Map

Image Redacted
Sensitive Information
Available Upon Request

Literature Cited

ANRPO. 2009. MU Vegetation Monitoring *in* Chapter 1.4.1 Ekahanui Ecosystem Restoration Management Plan *in* 2009 Status Report for the Makua and Oahu Implementation Plans.

ANRPO. 2019. Appendix 3-10 Ekahanui Management Unit Vegetation Monitoring, 2018 *in* 2019 Status Report for the Makua and Oahu Implementation Plans.

Ecosystem Restoration Management Plan

MIP Year 19-23, Oct. 2022– Sept. 2027

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

<u>Location</u>: Westernmost tip of Oahu, at Northern base of Waianae Mountains

<u>Land Owner</u>: State of Hawaii

<u>Land Managers</u>: Department of Land and Natural Resources (DLNR) - Natural Area Reserve System (NARS), DLNR – Land Division, DLNR – Division of State Parks.

<u>Acreage</u>: 29.9 acres

<u>Elevation Range</u>: Sea level to 894 ft.

<u>Description</u>: 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 ANRPO, and contains areas of native dominant dry coastal strand and shrubland. The Kaena East of Alau MU is located on a State Parks parcel managed by DLNR Land Division and receives a minimal amount of management by ANRPO 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

Waianae Vegetation Types	
Dry Costal	<u>Canopy includes</u>: *Myoporum sandwicense*, *Psydrax odorata*, <u>*Gossypium*</u> <u>*tomentosum*</u> <u>Understory includes</u>: *Eragrostis variabilis*, *Chenopodium oahuense*, *Sida fallax*, *Euphorbia degeneri*, *Jacquemontia ovalifolia*, *Wollastonia integrifolia*, *Lipochaeta lobata* subsp. *lobata*, *Plumbago zeylanica*, *Coleus australis*
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

Image Redacted
Sensitive Information
Available Upon Request

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**
Bird	*Asio flammeus sandwichensis*	Endangered
Bird	*Phoebastria immutablis*	Near Threatened
Bird	*Phoebastria nigripes*	Near Threatened
Insect	*Hylaeus longiceps*	Endangered
Mammal	*Neomonachus schauinslandi*	Endangered
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

Image Redacted
Sensitive Information
Available Upon Request

MU Threats to MIP/OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2022
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 or as needed at Kaena.
Ungulates	None	No Control	Ungulate sign has never been observed by ANRPO staff since management began. There are no fencing plans for either MU, besides the predator fence already installed by the State in Kaena MU.
Rodents	None	No Control	Potential rodent damage has been observed on *E. celastroides* var. *kaenana* at East of Alau; no plans for control.
Ants	*E. celastroides* var. *kaenana*	No Control	Ants have been surveyed and determined not to pose a significant threat, however staff will continue to observe whether or not ants have heavy activity on *E. celastroides* var. *kaenana* flowers. Risk of incipient ant species being introduced in this hot, dry climate and low elevation is very low.

Management History

- 2001: ANRPO staff begins weed control efforts within NAR targeting *Leucaena leucocephala, A. semibaccata*, and grass species around known *E. celastroides* var. *kaenana*.
- 2004: ANRPO staff begins weed control efforts at Kaena East of Alau MU targeting *L. leucocephala, A. 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 *E. celastroides* var. *kaenana* plants found by ANRPO 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 ANRPO.
- 2009 July: A wildland fire burned within 95 m of the Kaena East of Alau population. ANRPO 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 population 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 controlling rats, cats, mongoose, and mice around a portion of the NAR (which includes a subset of the *E. celastroides* var. *kaenana* population).
- 2011 July: ANRPO + Youth Conservation Corps weeded *Vachellia farnesiana* and *Leucaena leucocephala* in a special fuel reduction effort to create a buffer for the wild *E. celastroides* var. *kaenana* patch at Kaena East of Alau.
- 2015 September: ANRPO conducts a complete census of *E. celastroides* var. *kaenana* and maps the extent of all known populations.
- 2016: ANRPO Orange team takes over management from the Blue team.
- 2019: Possible rat damage observed on some plants at EupCelKae.KAE-A population.
- 2020: Borer damage observed on some plants at EupCelKae.KAE-A population not present from previous monitoring.
- 2021: Only one live, healthy plant observed during full census monitoring at EupCelKae.KAE-A population (East of Alau).

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 recent complete census of the *E. celastroides* var. *kaenana* population within the Kaena MU was conducted, it was determined that vegetation monitoring methods at Kaena in association with management of *E. celastroides* var. *kaenana* should be reconsidered. Vegetation communities have been monitored using annual photopoints and field observations. These existing ground-based photopoints do show some change in vegetative community over time, but are not easy to analyze and do not provide a comprehensive view of the habitat or *E. celastroides* var. *kaenana.* In 2022, staff decided to consider the possibility of Unmanned Aerial Vehicle (UAV) monitoring in place of photopoints. ANRPO is proposing to trial UAV flights at Kaena Point NAR to explore the potential application for UAV monitoring of *Euphorbia celastroides* var. *kaenana* and the associated vegetation within that population (KAE-B). The benefits of utilizing a UAV as an alternative to ground-based monitoring would be to mitigate potential damage to *E. celastroides* var. *kaenana* and other native vegetation resulting from trampling while walking through the population, and to improve the efficiency of the monitoring process by getting an overhead view of the area. Photopoint markers in this MU are difficult to find due to their low profile (this is intentional, to avoid drawing attention in such a public area), and efforts to find them result in additional trampling. From this trial, staff will assess the feasibility of flying a UAV in typical windy conditions at Kaena and evaluate the clarity of the imagery obtained from varying altitudes for identifying *E. celastroides* var. *kaenana* and the surrounding vegetation. Flights will not occur, or will be aborted, if sea birds are observed flying within close proximity. Flights will include pre-planned flight paths, as well as manually driven paths. The area covered will be limited to the existing *E. celastroides* var. *kaenana* population outside of the fence. After this trial, staff will reassess and solidify the plans for future vegetation monitoring in the MU. If the UAV monitoring does not prove to be a viable option, another possible route would be to modify existing photopoint locations and frequency to streamline the process.

Surveys

Potential Vectors: ANRPO 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 (RS-Kaena-01) is conducted on the dirt road starting at the terminus of Farrington Highway and ending at the rock wall barricade. There are no surveys done within the MU. Due to Kaena's small size, incidental observations during regular field management should suffice.

Survey Locations and Weed Control Areas Map

Image Redacted
Sensitive Information
Available Upon Request

Incipient Taxa Control (ICAs)

Evaluate any invasive plant species newly discovered in MU, and determine whether ICA-level control is warranted. Factors to consider include distribution, invasiveness, location, habitat, infestation size, availability of control methods, resources, and funding. For example, Kaena would be a great habitat for invasive species like *Cenchrus setaceus* and *Chromolaena odorata* to proliferate, and it is a highly trafficked public area.

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.

No incipient species have been identified by ANRPO in the MU, and therefore there are currently no ICAs. ANRPO will continue to monitor and consider control on possible target taxa when appropriate.

Incidental observation of incipient or novel alien taxa during field work is important in this MU, as invasion from high-risk incipients is higher due to high public use (fishing, hiking, etc.) and 4-wheel drive vehicles along the access road.

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: ANRPO 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. ANRPO will continue to work to remove all mature *Vachellia farnesiana* and *Leucaena leucocephala* within WCAs to ensure these species do not become the dominant taxa that impact *E. celastroides* var. *kaenana*. Return visits will be scheduled in order to prevent immature individuals from reaching maturity. 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. 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. Common native restoration efforts will not be a priority in this Management Unit.

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
Vachellia 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. ANRPO 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. ANRPO 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. Staff will continue to monitor the extent and perform control as

Taxa	Distribution	Notes
		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 ANRPO within WCAs.
Leucaena leucocephala	Widespread	The majority of ANRPO 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, clip and drip with Triclopyr 40%, or IPA using Aminopyralid.
Megathyrsus maximus	Scattered	Mostly found around the perimeter of MUs. ANRPO will target for removal within WCAs. Priority for removal due to fire threat.
Passiflora edulis	Scattered	Common along access road. Will monitor within WCAs and perform control as necessary.
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.

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 Kaena. However, restoration activities are not a priority at this MU in the next five years.

Taxa considerations for Restoration

Native Taxon	Growth Habit	Outplant/SDT	Notes
Capparis sandwichiana	Shrub	Outplant	No propagation notes. Collect seed.
Dodonaea viscosa	Shrub	Outplant/Seedsow	Grow from seed. Fast growing shrub/small tree.
Eragrostis variabilis	Grass	Outplant	Grow from seed. Good groundcover until larger canopy species can establish.
Erythrina sandwicensis	Tree	Outplant	Grow from seed. Drought/full sun tolerant.
Heteropogon contortus	Grass	Outplant	Grow from seed. Drought/full sun tolerant. Need collections.
Heliotropium anomalum var. *argenteum*	Herb	Outplant	Grow from seed if possible. Cuttings get leggy quickly. Need seed collections.
Jacquemontia sandwicensis	Vine	Outplant	Grow from seed if possible. Need seed collections.
Myoporum sandwicense	Shrub	Outplant	Can grow from seed, but Naio thrips present challenge.
Panicum torridum	Grass	Outplant	Grow from seed. Need collections.
Psydrax odorata	Tree	Outplant	Need to grab snatchlings if desired. Slow growing but hardy. Fruit often bored.
Santalum ellipticum	Shrub	Outplant	Grow from seed. Companion plant in container.
Scaevola taccada	Shrub	Outplant	Grow from seed if possible. Need seed collections.
Sida fallax	Herb	Outplant/Seedsow	Grow from seed. Sporadic germination.
Vitex rotundifolia	Herb	Outplant	Grow from seed if possible. Need seed collections.

Native Taxon	Growth Habit	Outplant/SDT	Notes
Waltheria indica	Herb	Outplant/Seedsow	Grow from seed. Need seed collections. Candidate for seed orchard.
Wollastonia integrifolia	Herb	Outplant	Grow from seed if possible. Need seed collections.

WCAs: Kaena-01

Veg Type: Dry Coastal

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

Targets: All woody alien species, particularly *V. 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 *M. maximus* 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 *V. farnesiana* and *L. leucocephela* within this WCA has succeeded in drastically diminishing their extent in the rare plant patches. 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 gradually connect the *E. celastroides* var. *kaenana* patches.

Although common along the access road, there is zero tolerance for *C. echinatus* and *A. aspera* var. *aspera* within the WCAs. *D. insularis* and *M. maximus* are targeted along the upper portion of WCA to aid fire suppression. ANRPO 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. ANRPO will continue to monitor and control *C. barbata* as necessary.

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

Common native plant reintroductions of *M. sandwicense* and *E. variabilis* were conducted in 2008 to aid in weedy grass control, habitat restoration, and fire prevention. *Eragrostis variabilis* was specifically planted in an experimental effort to replace zones where *A. semibaccata* and *C. barbata* were targeted during weed control. No formal monitoring was conducted to track the success or survivorship of these common native reintroductions. No other outplanting or restoration efforts have been conducted by ANRPO since, but outplanting of common native reintroductions to connect zones between *E. celastroides* var. *kaenana* will be considered in the future.

WCA: Kaena-02

Veg Type: Dry Coastal

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

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

Notes: This WCA is located within the predator-proof fence. ANRPO control efforts in Kaena-02 began in 2010. This WCA is enclosed by the predator control 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 *V. farnesiana* and *L. leucocephala* and grasses.

Notes: This WCA will be discontinued when the Kaena East of Alau *E. celastroides* var. *kaenana* Population Unit is discontinued. ANRPO control efforts began in 2004 at the Kaena East of Alau MU. Minimal weed control effort was needed because *E. celastroides* var. *kaenana* plants are found on rock talus with few weeds directly surrounding them. A small weed-free buffer was maintained around this talus slope to reduce any impacts to the *E. celastroides* var. *kaenana*, and to encourage recruitment. ANRPO has reduced fire fuel loads east of the patch by clearing a large stand of Kiawe (*P. pallida).* In 2021, only one plant within the EupCelKae.KAE-A was observed alive during a population census, therefore, management within this WCA and MU will be discontinued pending a final decision from the IT on whether to drop this PU as Manage for Stability for *E. celastroides* var. *kaenana*. Management will now focus in Kaena-01 and Kaena-02 at the healthy EupCelKae.KAE-B population.

Small Vertebrate Control

Species: *Rattus rattus* (Black rat), *Rattus exulans* (Polynesian rat), *Mus musculus* (House mouse), small Indian mongoose (*Herpestes auropunctatus*).

Threat Level: High for *Rattus spp*. on *E. celastroide*s var. *kaenana*. Unknown for *M. musculus*

Seasonality/Relevant Species Biology: Rats may cue in to different foods at different times of the year, and sometimes exclusively target certain food sources. Lack of water and seasonal drought may cause small vertebrates to predate on native plants for hydration.

Management Objectives:

- Monitor rare taxa populations for rat damage; promptly initiate control if damage is noted.

Strategy and Control Methods:

- Monitor rare plant (*E. celastroides* var. *kaenana*) populations, as well as other native species to determine impacts by rodents.
- If rat damage is detected on *E. celastroides* var. *kaenana*, deploy localized A-24 grid. Service traps every six months.

Discussion:

Currently no rodent control is conducted by ANRPO at Kaena. Potential rat or mouse damage was observed on *E. celastroides* var. *kaenana* in Kaena East of Alau during a population census monitoring in 2020, however there have been no other observations. Staff will look carefully for rat damage in the EupCelKae.KAE-B population during rare plant monitoring, and threat control will be considered if observed.

Ant Control

Species: *Anoplolepis gracilipes, Paratrechina longicornis, Solenopsis papuana, Tetramorium simillimum, Ochetellus glaber*

Threat Level: Unknown.

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 biennial 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 *E. celastroides* var. *kaenana* 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 (ANRPO 2010) and *E. celastroides* var. *kaenana* sites a once every a year (see table below). Use samples to track changes in existing ant densities and to alert ANRPO to any new introductions.
- If incipient species (particularly *Wasmannia auropunctata*) are found and deemed to be a high threat and/or easily eradicated locally (<0.5 acre infestation), begin control.
- Sample ants at rare taxa sites to track changes in existing ant densities and to alert ANRPO to any new introductions.
- Look for evidence of ant tending of aphids or scales on rare plants during annual rare plant monitoring.
- Look for evidence of ants impacting flowers or pollination of *E. celastroides* var. *kaenana*.

Ant Survey Site Table

Site description	Reason for survey
EupCelKae.KAE-B population	High risk of accidental ant introduction

Discussion:

Ants have been documented to pose threats to a variety of resources, including native arthropods, plants (via farming of Hemipterian pests), and birds. They may be limiting other native pollinators from visiting or limiting nectar resource availability. Staff should look for this type of activity during rare plant monitoring. It is therefore important to know their distribution and density in areas with conservation value. Since 2006, OANRP samples ants in high risk areas using the following method:

Vials are baited with SPAM, peanut butter and honey. Caps are removed and vials are spaced 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.

Ants had previously been sampled at the wild EupCelKae.KAE-A population, however, due to drastic decline in population, sampling will only take place at EupCel.KAE-B beginning in 2022. Ant sampling at Kaena to date has not identified any major problematic species.

Fire Control

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:

- 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.

Historic Fires near Kaena East of Alau MU

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Discussion:

ANRPO efforts have focused on preventative fire measures, notably weed control within the MUs. Removal of the most fire prone weeds (*V. farnesiana, L. leucocephela* and *M. maximus*) 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, more human traffic, and closer proximity of vehicles. In the past, ANRPO aimed to maintain a 50 m fuel break in order to reduce fuel loads surrounding the East of Alau EupCelKae.KAE-A population, but due to population decline, this effort will not be continued. See the Weed Control section for further details.

In recent years, the State has made a concerted effort to manage vehicular traffic at Kaena, which has resulted in less potential for intentional or unintentional arson. State Parks has also stationed a Kaena Point State Park Interpretive Technician in the area to monitor activity. ANRPO will focus on maintaining good communication with this designated technician, as well as 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

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

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

Ecosystem Restoration Management Plan

MIP Year 19-23, Oct. 2022 – Sept. 2027

OIP Year 16-20, Oct. 2022 – Sept. 2027

MU: Kaluakauila

Overall MIP Management Goals:

- Form a stable, native-dominated matrix of plant communities which support stable populations of IP taxa.
- Control ungulate, rodent, invertebrate, 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: Army Natural Resources Program on Oahu, Division of Forestry and Wildlife

Acreage: 110 acres

Elevation Range: 800-1750 feet

Description: This Management Unit (MU) spans 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 *H. 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 *Megathyrsus maximus*. Not much management is being done in this area, although a historical *Hibiscus brackenridgei* subsp. *mokuleianus* genetic storage reintroduction population exists.
In the gulches and on the 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 main Kaluakauila dry forest patches, called the "Upper Patch" and the "Lower Patch". These two areas are the main focus of management efforts in the MU, with the majority of current weed control and restoration efforts occurring in the Upper Patch. The Upper Patch contains the majority of IP taxa in the MU. Non-native grasses (mostly *M. maximus*) 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 is disappearing across Hawaii. 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

Waianae Vegetation Types	
Lowland Dry Shrubland/ Grassland	Canopy includes: *Diospyros spp*., *Dodonaea viscosa*, *Erythrina sandwicensis*, *Hibiscus arnottianus*, *Hibiscus brackenridgei* subsp. *mokuleianus*, *Myoporum sandwicense*, *Myrsine lanaiensis*, *Planchonella sandwicensis*, *Psydrax odorata*, *Santalum ellipticum*, *Sapindus oahuensis* Understory includes: *Abutilon incanum*, *Bidens* spp., *Carex meyenii*, *Carex wahuensis*, *Eragrostis variabilis*, *Heteropogon contortus*, *Leptecophylla tameiameiae*, *Microlepia strigosa*, *Osteomeles anthyllidifolia*, *Sida fallax*, *Waltheria indica*
Dry forest	Canopy includes: *Bobea elatior*, *Diospyros* spp., *E. sandwicensis*, *H. arnottianus*, *M. lanaiensis*, *M. sandwicense, Nestegis sandwicensis*, *P. odorata*, *Rauvolfia sandwicensis*, *Polyscias sandwicensis*, *S. ellipticum*, Understory includes: *Dodonaea viscosa*, *S. fallax*, *Bidens* spp.
NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted.	

Terrain and Vegetation Types at 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)	*Alectryon macrococcus* var. *macrococcus*	MMR-K*	MFS	Wild
Plant (MIP)	*Neraudia angulata*	MMR- F, G, H*	MFS	Reintroduction
Plant (MIP)	*Nototrichium humile*	MMR- A, J, L*, M*, N*	MFS	Wild
Plant (MIP)	*Wollastonia tenuifolia*	MMR-F	MFS	Wild
Plant (OIP)	*Abutilon sandwicense*	MMR-B MMR-C	GSC	Reintroduction
Plant (MIP)	*Delissea waianaeensis*	MMR-D	GSC	Reintroduction
Plant (MIP)	*Euphorbia celastroides* var. *kaenana*	MMR-B	GSC	Wild
Plant (MIP)	*Hibiscus brackenridgei* subsp. *mokuleianus*	MMR- C, D, E*	NM	Reintroduction

MFS= Manage for Stability *= Population Dead
GSC= Genetic Storage Collection
NM= No management

Other Rare Taxa at Kaluakauila

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

*population extirpated

Rare Resources at Kaluakauila

Hibiscus brackenridgei subsp. *mokuleianus*

Euphorbia haeleeleana

Wollastonia tenuifolia

Neraudia angulata

Locations of Rare Resources at Kaluakauila

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Threats to MIP/OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2022
Pigs	All	Across MU	No animals within fence
Weeds	All	Rare taxa sites primarily, across MU secondarily	Regular maintenance required several times per year
Rodents	*A. sandwicense, D. waianaeensis, N. angulata*	In the Upper Patch around *N. angulata* and *E. haeleeleana* populations, and eventually in the Lower Patch if resources are available	State has deployed 35 A24 traps that they will be maintaining and refilling in May 2022. Expansion and maintenance of this grid by ANRPO will begin once more inventory is available.
Slugs	*Delissea waianaeensis, N. angulata, Hibiscus brackenridgei*	Affected rare taxa sites only	Slugs generally sparse in this area due to dry conditions.
Ant	*Neraudia angulata*	No control	Surveys conducted before sling load operations or as needed
Black Twig Borer	*A. sandwicense, N. angulata*	No control	No control methods are known
Fire	All	Across MU, with targeted efforts along fencelines and around rare taxa sites	Regular grass 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 native forest patches.
- 1998: Elepaio observed in the Upper Patch.
- 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: Two *B. sandwicensis* with burn damage, fire within 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: Fire burns Makua after white phosphorous ordnance ignites, escaping from fire break road
- 2006: Arson fire from Yokohama Bay side 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.
- 2007-2014: Slug, ant and arthropod surveys conducted. Low slug numbers 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: ANRPO staff are prohibited from entering Makua Military Reservation due to issues concerning UXO.
- 2016: Rat control resumed by the State (DOFAW) around wild *E. haeleeleana* populations in the Upper and Lower patches.
- 2017: The first Common native reintroduction is established in Kaluakauila near the Upper Patch water catchment and includes about 100 *D. viscosa*, 52 *E. sandwicensis*, and 25 *M. sandwicense*.
- 2017: *Syzygium jambos* ICA (MMR-SyzJam-01) eradicated on 02/09/2017.
- 2018: *Cirsium vulgare* ICA (MMR-CirVul-02) eradicated on 08/08/2018.
- 2019: Common native reintroduction by shady East side of NerAng.MMR-F includes 71 *C. wahuensis*, 56 *D. viscosa*, and 75 *Plumbago zeylanica*.

- 2019: Common native reintroduction by sunny West side of NerAng.MMR-F includes 21 *C. wahuensis*, 3 *O. anthyllidifolia*, 56 *D. viscosa*, and 76 *P. zeylanica*.
- 2021: Common native reintroduction directly below Upper Patch water catchment includes 186 *C. oahuensis*, 43 *O. anthyllidifolia*, and 85 *D. viscosa*. 29 *P. zeylanica*, 13 *D. sandwichensis*, and 22 *H. arnottianus* are planted by NerAng.MMR-F population West of the trail down. Reintroduction of 100 *E. sandwicensis*, 64 *M. strigosa*, 49 *D. viscosa*, and 9 *O. anthyllidifolia* near Upper Patch water catchment above *D. sandwicensis* belt.
- 2021: Readiness and Environmental Protection Integration (REPI) funds granted to DOFAW for fire prevention efforts at Makua Military Reservation.
- 2021: New sighting of *Anredera cordifolia* in the Lower Patch, an ICA is created.
- 2022: Augmentation of NerAng.MMR-F population with 37 additional plants.
- 2022: Plant Extinction Prevention Program (PEPP) plans to maintain 35 traps that have been left on site since 2020. ANRPO plans to expand upon that rodent control with the installation of additional traps around *E. haeleeleana* populations in the Upper Patch.

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 Biologist to implement control.

Ungulate Management Map

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Discussion:

Due to the very large waterfalls along the gulch bottom, a complete fence check requires considerable time and effort. Controlling the *M. maximus* 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 replaced 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 and rusting from winds and corrosion due to the salt air. Portions of this line should be carefully inspected and replaced before failure.

A professional fence contractor will be sought in 2024 to replace and repair large sections of fence both on the crestline as well as gulch section.

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

ANRPO staff plans to conduct point-inercept monitoring every five years in WCA-01 and -02 beginning in Fall 2023. There will be approximately 500 points, with points every 2.5m along east-west transects spaced 50 m apart across the Lower Patch (to capture diversity of topography) and up-down slope in the Upper Patch (for logistical purposes). Cliffs will be skipped. Transects cross through rare plant and restoration areas and will cross through proposed new restoration areas. Transect will not cover areas where no management is planed in the foreseeable future. Transects will be permanently marked at the ends, and flagged every ~10m or so along transects. Points will not be permanent, but transects will be roughly followed. Since the majority of the MU is covered in weeds (*M. maximus*, *L. leucocephala*, etc.) and only a 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. Additionally, the MU is too small for belt plot monitoring. It could also be useful to map grass edges throughout the MU, which could be done with aerial imagery.

Proposed layout for point intercept vegetation monitoring at Kaluakauila WCA-01 and -02

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Surveys

Potential Vectors: NRM Staff 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 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.
- Survey access roads annually if used. This includes RS-Kaluakauila-01 and RS-KUAOKA-01. RS-Kaluakauila-01 begins at the Kaena Point Space Force Satellite Tracking Station access gate on Farrington Highway, continues through the DOFAW Firebreak Road, and ends at a Kaluakauila trailhead. RS-KUAOKA-01, which is surveyed biannually unless used more frequently, begins at the split of Pahole Road and Kuaokala Road and ends at the intersection of the Kaena Point Space Force Satellite Tracking Station road. GPS roads driven to document extent of survey in a given year.

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.

Staff is allowed access to Kaluakauila through the Kaena Point Space Force Satellite Tracking Station with permission from the U.S. Space Force. This access road is mostly paved, up until the point where the DOFAW Firebreak Road begins, and is generally safer and faster to use as opposed to Kuaokala Road. Kuaokala Road is usually only used in instances where staff members have not been granted access by the U.S. Space Force, hence the reduced frequency in required surveying of RS-KUAOKA-01. The parking areas for the Kuaokala Road and the Kaena Point Space Force Satellite Tracking Station access road include three separate trailheads (two on the former and one on the latter), all of which are included in WT-Kaluakauila-01. Staff will only survey sections actually used to access the MU within that given year. Two species that staff should particularly be on the lookout for are *Cenchrus setaceus* and *Chromolaena odorata,* given that there is an infestation of *C. setaceus* across MMR at Ohikilolo and *C. odorata* has been found on Kuaokala road.

In Kaluakauila, LZs are not used often since the MU can be reached easily via the Kaena Point Space Force Satellite Tracking Station access road or Kuaokala Road. However, in times of outplanting, LZs may be used to shuttle staff closer to worksites. Camping also occurs during large outplanting event. Staff has previously camped at campsites within the MU, however, they have not been in use for many years. The campsites used now are close to the road and are used recreationally by the public, therefore, scheduled campsite surveys do not occur.

Weed Transect Survey Locations

Image Redacted
Sensitive Information
Available Upon Request

Road Survey Locations

Image Redacted
Sensitive Information
Available Upon Request

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:

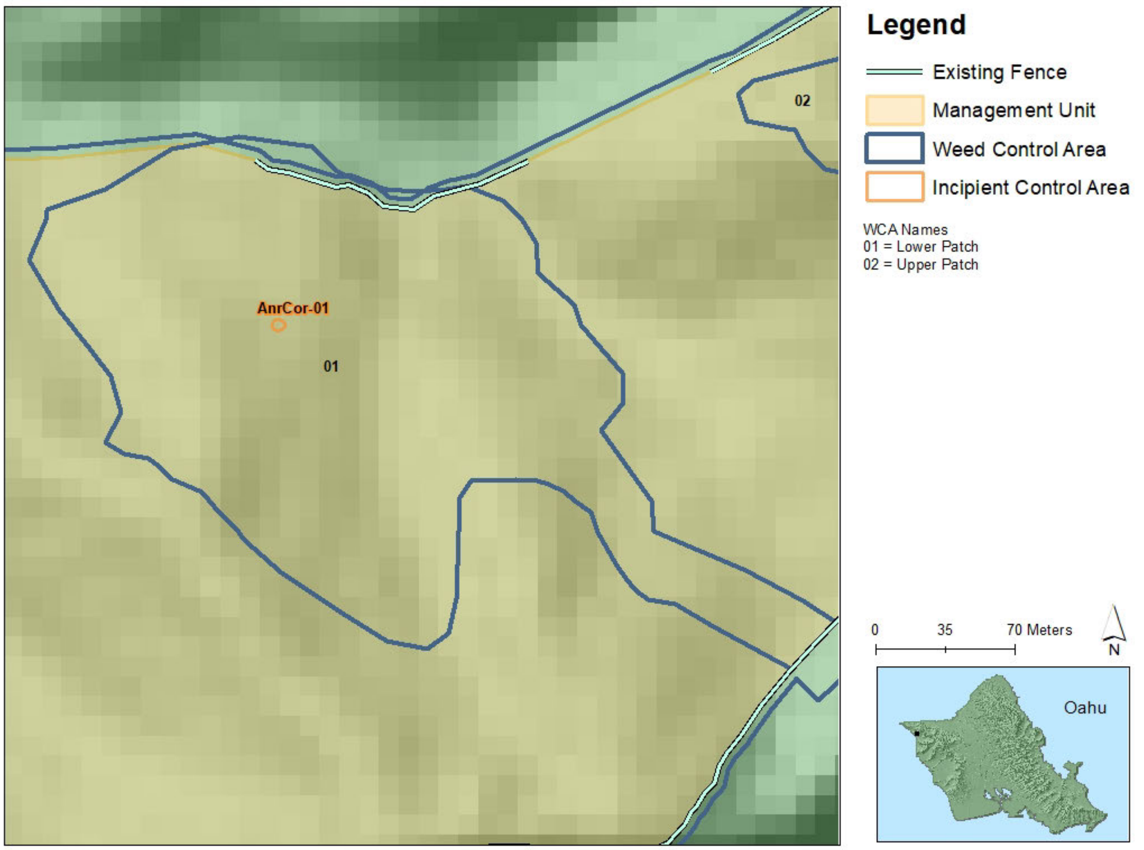
- Eradicate ICAs through regular and thorough monitoring and treatment. In the absence of any information about seed bank longevity for a particular species, eradication is defined as 10 years of consistent monitoring with no target plants found.
- Study seed bank longevity of ICA taxa, and revise eradication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

Incipient Control Area Map



Summary of ICAs

Taxon	ICA Code	Control Discussion
Anredera cordifolia	MMR-AnrCor-01	*Anredera cordifolia* spreads mainly by large numbers of aerial tubers that are produced along the stems. They can also spread by falling off stems high in the canopy and can be transported in waterways. If fragments end up in waterways, they can be easily transported to new locations. It also spreads vegetatively by tuberous roots and creeping rhizomes. This ICA is within the Lower Patch of Kaluakauila. One plant was found within the Upper Patch of the MU in 2005 and has not been seen since. Recently, in 2021, another *A. cordifolia* was found in the Lower Patch, within the *E. haeleeleana* and *Diospyros sandwichensis* band. ANRPO staff has plans to monitor and control *A. cordifolia* within this area. It is highly probable that *A. cordifolia* can be eradicated from this ICA.

<u>ICAs Eradicated at Kaluakauila:</u> *Syzigium jambos* (MMR-Syzjam-01) and *Cirsium vulgare* (MMR-Cirvul-02).

Incipient Weed Photos

Anredera cordifolia left: flowers; right: habit. Photos: Forest & Kim Starr

Weed Control Areas Map

Image Redacted
Sensitive Information
Available Upon Request

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.
- 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 (*M. maximus*) levels low in WCA-01 and WCA-02 and along fenceline.

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 (*M. maximus*) and shrubs (*L. leucocephala*), which readily move in to the patches if not kept in control. Strategies for removal include targeting canopy species (*Grevillea robusta*, *A. moluccana*, *Schinus terebinthifolius*, 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 (*Rivina humilis*, *Blechnum appendiculatum*, *Ageratina riparia*, *Passiflora suberosa*, etc.) are removed selectively, especially around rare taxa. Staff aim not to completely remove herbaceous understory weeds in sensitive, rocky areas directly around rare taxa, particularly where recruitment is occurring. Qualitative assessments on weed abundance have been ongoing by ANRPO staff and weeding occurs as needed.

Common reintroductions will continue to be used to complement weeding efforts. Common native restoration can include seed sowing, divisions, transplanting of seedlings already found in the field, and outplanting of greenhouse grown plants. The first common reintroductions began in November 2017, which included greenhouse-grown cuttings and plants from seed. ANRPO staff are currently experimenting with which species and methods are best for Kaluakauila.

Target canopy sweeps across both WCAs will begin in Fall 2022, occurring twice per year with the goal of covering the entirety of each WCA within a year's time. *Passiflora suberosa* will also be a target during these sweeps, as staff members have observed that abundance of that species has increased steadily over time and threaten rare taxa as well as large stands of *Diospyros* spp.

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.
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.
Chromolaena odorata	Restricted	Absent within the unit, but one individual was found along Kuaokala road in 2021.
Elephantopus mollis	Scattered	A medium sized aster found along the trail from the trailhead to the upper patch crossover. Controlled by means of trail spraying with a glyphosate mixture. Both mature and immature plants have been observed regularly.
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 laurifolia	Scattered	Vines and liannas that can grow up to 10m long. Those found at the trailhead in 2020 are outside of their historical elevational range within the islands.
Passiflora suberosa	Widespread	Widespread throughout the MU, especially in forest patches (Kaluakauila-01 and Kaluakauila-02).Target especially near rare taxa and as it can suffocate natives.
Pinus luchuensis	Scattered	Large trees and recruits scattered throughout the MU and along the fenceline and trail to MU. This has been discussed as a specific target for fire threat.
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. Staff will not target this taxon heavily in grassy zones adjacent to native forest patches.
Syzigium cuminii	Widespread	Large trees, especially in forest patches and ridges. Control near outplantings.
Megathyrsus maximus	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	Growth Habit	Outplant/SDT	Notes
Abutilon incanum	Shrub	Outplant/Seedsow	Grow from seed. Sporadic germination
Bobea elatior	Tree	Outplant	Grow from seed. Slow grower. Need more seed collections.
Carex meyenii	Sedge	Outplant	Grow from seed. Good ground cover in shadier areas.
Carex wahuensis	Sedge	Outplant	Grow from seed. Good ground cover until larger canopy species can establish.

Native Taxon	Growth Habit	Outplant/SDT	Notes
Chenopodium oahuensis	Shrub	Outplant/Seedsow	Grow from seed. Sporadic germination.
Diospyros spp.	Tree	Outplant/Seedsow/ Transplant	Grow from seed. Seed is recalcitrant. Has good recruitment under mother trees. Slow grower. Can try to transplant in other areas.
Dodonaea viscosa	Shrub/Small tree	Outplant	Grow from seed. Fast growing shrub/small tree.
Eragrostis variabilis	Grass	Outplant	Grow from seed. Good groundcover until larger canopy species can establish.
Erythrina sandwicensis	Tree	Outplant	Grow from seed. Drought/full sun tolerant.
Heteropogon contortus	Grass	Outplant	Grow from seed. Drought/full sun tolerant. Need more seed collections.
Hibiscus arnottianus	Tree	Outplant	Grow from seed.
Metrosideros polymorpha var. incana	Shrub/Tree	Outplant	Grow from seed. Need more seed collections.
Microlepia strigosa	Fern	Outplant	Grow from spore. Good groundcover until larger canopy species can establish. Plant in 18" spacing or tighter for weed suppression.
Myoporum sandwicense	Tree	Outplant	Grow from seed, but Naio thrips present challenge
Myrsine lanaiensis	Tree	Outplant	Grow from seed. Need more seed collections.
Osteomeles anthyllidifolia	Shrub	Outplant	Grow from seed. Neeed more seed collections from seed zone.
Pittosporum confertiflorum	Shrub	Outplant	Grow from seed.
Planchonella sandwicensis	Tree	Outplant/Seedsow	Grow from seed. Slow grower.
Plumbago zeylanica	Shrub	Outplant/Seedsow	Grow from seed and cuttings.
Psydrax odorata	Tree	Outplant	Grow from seed. Need to grab snatchlings if desired. Slow growing but hardy. Fruit often bored.
Santalum ellipticum	Shrub	Outplant	Grow from seed. Companion plant in container.
Sapindus oahuensis	Tree	Outplant/Seedsow	Grow from seed. Slow growing but large footprint once established. Seedsows possible especially if cleaned and soaked prior to sow.
Sida fallax	Herb	Outplant/Seedsow	Grow from seed. Sporadic germination.
Sophora chrysophylla	Shrub/Tree	Outplant	Grow from seed.
Waltheria indica	Herb	Outplant/Seedsow	Grow from seed. Need more seed collections. Candidate for seed orchard.

WCA: Kaluakauila-01 (Lower Patch)

<u>Veg Type:</u> Dry forest

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

<u>Targets:</u> All perennial weeds including *S. terebinthifolius*, *Leucaena leucocephala*, *Grevillea robust*a, *M. maximus*, *Melinus minutiflora*, and *R. humilis*.

<u>Notes</u>:

The Lower Patch is dominated at its center by a dense stand of *Diospyros* spp. Large *E. sandwicensis, S. oahuensis,* and *E. haeleeleana* are also significant native components. *Euphorbia haeleeleana* is an

Integrated Natural Resource Management Plan (INRMP) taxon. The new, updated INRMP will likely call for increased management of this taxon, especially on Army lands. Several other rare taxa are present, including *Hibiscus brackenridgei* subsp. *mokuleianus*, *W. tenuifolia* and *N. humile*. A few failed reintroductions are in the Lower Patch and are not a priority to weed around.

Most of the weeding effort has been directed toward the control of *M. maximus* and other grasses in order to reduce fuel loads and increase shrub and canopy tree recruitment. *M. maximus* control should also focus on the cliff area at the bottom of the WCA and to the western makai end to reduce the ability of any fire to move into the core dry forest area. *L. leucocephala* has been significantly reduced in the Lower Patch, although it still recruits readily and control is ongoing. Annual weeds, such as *Mesosphaerum pectinatum*, are largely uncontrollable given their high density during the rainy season. *M. pectinatum* should be pulled or treated only around rare outplantings unless a better control method is found.

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 *S. terebinthifolius*, *L. leucocephala*, *G. robusta*, *M. maximus*, *M. minutiflora*, *Oplismenus hirtellus P. suberosa* and *R. humilis*.

Notes:

Several wild rare taxa are present including *E. haeleeleana* and a large number of *N. humilie*. The Upper Patch is dominated at its center by a dense stand of *Diospyros* spp., large *E. sandwicensis*, *S. oahuensis*, *P. sandwicensis* and *E. haeleeleana* are also significant native components. Several rounds of *N. angulata* reintroductions have occurred in the Upper Patch within two areas, designated as the “Sunny Patch” and the “Shady Patch.” Outplantings have been successful in the “Sunny Patch” with dozens of recruits having been observed. One *D. waianaeensis* remains from an unsuccessful outplanting in the Upper Patch. *Leucaena 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.

Weeding around the *N. angulata* patch within the WCA consists mostly of controlling smaller weeds such as *O. hirtellus*, *A. riparia*, *P. suberosa*, *Youngia japonica*, and *R. humilis.* In past years, 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. Focus in recent years has been on clearing larger areas, including targeted control of *S. terebinthifolius* and *P. cattleianum,* for common native restoration and *N. angulata* site expansion. The goal for restoration in this WCA has been to connect common native outplantings near the Upper Patch water catchment down to the core of the NerAng.MMR-F “Sunny Patch.” Common native restoration site includes the following taxa: *C. oahuensis*, *D. sandwicensis, E. sandwicensis*, *H. arnottianus*, *M. strigosa*, *O. anthyllidifolia*, and *P. zeylanica.* Staff will continue to focus restoration efforts for this MU exclusively within this WCA for the next five years.

WCA: Kaluakauila-03 (Infrastructure)

Veg Type: N/A

MIP Goal: N/A

Targets: Non-native grasses and other fire prone weeds, including *M. maximus* and *Vachellia farnesiana*.

Notes:

This WCA encompasses the entirety of the MU and accounts for all weed control that takes place in order to maintain the fenceline and facilitate fence checks. The main goal of this WCA is to have a proactive effort in reducing fuel loads around the MU in the event that a fire may occur in the area. In addition to keeping fuel loads low, a clear fenceline facilitates fence checks and hiking along the fenceline. As mentioned above in the ungulate management discussion, controlling the *M. maximus* along the westernmost makai fenceline using aerial spraying of glyphosate and a pre-emergent herbicide will be considered in order to make checking that line easier for staff.

WCA: KuaokalaNoMU-02 (Infrastructure/Kaluakauila Trail)

Veg Type: N/A

MIP Goal: N/A

Targets: Non-native grasses and other fire prone weeds, including *M. maximus* and *V. farnesiana*. Trail obscuring weeds such as *S. terebenthifolius*, *Casurina equestifolia, Psidium guajava*, etc. Target taxa that are found along the trail and road including *E. mollis* and *P. laurifolia*.

Notes:

The WCA extends from the main trailheads off both access roads to the trail that leads to the MMR-L fence gate. Actions here include trail grass sprays as well as targeted control of *E. mollis*, *P. laurifolia* and *P. luchuensis*. The main goals of this WCA are to maintain the most efficient path for staff members to get to and from worksites, to reduce the spread of novel weeds by hikers, and to track target taxa when observed outside the MU. Trail sprays and clearing efforst help staff to be more efficient with getting to and from their worksites, but also aid in preventing the establishment of target taxa.

Small Vertebrate Control

Species: *Rattus rattus* (Black rat), *Rattus exulans* (Polynesian rat), *Mus musculus* (House mouse), *Herpestes auropunctatus* (small Indian mongoose), *Lophura leucomelanos* (Kalij pheasant).

Threat Level: High for *Rattus spp* for *N. angulata, A. sandwicense,* and *D. waianaeensis*. Unknown for *M. musculus, H. auropunctatus,* and *L. leucomelanos.*

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:

- Monitor rare taxa populations for rat damage; promptly initiate control if damage is noted.

Strategy and Control Methods:

- Monitor rare plant (*E. haeleeleana*, *N. angulata* and *A. sandwicensis*) populations, as well as other native species to determine impacts by rodents.
- A small grid of rat traps in the Upper Patch deployed by DOFAW/PEPP will be reinstalled and maintained by ANRPO, beginning in 2022.

Discussion:

Although rodent control used to be conducted by ANRPO in this MU, efforts were entually prioritized to other MUs and IP taxa. Currently no rodent control is conducted by ANRPO at Kaluakauila, since rodents have not been deemed a threat to MFS populations. In the past, the State was managing an A24 grid in the Upper and Lower Patches around *E. haleleeleana* to promote seedling recruitment and protect trees from damage. ANRPO will collaborate with PEPP to maintain the A24 grid in the Upper Patch around *E. haeleeleana,* beginning in 2022. If MFS populations of *N. angulata* and *A. sandwicense* are determined to be adversely impacted by rodents, ANRPO will evaluate the use of localized rodent control for the protection of these species. Additionally, Elepaio, which would benefit from rodent control measures, have previously been observed in the Upper Patch. 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 *D. waianaeensis* and *N. angulata*.
- Avoid potential impacts to rare snails.

Strategy and Control Methods:

- Define Slug Control Areas (SLCAs) around rare plant locations. Prior to any control, complete the Pre-Application Survey Protocol; see below. A buffer of at least 5 meters from vulnerable plants is recommended. 10 meters is optimal.
- Calculate amount of Ferroxx needed to treat SLCA. Orient staff to SLCA and train applicators.
- Apply Ferroxx at interval determined by forest type (dry), seasonality of slugs at site (wet season), risk to rare taxa, accessibility. Highest frequency is every 6 weeks, however, this may be lengthened based on the factors listed.
- If rare snails are found in an established SLCA, treatment will be halted. Rare snails will be relocated to the MU snail enclosure, and the Pre-Application Survey Protocol will resume.
- Conduct slug abundance monitoring with baited beer traps. Use data to inform whether control is needed, and/or if it may be seasonal versus annual.

Discussion:

Slug control is conducted at rare plant sites where slugs pose a significant threat to the survivorship of individual plants and/or survivorship of seedlings, where slugs are present, and where native snails are absent.

During annual rare plant monitoring, inspect plants for herbivory, and document potential slug damage and presence on plants. Indications that slugs are responsible include 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). Some rare plant taxa are known to be susceptible to slug damage, and control may be warranted even before any impact is seen.

Another factor to consider is slug abundance and seasonality. Slugs may only be present seasonally, or in low numbers, especially in dry habitats. Control may not be needed at all, or not at certain times of year. Slugs will be sampled in the Upper Patch once at the beginning of the the wet season using baited beer traps. If the number of slugs captured per trap over two weeks exceeds one slug per trap, slug control may be needed. Beer trap monitoring requires frequent visits, and is just one optional tool to inform control needs and frequency.

Consult with the Rare Plant Program Coordinator and Invertebrate & Forest Invasive Species Biologist to determine if slug control is warranted at a particular site. Prior to any control, follow the Pre-Application Survey Protocol:

Pre-Application Survey Protocol:
For control only of slugs and non-native snails via listed, approved molluscicide application in forests, on offshore islands, and in other natural areas to protect threatened and endangered Hawaiian plants. Only Ferroxx AQ® Slug and Snail Bait is approved for use in forest areas in Hawaii. Area must be thoroughly searched by experienced malacologists prior to application of Ferroxx AQ® granules to ensure that non-target native Hawaiian snail species are not impacted. Do not apply in areas where it may come into contact with known populations of endemic Hawaiian snail species from the following rare families or subfamilies: Amastridae, Achatinellinae and Endodontidae. Bait cannot be applied within 20 m of any tree known to harbor endangered Hawaiian tree snails (*Achatinella* spp.). 1. Conduct thorough day survey of proposed treatment area to include searching trees and all understory vegetation. The ground and rock talus areas will also be search. An effort to identify other snails found and their rarity will be made prior to Ferroxx use. 2. If proposed treatment area is known *Achatinella* spp. site or if *Achatinella* spp. is observed during day survey, then must conduct night survey and remove all *Achatinella* spp. to a snail enclosure/protected area prior to bait use. 3. Area will continue to be surveyed and *Achatinella* spp. translocated to enclosures until all *Achatinella* spp. are removed from the area and at least one survey is conducted where 0 snails are found within area. 4. If *Achatinella* spp. are abundant in large numbers or are found on multiple trips, use of Ferroxx will not be allowed in area. 5. If *Achatinella* spp. are located in the area in the course of other field work, then surveys and relocation efforts will resume. 6. An effort to identify other snails found and determine their rarity will be made prior to Ferroxx use.

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*.

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.
- 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) annually (see table below). Use samples to track changes in existing ant densities and to alert ANRPO 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
Upper Patch Catchment	High risk of accidental ant introduction via ANRPO staff
Lower Patch Catchment	High risk of accidental ant introduction via ANRPO staff
Parking Area/Trailhead	High risk of accidental ant introduction via ANRPO staff

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.

Ant sampling in Kaluakauila began in March of 2021, and will occur annually at the Upper Patch catchment as well as the parking area/trailhead. Ant sampling at the Lower Patch catchment will be considered if more weed control and restoration efforts begin to take place in that area. ANRPO staff have observed what may be *A. gracilipes* at the Lower Patch catchment but have not yet obtained samples. Because staff and hikers travel the area repeatedly, transport of these ants could easily spread to other

Management Units. The probablity of transporting *A. gracilipes* to new MUs is the highest during sling load operations. If ANRPO staff should resume camping within the MU, sling load operations could pose a possibility for transporting unwanted species from Kaluakauila to a new area. ANRPO staff will survey ant species at Kaluakauila DZs and LZs in the methods mentioned above one month before anyoperations where sling loads would be transported in and out of the MU. 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 *A. sandwicense* and *N. 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, and if damage is seen.

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. *M. maximus* 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 along the fenceline.
- Control large weedy tree species (*G. robusta, L. leucocephala, S. terebinthifolius*, 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.
- Use Seibert stakes or similar visual cues for pilots to mark the fence.
- Clear LZs on ridgeline for fire use.
- Coordinate with State on REPI work, including aerial spray of grass along ridgeline as a pilot project.

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.

Historical Fires

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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 erode 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 *Euphorbia 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 U.S. Fish and Wildlife Service went on a site visit to look at different pre-suppression options with agency partners.

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 Army Natural Resource Program on Oahu (ANRPO) 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, [ANRPO] became involved with the project specifically to guide the IVMP in selection/placement of remote fuel breaks. Later, [ANRPO] 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."

In 2021, REPI funds were granted to DOFAW to create firebreaks to contain fires generated in Makua Military Reservation and Schofield Barracks Military Reservation. The main goals for the work proposed in Kaluakauila are to reduce fuel loads along 6,695 ft. of firebreak, to improve roads to better enable firefighter response, and to outplant 1,000 native plants. ANRPO Staff will be conducting site visits with partner agencies in 2022 to discuss potential collaborative efforts.

Ecosystem Restoration Management Unit Plan

OIP Year 16-21, Oct. 2022 – Sept. 2027

MU: Koloa

Overall OIP Management Unit Goals:

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

Background Information:

Location: Summit of Northern Koolau Mountains

Land Owner: Hawaii Reserves Inc.

Land Managers: ANRPO, Hawaii Reserves Inc.

Acreage: 164 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 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 Hesperomannia swezeyi,* and *Viola oahuensis.* The Koloa MU can be accessed via the Kawailoa and Laie trails, however due the length of these trails, ANRPO uses helicopters to access the MU to do management.

Native Vegetation Types

Koolau Vegetation Types	
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*, *Hydrangea arguta*, *Dianella sandwicensis*, *Dubautia* spp. Less common subcanopy components of this zone include *Clermontia* and *Cyanea* spp.
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 *Melicope* spp., *Cibotium chamissoi, Machaerina angustifolia*, *Nertera granadensis,Kadua centranthoides*, *Nothoperanema rubiginosa*, and *Hydrangea arguta*.
NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted.	

Terrain and Vegetation Types at 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	OIP Tier Designation
Plant	*Euphorbia rockii*	KOL-A,B, D,E,G,H,J,L	Kaipapau, Kawainui to Koloa and Kaipapau, and Kawainui	GSC	Wild	2
Plant	*Cyanea acuminata*	KOL-L*	None	None	Wild	1
Plant	*Cyanea koolauensis*	KOL-B,C, D,E,F,G,H,J, K,L,N,O	Kaipapau, Koloa, and Kawainui	MFS	Wild	1
Plant	*Cyrtandra viridiflora*	KOL-B,C,H,K	Kawainui and Koloa	GSC	Wild	2
Plant	*Geniostoma cyrtandrae*	KOL-A*, B	Kaluanui to Koloa	MFS	Reintroduction	1
Plant	*Hesperomannia sweyzei*	KOL-A,D	Kamananui to Kaluanui	MFS	Wild	1
Plant	*Myrsine juddii*	KOL-B	Kaukonahua to Kamananui-Koloa	GSC	Wild	2
Plant	*Phlegmariurus nutans*	KOL-B	Koloa and Kaipapau	GSC	Wild	2
Plant	*Phyllostegia hirsuta*	KOL-A,C,E*,H	Koloa	MFS	Wild/ Reintroduction	1
Plant	*Viola oahuensis*	KOL-A,B,C, D,	Koloa	GSC	Wild	2
Snail	*Achatinella livida*	KOL-B*	None	None	Wild	N/A

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

Other Rare Taxa at Koloa

Organism Type	**Species**	**Federal Status**
Plant	*Cyanea calycina*	Endangered
Plant	*Cyanea humboldtiana*	Endangered
Plant	*Cyanea lanceolata*	Endangered
Plant	*Joinvillea ascendens* ssp. *ascendens*	Endangered
Plant	*Lobelia gaudichaudii* ssp.*gaudichaudii*	Species of Concern
Plant	*Myrsine fosbergii*	Endangered
Plant	*Psychotria hexandra* var. *oahuensis*	Endangered
Plant	*Zanthoxylum oahuense*	Endangered
Insect	*Drosophila nr. truncipenna*	Rare
Insect	*D. nigribasis*	Rare
Insect	*D. oahuensis*	Rare

Locations of Rare Resources at Koloa

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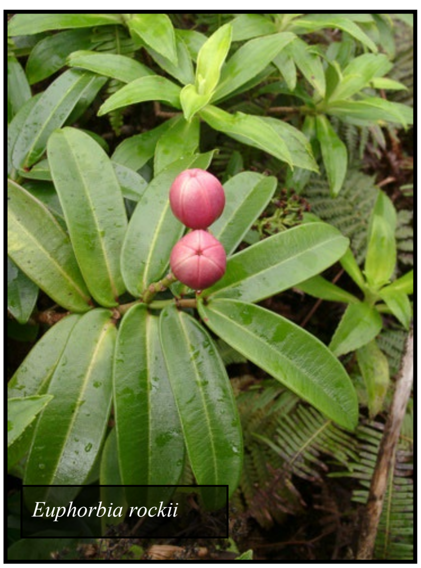
Rare Resources at Koloa

Viola oahuensis

Cyanea koolauensis

Zanthoxylum oahuense

Phlegmariurus nutans



Euphorbia rockii

Achatinella livida

Threats to OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2022
Pigs	All	Across MU	No animals within fence
Weeds	All	Rare taxa sites primarily, across MU secondarily	Regular maintenance required several times per year
Rodents	*Cyanea koolauensis*, *Phyllostegia hirsute, Hesperomannia sweyzei, Geniostoma cyrtandrae*	Across MU	Trap grid will be installed among the densest population of these plants.
Slugs	*Cyanea koolauensis, Phyllostegia hirsuta, Hesperomannia sweyzei, Geniostoma cyrtandrae*	Affected rare taxa sites only	Slug control toxicant applied quarterly
Powdery Mildew	*Phyllostegia hirsuta*	No control	Monitor rare plants; no tools to control in field
Ants	*Drosophila spp*	No control	No known populations of managed *Drosophila* spp. Control ants if needed.
Oryctes rhinoceros	*Pitchardia spp*	No control	Unknown if *O. rhinoceros* is present in Koloa.
Fire	All	No control	One incident of an open fire on the cabin DZ

Management History

- 1993: Hawaii Natural Heritage Program (HINHP) conducts rare resource surveys along Koolau Summit Trail (KST) through Koloa.
- 1997: First ANRPO record of an endangered plant in Koloa.
- 1998: First ANRPO record of *A. livida.*
- 1998: Incipient weed taxa *Hedychium spp* control begins.
- 2002: Predator control around *A. livida* begins.
- 2009: MU Fenceline scoped.
- Sept. 2011: MU fence construction begins and WCA boundaries are drawn. Container cabin flown to Puu Kainapuaa to serve as fence contractor campsite.
- Sept. 2012: Fence completed, ungulate control initiated. One volunteer hunt conducted catching several pigs. One pig trapped between fence and cliff No pigs caught in several hundred snares.
- 2013 Cabin construction completed.
- 2013: Feb 5th- Last recorded observation of *A.livida* Kol-A. Predator control around *A.livida* ends.
- 2013: June 27th- [125] new *GenCyr*.KOL-A out-planted in WCA Koloa-13.
- 2013: Dec 16th- [41] more *GenCyr*.KOL-A introduced in WCA Koloa-13.
- 2014: Mar 4th- [119] new *PhyHir*.KOL-C out-planted in WCA Koloa-03
- 2015: Mar 17th- [91] more *PhyHir*.KOL-C introduced in WCA Koloa-03
- 2017: Feb 17th- [17] new *GenCyr*.KOL-B outplanted in WCA Koloa-02

- 2017: Three small landslides took out portions of the fence along the KST and the stream section on the western line. Repairs were made and there was no pig sign seen.
- 2018: Rust on the Eastern portion of the fence was noted. Work was done to replace rusty hog rings along this portion.
- 2019: *S. papuana* found at Koloa Cabin.
- 2020-present: Added security measures to address ongoing cabin break-ins, repairs have occurred. Despite cabin use, cleanliness of the cabin remains good.
- 2020: Aug 25th- All *GenCyr*.KOL-A population deceased.
- 2022: *Psidium cattleianum* biocontrol (*Tectococcus ovatus*) was released.
- 2022: Graduate assistantship awarded to Yoko Uyehara (advisor Qi Chen) to build AI software to detect *Pritchardia spp* and *Aniopteris evecta* using Koloa imagery.
- 2022-2023: Installation of small scale rat grids are proposed for Koloa-03 in Q4 of 2022 or Q1 of 2023 to manage rat threats to PhyHir, CyaKoo, and GenCyr.
- 2023: New outplanting site of *G. cyrtandrae* in Koloa-03 and additional outplanting for PhyHir.Kol-A in KOL-03.

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 (KOL-A).
- Conduct quarterly fence checks and fences across streams 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.

Discussion:

The MU fence is 4.5 kilometers long and encompasses 164 acres. The major threats to the perimeter fence include fallen trees, vandalism, stream crossings, and flooding. Waterfalls in Koloa provide excellent natural barriers against ungulates and strategic areas for the fence to tie into to avoid the need to cross streams and create fence sections that are vulnerable to extreme weather events such as flooding. 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. 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 lifetime of the fence is estimated to last between ten and fifteen years due to climatic conditions of the Koolau mountain range along with the threat of landslides because of the topography of the MU. Since the fence was completed in 2012, it may be approaching replacement time. In 2017, two significant landslides occurred causing damage to the fenceline. Approximately 50 m total in length in two separate locations along the fenceline were blown out. The damage to the fence was observed and fixed in April by replacing with panels. No signs ungulate incursion occurred. Currently, there is also an encroaching landslide on the outside of the eastside section by tag 387 and it is about 16 m long. The landslide is about 1 m from the fence. With being on the windward side of Oahu, the fence has started showing signs of rust on both fence panels, skirting, and hog rings. In 2019, NRS began replacing hog rings along the fenceline starting from fence tag #361- #420 and section #001 - #055. Because of these recent developments, a thorough scoping of the fence line will take place in 2023 and will determine what areas will have priority to be repaired. Possible fence needs could be: replacing/installing skirting, replacing rusty fence panels, and fickle fencing in areas where ungulate sign has been observed.

Most recent ungulate activity outside of the fence were observed at: Mid-ridge LZ, southeast quadrant of the fenceline, and areas along the Koolau Summit Trail (KST). There were signs of digging at both Mid-Ridge LZ and the KST. There was scat found along the fenceline of the southeast quadrant of the MU.

Ungulate Management Map

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Weed Control and Vegetation Restoration

Weed Control actions are divided into 4 subcategories:

- Vegetation Monitoring
- Surveys
- Incipient Taxa Control (Incipient Control Area - ICAs)
- Ecosystem Management Weed Control (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 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 via drones, remote vegetation mapping, or a combination of both. Utilizing new technologies and methodologies to develop vegetation monitoring protocols is a priority for this MU.

Surveys

Potential Vectors: ANRPO and BYU activity, hikers/hunters, pigs, alien birds, wind, etc.

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 (Koloa Middle Ridge, Koloa Cabin and Kaipapau Ridge) and Campsite used in the course of field work, not to exceed once per quarter.
- Survey weed transect (WT-Koloa-01) annually, which includes: the Koolau Summit Trail (Western fence corner to the cabin).

Discussion:

Surveys are designed to be the first line of defense in locating and identifying potential new weed species. The weed transect (WT-Koloa-01) is done once per year in the first quarter. Also landing zones (LZs) and campsite surveys are done on a quarterly basis. No unusual findings have occurred; however, the survey provides a look at potential weeds being brought in to the MU from the most-used portion of Koloa, the KST. 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.

Survey Locations Map

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Sensitive Information
Available Upon Request

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:

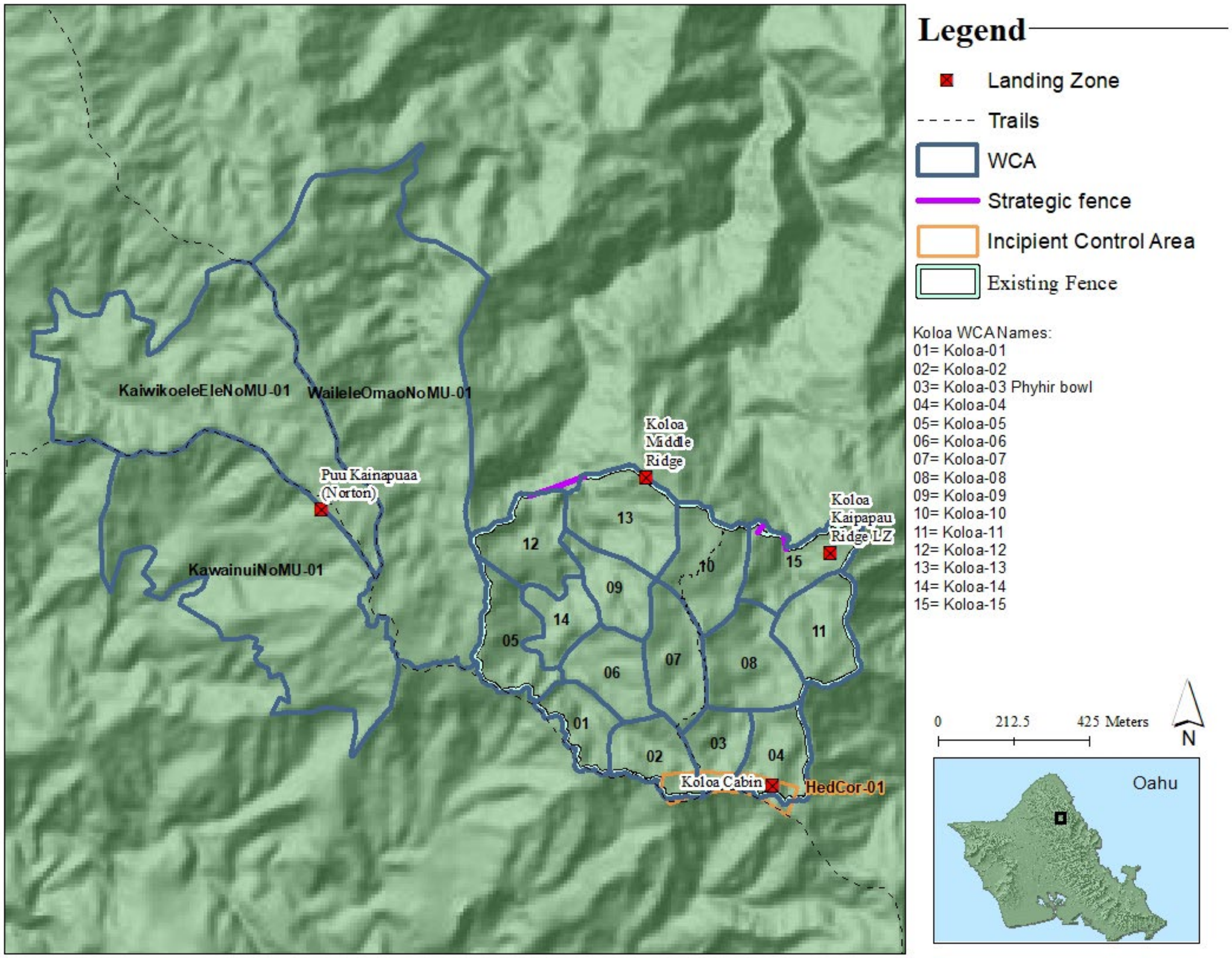
- Species and ICAs are listed in the table below. History and strategy is discussed for each species.
- Monitor the progress of management efforts, and adjust visitation rates to allow staff to treat plants before they mature. Remember that one never finds 100% of all plants present.
- Use aggressive 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
Hedychium coronarium	Koloa-HedCor-01	This highly invasive ginger is widespread throughout Oahu, especially in wet environments in which it can take over as groundcover rapidly. Less than 5 individuals were found in the last 5 years. Since the ICA is fairly large and was never thoroughly surveyed, a scope will have to be conducted to better define the boundaries. To complete that, we will look at past *H. coronarium* points and buffer around them, and using binocular or drone scoping into gulches from the ridge-line to prevent any unnecessary native ground cover damage.

Incipient Weed Photos

Incipient and Weed Control Areas Map



Ecosystem Management Weed Control

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.

Discussion:

Koloa is dominated by native taxa, and may already meet the goal of 50% or less cover of alien vegetation across the MU. 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. Staff will use aerial surveys, ground surveys and high-resolution imagery to guide control efforts. The WCAs that are most accessible, have the gentlest terrain, and the greatest number of rare resources will be prioritized for control. In addition, WCAs are divided amongst two teams (Green and Vegetation Restoration). For the Green Team, WCAs -01 through -04 are the areas with the most priority and will be rotated every six quarters in order to maximize consistent weeding sweeps. The Vegetation Restoration team prioritizes *P. cattleianum* control in WCA-05 and -08.

Staff have noticed a larger presence of *A. evecta* creeping up towards the KST, where many of the rare resources are. Sweeps of *A. evecta* will occur opportunistically, as crews sweep for *P. cattleianum*, or during targeted sweeps. The Vegetation Restoration team plans to do single-target *A. evecta* sweeps in the two largest drainages in Koloa. In addition, using a combination of aerial surveys and aerial imagery, staff can better understand the scope of the spread within the MU and strategize control of *A. evecta* in the future.

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 release of *Tectococcus ovatus*, a bio-control for *P. cattleianum* will start being strategically placed around the MU. *Psidium cattleianum* stands will be inoculated with the bio-control along the fence perimeter and along mid-ridge trail. These areas were chosen to maximize staff efforts and strategically place them on ridgetops to facilitate spread by wind. After *T. ovatus* is released, inoculation would have occurred on the perimeters of all WCAs except Koloa-08 and -14. *Tectococcus ovatus* affects the new growth of the *P. cattleianum*, stunting them, and eventually forming galls all over the leaves of the plant. *T. ovatus* is not known for killing *P. cattleianum*, but hopefully reduces vigor, fruit set, and dispersal. The movement of the biocontrol is slow-going and signs of spread and effectiveness will be difficult to assess.

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	*A. virginicus* tends to show up along trails and cliffs. Target to keep off cliffs as difficult to control in steep areas.
Angiopteris evecta	Widespread	Incidental observations of *A. evecta* around the MU have been made. Plants seen should be removed manually on discovery. The adjacent Kaipapau MU is infested with this taxon, 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 or imagery scans as needed and consider future aerial spray operations.
Clidemia hirta	Widespread	*C. hirta* is a well-established part of the Koolau vegetation type. Staff will target around rare plant taxa, but is not a main target during sweeps.
Erigeron karvinskianus	Unknown	Status of this species in the MU is unknown. Note locations of *E. karvinskianus* during regular control work. Evaluate whether species should

Taxa	Distribution	Notes
		be a target once have additional distribution information. This taxon is a threat to open cliff communities.
Falcataria moluccana	Unknown	Not known in Koloa at this time, but known from adjacent area in Kawainui. Target for control during regular weed sweeps.
Leptospermum scoparium	Scattered	Few were found in the MU, however control at surrounding areas Wailele, Kaiwikoele, Kawainui, and is ongoing to prevent the spread of *L. scoparium* into Koloa.
Melaleuca quinquenervia	Restricted	A few trees were treated in adjacent Wailele gulch by KMWP in 2010. If seen in the MU, this taxon will be targeted during regular weed sweeps.
Oxyspora paniculata	Restricted	A single individual was found on the outside of the North Eastern corner of the MU fence line.
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.
Psidium cattleianum	Widespread	Patches scattered across Koloa. Primary target of WCA sweeps. The largest and thickest stands tend to be in gulches and draws. In areas with difficult terrain, staff will investigate alternative control techniques, such as Herbicide Ballistic Technology and aerial ball spraying. The release of *T. ovatus* will start being placed in the MU starting 2022.
Setaria palmifolia	Unknown	None known from MU, but has been observed in other Koolau MUs. If any *S. palmifolia* is found, it will be evaluated for control as an ICA.
Sphaeropteris cooperii	Restricted	A few individuals found in deep gulches, but there are no known hotspots. *Sphaeropteris cooperi* will be targeted during regular weed sweeps. One mature was found in 2021.

The table below contains specific notes on what native taxa and what type of stock may be appropriate for projects at Koloa.

Taxa Considerations for Restoration Actions

Native Taxon	Growth Habit	Outplant/SDT	Notes
Antidesma platyphyllum	Tree	Outplant/ Seedsow	Grow from seed. Seeds likely recalcitrant. Collect and grow as needed.
Cheirodendron spp.	Tree	Outplant	Grow from seed. Decently fast growing.
Cibotium spp.	Fern	Outplant	Grow from spore. Need 2 years to produce quart pot size from sow date. Can propagate from divisions or transplants.
Coprosma longifolia	Shrub	Outplant	Grow from seed.
Dubautia laxa	Shrub	Outplant	Grow from seed if available. Can propagate from cuttings if needed. Need collections.
Freycinetia arborea	Liana	Outplant	Grow from seed. Need collections.
Hydrangea arguta	Shrub	Outplant?	Potentially difficult to produce. Seeds have germinated in greenhouse but did not survive long term.
Ilex anomala	Tree	Outplant	Grow from seed.
Kadua affinis	Shrub	Outplant	Grow from seed. Need collections from this MU.
Machaerina angustifolia	Sedge	Division/Transplant	Have not tried propagating this species. Anecdotal evidence suggests divisions or transplants may work.

Native Taxon	Growth Habit	Outplant/SDT	Notes
Melicope spp.	Tree	Outplant	Grow from seed. Need collections.
Metrosideros polymorpha	Tree	Outplant	Grow from seed. Need collections from this MU.
Perrottetia sandwicensis	Tree	Outplant	Grow from seed. Ripe fruiting season very short. Collect in December. Need collections.
Phyllostegia grandiflora	Liana	Outplant	Grow from seed. Need collections. Can propagate from divisions or transplants.
Psychotria spp.	Tree	Outplant	Grow from seed. Need collections.
Sadleria pallida	Fern	Outplant	Grow from spore. Have not tried to propagate this species yet. Need collections.
Scaevola spp.	Shrub	Outplant	Grow from seed. Need collections from this MU.
Syzygium sandwicense	Tree	Outplant	Grow from seed.
Wikstroemia oahuensis	Shrub	Outplant	Grow from seed. Have collections from Lower Opaeula but should get from this MU.

WCA: Koloa-01

Veg Type: Wet Montane

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

Target: *P. cattleianum* and other alien tree species

Notes: Weed sweeps can be performed in this WCA North from the Summit Trail 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). *T. ovatus* has been strategically released along the SW boundary of the WCA with the intent that the bio-control will be wind dispersed throughout the MU.

WCA: Koloa-02

Veg Type: Wet Montane

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

Target: *P. cattleianum*, *Pterolepis glomeratus*, *C. hirta*, *Cuphea carthagenesis*.

Notes: This is a high priority WCA and is the most fragile in the MU, containing large populations of wild *V. oahuensis, C. rockii, C. humboltiana, C. calycina,* and the *P. nutans,* among others. In 2017 the second outplanting of *G. cyrtandrae* (KOL-B) in Koloa was planted in a steep drainage within the WCA. The health of the plants at this population has been good, however, landslides caused physical transformation of the habitat where many of the plants were uprooted. This WCA contains a large amount of *P. cattleianum*. To minimize the impact to the area, sweeps will be done via Spot-and-treat method with extreme care taken to minimize disturbing native habitat. All disturbed areas in this WCA are covered in *P. glomerata*. This is especially true on the trail to the *G. cyrtandrae* outplanting.

WCA: Koloa-03 Phyhir Bowl

Veg Type: Wet Montane

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

Target: *P. cattleianum*,*A. evecta*, *Paspalum conjugatum*, *P. urvillei*, *Andropogon virginicus*, and *P. glomeratus*.

<u>Notes</u>: This is a high priority WCA and is home to a large population of *E. rockii, P. hirsuta* (outplanted) and *C. koolauensis* and consists of many small ridges and gulches. Many of these taxa are centered in the WCA around a natural bowl, called the Phyhir bowl. The Phyhir bowl contains many weeds, including weedy grasses (*P. conjugatum*, *P. urvillei*, *A. virginicus*) and understory weeds (*P. glomeratus*, *C. carthagenesis*, *C. hirta*, etc.) Large stands of *P. cattleianum* have been controlled in the bowl and efforts will continue to extend down gulch. If there is a need for common restoration, Koloa-03 would be a candidate for it, because of the open and available space in the PhyHir Bowl. Sweeps for *A. evecta* have also been performed using Incision Point Application with 100% Imazapyr. Larger individuals have been seen as elevation decreases within the WCA.

WCA: Koloa-04

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

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

<u>Target:</u> *P. cattleianum* and other alien tree species

<u>Notes</u>: This WCA is along the Eastern border of the MU that surrounds the camp site, borders the Kaipapau MU, and consists of more endangered species than any other WCA. Plants found in this WCA include *C. calycina*, *C. koolauensis*, *C. viridiflora*, *H. sweezeyi, 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 Spot-and-treat method. The time spent though could be less due to WCA shape and amount of target taxa found and treated.

WCA: Koloa-05

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

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

<u>Target:</u> *P. cattleianum* and other alien tree species

<u>Notes</u>: 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. *T. ovatus* has been strategically introduced to large stands of *P. cattleianum* along the SW boundary of the WCA, with the intention that the bio-control will be wind distributed throughout the MU. Vegetation Restoration team plans to reduce the amount of time spent controlling *P. cattleianum* to allow *T. ovatus* to run its course and assess its effectiveness.

WCA: Koloa-06

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

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

<u>Target:</u> *P. cattleianum* and other alien tree species

<u>Notes</u>: 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. This WCA is rarely visited and management is a low priority.

WCA: Koloa-07

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

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

<u>Target:</u> *P. cattleianum* and other alien tree species

Notes: 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. *T. ovatus* has been strategically introduced to large stands of *P. cattleianum* along the Mid-ridge trail that runs to the west of the WCA, with the intention that the bio-control will be wind distributed throughout the MU.

WCA: Koloa-08

Veg Type: Wet Montane

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

Target: *P. cattleianum* and other alien tree species

Notes: To minimize 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. The WCA is along the eastern border of the MU, and *T. ovatus* could be released here if there is abundance of *P. cattleianum*. This WCA has been a focus area for the Vegetation Restoration team, where they have done *P. cattleianum* control.

WCA: Koloa-09

Veg Type: Wet Montane

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

Target: *P. cattleianum* and other alien tree species

Notes: This WCA is steep. To minimize the impact to the area, and for safety concerns of our staff, sweeps will be done via Spot-and-treat method, and may be a candidate for remote/aerial control techniques. The WCA is along Mid-Ridge trail, and *T. ovatus* could be released here if there is abundance of *P. cattleianum*.

WCA: Koloa-10

Veg Type: Wet Montane

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

Target: *P. cattleianum* and other alien tree species

Notes: This WCA for the most part is relatively flat; full weed sweeps can be used. The vegetation in this WCA consists mostly of *Pritchardia spp* in the canopy and open rolling hills of short-statured *M. polymorpha*, *Melicope spp*, *Kadua spp*, and *H. arguta*. Weedy species such as *P. cattleianum* and *P. glomerata* persist in open and degraded areas. As with other woody canopy species in this WCA, *P. cattleianum* is also short-statured.

WCA: Koloa-11

Veg Type: Wet Montane

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

Target: *P. cattleianum* and other alien tree species

Notes: To minimize the impact to the rare plants in this 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. This WCA borders the Kaipapau MU.

WCA: Koloa-12

Veg Type: Wet Montane

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

Target: *P. cattleianum* and other alien tree species

Notes: This WCA is the most northwest and is very steep. 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. Area has not been well surveyed yet. A stream on the eastern border of this WCA divides Koloa-12 and Koloa-13. This stream was the site of a failed 2013 Gencyr.KOL-A outplanting. There are populations of *C. koolauensis* among the slopes near the fence and in the stream bottom.

WCA: Koloa-13

Veg Type: Wet Montane

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

Target: *P. cattleianum* and other alien tree species

Notes: This WCA is very steep. 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. *Psidium cattleianum* sweeps have begun in this WCA near the Middle Ridge LZ, but priority for control has been reduced due to the lack of resources. A stream on the western border of this WCA divides Koloa-12 and Koloa-13. This stream was the site of a failed 2013 Gencyr.KOL-A outplanting.

WCA: Koloa-14

Veg Type: Wet Montane

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

Target: *P. cattleianum* and other alien tree species

Notes: 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 Spot-and-treat method: spotting from open ridges with binoculars and directing other staff to the plants for treatment. Area has not been well surveyed yet. This WCA is rarely visited and management is low priority.

WCA: Koloa-15

Veg Type: Wet Montane

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

Target: *P. cattleianum* and other alien tree species

Notes: This WCA is the most North East and is very steep. 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. Area has not been well surveyed yet and active management is a low priority.

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: spotting from open ridges with binoculars and directing other staff to the plants for treatment.

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* but has since been swept a few times. 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 areas. Norton (Puu kainapuaa) LZ is located near this WCA. If the Cabin LZ is socked in, staff can fly out of Norton LZ as it is slightly lower in elevation. The Vegetation Restoration Team uses this LZ to access the Western portions of the MU.

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 encompasses part of the KST and 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: Medium

Seasonality/Relevant Species Biology: year round

Management Objectives:

- Maintain low levels of rat activity across entire MU.

Strategy and Control Methods:

- Establish small scale A-24 grid around rare taxa sites.
- Monitor rare plant *(P. hirsuta, G. cyrtandrae, C. koolauensis, H. sweyzei*) populations, as well as other native species to determine impacts by rodents.

Discussion:

Currently, there are only A-24s set up around the Koloa cabin, otherwise there is no rodent control in the Koloa MU. In early 2023, an A-24 grid of 15-20 traps will be established in Koloa-03 in what is known as the PhyHir Bowl. Rare plants in the area include: *P. hirsuta, C. koolauensis, C. humboldtiana,* and *C. lanceolata.* Koloa-03 is also the site of the future outplanting of *G. cyrtandrae* and will benefit from the rodent control grid.

Slug Control

Species: *Limax maximus*, *Deroceras laeve*

Threat level: High

Seasonality/Relevant Species Biology: Year-round

Management Objectives:

- Manage slugs locally to ensure germination and survivorship of *C. koolauensis*, *P. hirsuta*, and *G. cyrtandrae*.
- During annual rare plant monitoring, look for seedling recruitment and slug herbivory.
- Avoid potential impacts to rare snails.

Strategy and Control Methods:

- Define Slug Control Areas (SLCAs) around rare plant locations. Prior to any control, complete the Pre-Application Survey Protocol; see below. A buffer of at least 5 meters from vulnerable plants is recommended. 10 meters is optimal.
- Calculate amount of Ferroxx needed to treat SLCA. Orient staff to SLCA and train applicators.
- Apply Ferroxx once per quarter, based on accessibility and risk to rare taxa.
- If rare snails are found in an established SLCA, treatment will be halted. Rare snails will be relocated to the MU snail enclosure, and the Pre-Application Survey Protocol will resume.
- Conduct slug abundance monitoring with baited beer traps. Use data to inform whether control is needed, and/or if it may be seasonal versus annual.

Discussion:

Slug control is conducted at rare plant sites where slugs pose a significant threat to the survivorship of individual plants and/or survivorship of seedlings, where slugs are present, and where native snails are absent.

During annual rare plant monitoring, inspect plants for herbivory, and document potential slug damage and presence on plants. Indications that slugs are responsible include 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). Some rare plant taxa are known to be susceptible to slug damage, and control may be warranted even before any impact is seen. In Koloa slug herbivory is consistently observed on an outplanting of *G. cyrtandrae* (KOL-B). Slug predation is also known to affect *Cyanea* spp. Because *Cyanea* spp. in Koloa are rarely visited and there are no actively managed populations, it is unknown what impacts slugs have on these plants and for recruitment. If future outplantings of *G. cyrtandrae* or *Cyanea* spp. occurs, slug control needs to be implemented to deter herbivory.

Another factor to consider is slug abundance and seasonality. Slugs may only be present seasonally, or in low numbers, especially in dry habitats. Control may not be needed at all, or not at certain times of year. At some sites, it may be useful to measure slug abundance using baited beer traps, monitored after two weeks. If the number of slugs captured per trap over two weeks exceeds one slug per trap, slug control may be needed. Beer trap monitoring requires frequent visits, and is just one optional tool to inform control needs and frequency. Beer trap monitoring has been performed in Koloa. The number of slugs captured per trap over two weeks greatly exceeded one slug per trap, at an average of 8 per trap. A rare native snail survey needs to be conducted of the area, if no rare native snails are present, we will apply FerroxxAQ quarterly. Because Koloa is a difficult place to access, crews only visit the MU 1-2 times per quarter at most. In this case FerroxxAQ would be applied less than suggested by the pesticide label at a frequency of once per quarter, providing at least some protection to rare resources for part of the year.

Consult with the Rare Plant Program Coordinator and Invertebrate & Forest Invasive Species Biologist to determine if slug control is warranted at a particular site. Prior to any control, follow the Pre-Application Survey Protocol:

Pre-Application Survey Protocol:

For control only of slugs and non-native snails via listed, approved molluscicide application in forests, on offshore islands, and in other natural areas to protect threatened and endangered Hawaiian plants. Only Ferroxx AQ® Slug and Snail Bait is approved for use in forest areas in Hawaii. Area must be thoroughly searched by experienced malacologists prior to application of Ferroxx AQ® granules to ensure that non-target native Hawaiian snail species are not impacted. Do not apply in areas where it may come into contact with known populations of endemic Hawaiian snail species from the following rare families or subfamilies: Amastridae, Achatinellinae and Endodontidae. Bait cannot be applied within 20 m of any tree known to harbor endangered Hawaiian tree snails (*Achatinella* spp.).

1. Conduct thorough day survey of proposed treatment area to include searching trees and all understory vegetation. The ground and rock talus areas will also be search. An effort to identify other snails found and their rarity will be made prior to Ferroxx use.
2. If proposed treatment area is known *Achatinella* spp. site or if *Achatinella* spp. is observed during day survey, then must conduct night survey and remove all *Achatinella* spp. to a snail enclosure/protected area prior to bait use.
3. Area will continue to be surveyed and *Achatinella* spp. translocated to enclosures until all *Achatinella* spp. are removed from the area and at least one survey is conducted where 0 snails are found within area.

4. If *Achatinella* spp. are abundant in large numbers or are found on multiple trips, use of Ferroxx will not be allowed in area.
5. If *Achatinella* spp. are located in the area in the course of other field work, then surveys and relocation efforts will resume.
6. An effort to identify other snails found and determine their rarity will be made prior to Ferroxx use.

Ant Control

Species: *Solenopsis papuana*

Threat level: Unknown

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

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 (Koloa cabin, Koolau Summit trail) using the standard survey protocol (OANRP 2010) a minimum of once a year (see table below). Use samples to track changes in existing ant densities and to alert ANRPO to any new introductions.
- If incipient species are found and deemed to be a high threat and/or easily eradicated locally (<0.5 acre infestation), begin control.
- Sample ants at campsite, LZ, rare taxa sites, DZ, and fencelines to track changes in existing ant densities and to alert OANRP to any new introductions.
- Look for evidence of ant tending of aphids or scales on rare plants during annual rare plant monitoring.

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. Since 2006, staff samples ants in high risk areas using the following method:

Vials are baited with SPAM, peanut butter and honey. Caps are removed and vials are spaced 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.

Recent surveys have indicated the presence of *S. papuana*. Frequent use of the cabin by recreational hikers as well as natural resource staff could be possible means of introducing ant species to Koloa. Unmanaged *Drosophila* taxa are found at Koloa and may be at risk through the introduction of *S.*

papuana. The cabin is the only site where surveys are done regularly. If there are managed species discovered at Koloa, staff will address the threats and control as needed.

Ant Survey Site Table

Site description	Reason for survey
Koloa Cabin	*Drosophila* are sensitive to high ant abundance

Coconut Rhinoceros Beetle

Species: *Oryctes rhinoceros*

Threat level: Unknown

Seasonality/Relevant Species Biology: Instar stages inhabit the soil, while mature beetles persist above the ground and are able to fly.

Management Objectives:

- Early detection of *O. rhinoceros* to determine spread on Oahu and prompt action for *Pritchardia* management.

Strategy and Control Methods:

- Find suitable locations to install CRB traps using UV lure.
- Monitor *Pritchardia spp* populations to determine impacts by CRB.

Discussion:

The introduction of CRB to Oahu in 2013 has led many species in the palm family to be susceptible to damage or death. A recent influx of CRB hits at many locations throughout Oahu have prompted serious discussion on what can be done to save native palms, specifically *Pritchardia*, which are a major component in mesic-wet forests with some taxa being endangered. Although CRB prefer palm species, they have been found to persist on other hosts too. Research is being done to determine all hosts affected by CRB, which could include OIP taxa.

There is no evidence of CRB in Koloa, but there have been occurrences of them in traps on the North Shore. It is unknown if CRB larvae can complete its lifecycle within the soil of Koloa. Staff are working with partners on attaining climate data at Koloa to determine if conditions are favorable for CRB reproduction.

A trap had been previously set by the cabin to determine longevity under intense field conditions (wind, consistent moisture, etc.) but due to high winds could not maintain position and fell on the ground. If CRBs are a threat, another trap type will have to be employed as the current model did not fare well in Koloa. Until either physical signs of damage or new evidence that concludes that CRB can survive in the Koolau summits, no further actions regarding CRB are planned in the immediate future. Until either physical signs of damage or new evidence that concludes that CRB can survive in the Koolau summits, no further actions regarding CRB are planned in the immediate future.

Powdery Mildew Control

Species: species in the order Ersiphales (exact species unknown)

Threat Level: High

Seasonality/Relevant Species Biology: Prevalent in warm and moist conditions.

Management Objectives:

- Maintain low occurrences of mildew or mildew-free plant populations.

Strategy and Control Methods:

- Look for evidence of powdery mildew on rare plants during annual rare plant monitoring.
- Reintroduce plants into areas that do not have a prevalent mildew problem.

Discussion:

There are no current methods to control or limit the spread of downy mildew in the field. In the greenhouse downy mildew is prevalent and easy to control with fungicide. However, in the field downy mildew is usually not very common as higher elevations may not support a favorable climate. A large population of common *P. hirsuta* was outplanted in the Phyhir bowl and no plants were observed to be heavily affected by powdery mildew. In addition, other mint species (*P. grandiflora* and *Stenogyne* spp.) do not seem to be affected. With the unfeasibility of powdery mildew control in the field, staff should limit outplantings in places where powdery mildew is prevalent. If outplantings of *P. hirsuta* are occurring, staff should control powdery mildew at the greenhouse before taking plants into the field.

Fire Control

Threat Level: Low

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. Although Koloa is very wet, other places in forested Koolau Mountains have caught fire, including Kaukonahua.

Management Objective:

- 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:

- 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.

Discussion:

During most times of year Koloa is very wet and rainy, which are perfect conditions to prevent fire. However, with the lack of a rainy season and dry summers, there is potential for fire to occur. Ignition sources could include recreational hikers/campers. In 2021 the crew observed evidence of an open fire on the DZ near the cabin. Although the threat level is relatively low, fires could pose a huge threat to the resources in the area. Since the MU is mostly native, there is little that can be done to reduce fuel loads without destroying native plants. In the event of a fire, staff will utilize contract helicopters and Wildland Fire for assistance. Working with HRI, signage could be displayed on both sides of the KST and on the cabin.

Ecosystem Restoration Management Plan

MIP Year 19-23, Oct. 2022 – Sept. 2027

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: Army Natural Resources Program on Oahu

Acreage: 676 acres

Elevation Range: 1200-2200 ft.

Description: Ohikilolo (Lower Makua) MU is located in the Makua Military Reservation (MMR). The area is accessed at the mouth of the valley, or by helicopter to Landing Zones (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.

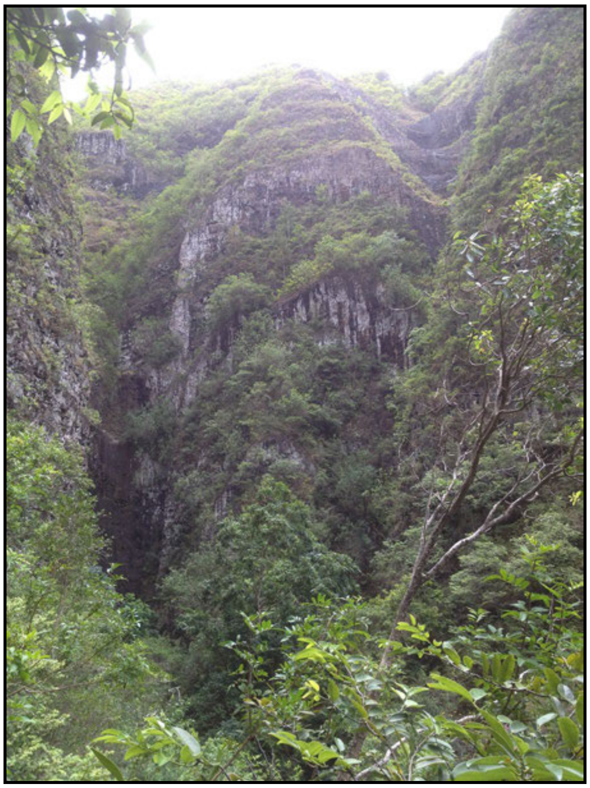
The Ohikilolo Management Unit (MU) is one of the larger MIP MUs. Management for this MU has long been divided informally among ANRPOO staff as the two following areas; Ohikilolo (Upper) and Ohikilolo (Lower Makua). The division is useful for management purposes because the access issues to each of the 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. Ohikilolo Upper and Lower have been treated separately in past reports because they are managed by two different field teams. For the purposes of the year-end report, they have been reported in Ecosystem Restoration Management Plans as two separate areas within the same MU.

Lower Makua is home to a variety of rare plant taxa. The 2003 Biological Opinion (BO) and Makua Implementation Plan (MIP) identified rare taxa, listed below, for management and set out goals and metrics for each species. However, the Army is currently in a re-consultation with Fish and Wildlife Service (FWS) and future BOs may support other taxa (Conservation Measures Taxa), also listed below. In addition the Army is revising its Integrated Natural Resources Management Plan (INRMP). As part of this the Army assessed the number of endangered taxa on Army land, the percentage of these taxa on Army land and the relative responsibility of the Army to manage these taxa. INRMP taxa are listed below.

Native Vegetation Types

Waiʻanae Vegetation Types	
Dry-mesic forest	Canopy includes: *Diospyros* sp., *Sapindus oahuensis, Psydrax odoratum, Nestegis sandwicensis, Myoporum sandwicense, Erythrina sandwicensis, Polyscias sandwicensis, Rauvolfia sandwicensis, Santalum ellipticum*, and *Myrsine lanaiensis*. Understory includes: *Dodonaea viscosa, Sida fallax, Bidens* sp., *Microlepia strigosa, Alyxia stellate.*
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 towards cliffs above

Steep cliffs of Koiahi gulch looking East

Photo taken from the Kahanahaiki overlook looking south to Makua

MIP Rare Resources at Lower Makua

Organism Type	IP Species	Population Reference Code	Population Unit	Management Designation	Wild/ Reintroduction
Bird	*Chasiempsis ibidis*	N/A	N/A	Manage	Wild
Plant	*Alectryon macrococcus* var. *macrococcus*	MMR- A*, D*, E*, F*, O-Q*, R	Makua	MFS	Wild
Plant	*Flueggea neowawraea*	MMR-C, D*, E*, I	Ohikilolo	GSC	Wild
Plant	*Hibiscus brackenridgei* var. *mokuleianus*†	None	Makua	None	Possible reintroduction
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

MFS= Manage for Stability GSC= Genetic Storage Collection *= Population Dead †= BO Conservation Measures taxa

Other Rare Taxa at Lower Makua

Organism Type	**Species**	**Status**
Bird	*Asio flammeus sandwichensis*	Species of concern
Bird	*Chasiempis ibidis*	Endangered
Bat	*Lasiurus cinereus semotus*	Endangered
Plant	*Alphitonia ponderosa*	Rare
Plant	*Asplenium dielfalcatum** (1)	Endangered
Plant	*Bobea sandwichensis*	Vulnerable

Organism Type	Species	Status
Plant	*Bobea timonioides*	Vulnerable
Plant	*Bonamia menzesii** (2)	Endangered
Plant	*Ctenitis squamigera** (3)	Endangered
Plant	*Dracaena forbesii** (1) †	Endangered
Plant	*Euphorbia haeleeleana** (1) †	Endangered
Plant	*Korthalsella degneri** (1) †	Endangered
Plant	*Lobelia niihauensis** (2) †	Endangered
Plant	*Melicope makahae** (1)	Endangered
Plant	*Nothocestrum latifolium** (3)	Endangered
Plant	*Ochrosia compta*	Rare
Plant	*Polyscias kavaiensis*	Endangered
Plant	*Pteralyxia macrocarpa** (1)	Endangered
Plant	*Sideroxylon polynesicum*	Vulnerable
Plant	*Spermolepis hawaiiensis** (2)	Endangered

* = INRMP taxa with relative priority designation in parentheses   †= BO conservation measures taxa

Locations of rare resources at Lower Makua

Image Redacted
Sensitive Information
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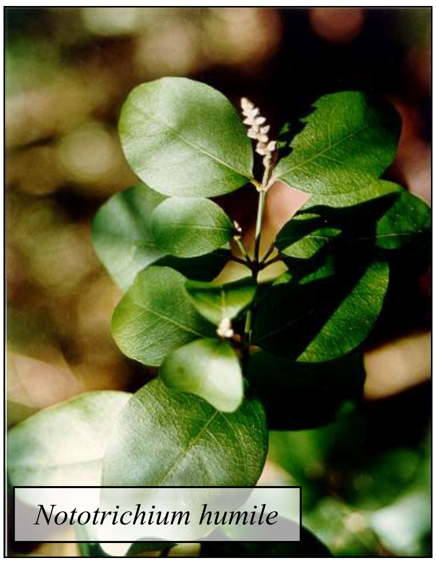
Rare Resources at Makua

Alectryon macrococcus var. *macrococcus* fruit

Chasiempsis ibidis



Nototrichium humile

Flueggea neowawraea

Neraudia angulata var. *angulata*

Sideroxylon polynesicum

Threats to MIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2022
Pigs	All	Across MU	Still Present in MU. Ongoing control in progress
Goats	All	Across MU	Unknown. Breaches occur above the MU on Ohikilolo Ridge but unknown if goats visit the lower valley.
Weeds	All	Rare taxa sites primarily, across MU secondarily	Regular maintenance required several times per year
Rat	*Chasiempis ibidis,* Potential threat to *N. angulata* and *N. humile*	Territory-specific A24 grids	Territory grids established 2022.
Feral Cat	*Chasiempis ibidis*	No control	No control necessary at this time
Mongoose	*Chasiempis ibidis*	No control	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
Cocount Rhinoceros Beetle	*Pritchardia* spp.	2 traps placed near LZs (Camp and Luna-Skeet)	No beetles caught. Traps act as a warning for protecting *P. kaalae* at Ohikilolo Upper.
Black Twig Borer	*Fluggea neowawraea*	None	No feasible control methods available at this time.
Fire	All	Across MU	Fire breaks, reducing fire fuel (ex. Grasses), planting common native plants.

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. Fence ran from junction with Keaau ridge to saddle above the "Hibiscus patch."
- 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. ANRPO began to employ neck snares as a management tool.
- 2001: The portion of the fence to West Makaleha was completed separating the valley from the core populations of goats in Keaau and staff employed aerial shooting and "Judas goats" as management tools.
- 2001-2004: Army resumes live fire training on a limited basis.
- 2002: Staff completed a small fence around a single *F. neowawraea* at MMR-C to prevent goat grazing.
- 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. Staff completed a strategic fence (MMR-G) protecting *N. angulata* var. *angulata* MMR-D from pig damage, after which the *N. angulata* MMR-E reintroduction population was established to augment the existing MMR-D population.

- 2004: ANRPO eradicated feral goats from lower Makua Valley, however, they may still be entering above from the fence on Ohikilolo Ridge.
- 2005: ANRPO completed two strategic fences (MMR-H) in the back of Koiahi gulch; they protect *N. angulata* from pig damage.
- 2006: Four goats breached perimeter fence, all were caught.
- 2009: Last two mating pairs of elepaio thought to be observed, however, new pairs were discovered in the valley in 2022.
- 2010-2011: ANRPO participated in fuels management work conducted by CALIBRE.
- 2011: Forest tree line mapped from helicopter using GPS to establish accurate weed control boundaries.
- 2013: Staff completed strategic fence (MMR-J) creating pig protected habitat for outplanting *N. angulata* var. *angulata* MMR-I outplanting.
- 2016: Final section of perimeter fence built to Kamehameha Highway; initiated snaring program across the valley.
- 2018: Staff lose access to Lower Makua MU due to UXO presence in work areas.
- 2021: Staff swept through MU identifying UXO.
- 2022: Detonation of known ordinance allows staff to commence working in MU again.
- 2022: Two mating pairs and two individual elepaio observed.
- 2022: *N. angulata* var. *angulata* MMR-E population is dead.

UXO Concerns and Discussion

There are many challenges to management in Makua. Access is limited, and scheduling with Range Control and Explosive Ordnance Disposal (EOD) specialists are required, due to UXO present in the valley. Most recently, personnel were locked out of Lower Makua from 2018-2021 due to UXO issues, lack of personnel during the COVID-19 pandemic, and coordinating appropriate Army entities. In September of 2021 staff worked to revisit all known UXO sites in the MU and survey additional areas with Army EOD. Through the end of 2021 DPW staff spearheaded extensive planning efforts with Range Control, Army EOD (Garrison and Battalion level), Army Wildland Fire, Army Aviation, and Army Public Affairs to develop a disposal plan. On January 11, 2022 two teams disposed of known UXO in the MU. However, two items previously seen could not be located on this date. Based on the type of ordnance and guidance from Army EOD, a shape was drawn around the GPS point as a “no-go” zone.

In addition to clearing all UXO, trails were recorded on GPS and marked clearly with blue flagging and orange spray paint. “Cleared” areas for resource management work include blue flagged trails and areas above this trail within Weed Control Areas (WCAs) (see map below). Areas above Lower Makua have been deemed safe and designated as UXO-free zones (ie: Kahanahaiki subunit II and Ohikilolo Ridge) where there is no change in management activities.

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. Medium for goats; Goats have breached the Ohikilolo fence on occasion, there are numerous goats on the south facing slope of Keaau.

Management Objectives:

- To maintain all areas of the MU as goat-free and have minimal pig activity observed.
- Utilize box traps, snares, and corral trap methods to suppress pig population within MU and eventually entire valley.

Strategy and Control Methods:

- Conduct quarterly PU fence checks: Makua Valley (MMR-G and MMR-J), Koiahi Gulch (MMR-H).
- Note any ungulate activity while preforming day to day actions within fenced MU.
- Establish ungulate monitoring

Discussion:

The entire Makua Valley perimeter is currently fenced off, but there is still ungulate signs within it. The presence of UXO in the valley make it difficult to do ungulate control with on-the-ground methods (snares, game cameras, trapping, tracking, etc.). With the addition of thermal cameras within the helicopter, early morning surveys are now possible. On January 18th, 2022 a thermal aerial survey was conducted in Makua Valley. Thirteen pigs were observed inside the MU, and a small herd of goats were spotted outside the fence in Keaau. We are actively on watch at all times for any physical signs of both pig and goat while in the MU. The program is interested in developing protocols for aerial drone use for ungulate monitoring, but not actively pursuing it at this point in time. Using these techniques at our disposure, we can ensure the safety of personnel while surveying in Makua.

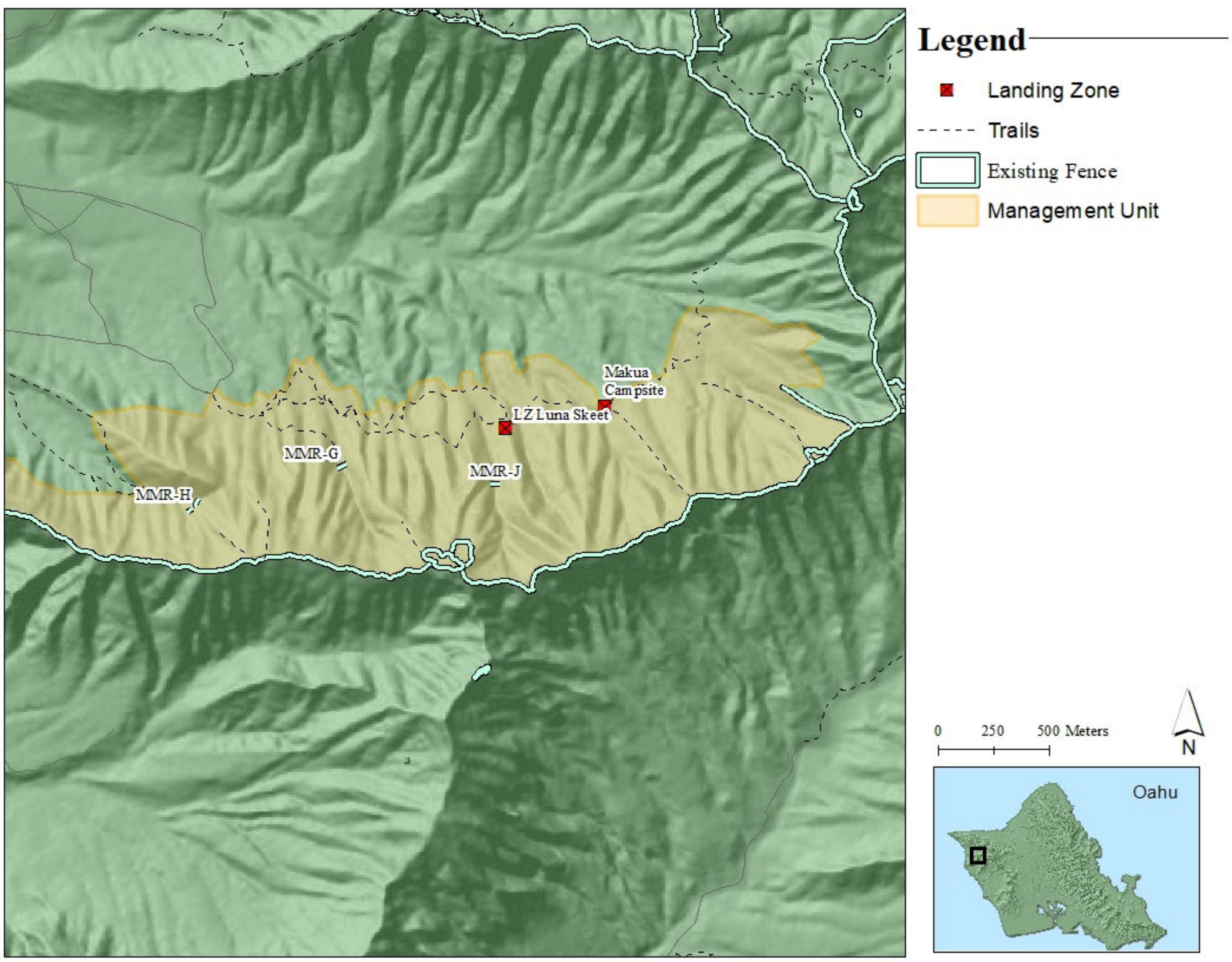
Monitoring movement is also a tool to get an idea of how many pigs frequent a certain area. One method is by using static motion detection game cameras along trails. The cameras both have colored daytime lenses along with an infrared lenses for night vision. We are considering two methods for camera placement: the first one is to place the cameras in 1km grids where deemed accessible, and the second option is random sampling via 50/50 split between ridge/gulch, again where deemed safe and accessible. Bait will be placed in these strategic areas to lure in ungulates to determine the density of the population within these key areas. Based on the photos, a decision can be made to implement control in the area and determine if current techniques are working or not. Another monitoring method would be utilizing GPS. This method would include GPS collars, ear tags and game cameras to assess population density and location. Based on the number of tagged/collared pigs vs non-tagged pigs, we can begin to make an assessment of the population size within our study area. The results will yield patterns in movement, home ranges, and determine if the control techniques are successful.

Since pigs were observed in the MU in early 2022, snaring lines will have to be re-established by using the current snare lines or making new lines. Live traps are also proposed along the firebreak road. With the constant threat of UXO in the area, most of the snaring efforts will remain along and above the blue hiking trail, which crosses through the entire MU.

Hunters can sometimes enter the MU from the outside, most recently from Kuaokala and possibly through the sluice gates along Farrington Highway. This is an issue because of the threat of UXO and snares in the area. It is a danger for themselves and the dogs they use in hunting activities. There are warning signs about the potential dangers in Makua set up on the perimeter fence, but if ungulate control continues in Makua and the pig numbers go down, it might deter hunters from entering Makua at all. There are also concerns about vandalism to natural resource gear in the field like game cameras, fence/snare damage.

While the perimeter fence on the adjacent ridgeline of the MU is managed by the Blue Team, there are three interior fences in lower Makua valley (MMR-G and MMR-J) and one in Koiahi gulch (MMR-H) that are covered in this management plan. All interior fences are enclosing populations of *Neraudia angulata* var. *angulata* and *Nototrichium humile*. 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.

Ungulate Management Map



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

MU Vegetation Monitoring

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 in 2016. The steep cliffs dividing Ohikilolo (Upper) from Ohikilolo (Makua) cannot be monitored for vegetation cover at the current time. This document focuses on the lowest elevation section of the MU, Lower Makua.

Given the low number of MIP taxa (5) located in the Makua portion of the MU and since Makua is entirely in a UXO area and entry requires a UXO escort, ground-based monitoring would be very expensive and is not a feasible option at this time. However, with advances in technology, aerial imagery with the utilization of drones could prove a useful tool in monitoring canopy and cliff species in the MU or to detect novel alien canopy weeds, which will be a priority for control. Other options for vegetation monitoring, are the use of photo points and point intercept methods which will measure the results of weed control efforts or the lack thereof. LiDar imagery is also an option as high-quality images have been taken at other MUs.

Surveys

Potential Vectors: ANRPO staff and helicopter operations, ungulates, 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.

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.

Discussion:

Surveys are designed to be the first line of defense in locating and identifying potential new weed species. Roads, landing zones, fencelines, and other highly trafficked areas are inventoried regularly; Army roads and LZs are surveyed annually, non-Army roads are surveyed annually or biannually, transects are surveyed at least annually, while all other sites are surveyed quarterly or as they are used. At Makua, two landing zones (Campsite and Luna-Skeet) will be surveyed at least once per quarter. A weed transect will be established along the blue trail.

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 ANRPO in the MU, but due access challenges the ICA is not visited frequently. ANRPO will continue to monitor and conduct incipient control when appropriate.

Summary of ICAs

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 the lower stretches of Makaha valley. The ICA is located at Makua Well site, at the bottom of NerAng gulch. One immature tree was found in 2013 and none were spotted in 2021. May discontinue according to seed longevity and absence of plants.

Incipient Weed Photos

Sideroxylon persimile

Incipient and Weed Control Areas Map

Image Redacted
Sensitive Information
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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.
- If monitoring for any MIP goal is installed, and if results suggest goals are not being met, staff will increase/expand weeding efforts.

Discussion:

The Ohikilolo Makua dry forest is unique, with impressively tall native canopy and numerous *O. compta.* There are large groves of native-dominated dry forest, and observations of previously 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. The following WCAs will be prioritized based upon rare resources and the status of each WCA based upon staff observations, WCAs: 05, 12, 15, 16.

UXO is a major safety concern. Since the UXO scope and clean-up in 2021-2022, it was decided that areas below the blue trail (where UXO sweeps have not occurred) will be off limits except for areas that have been previously weeded. If an area is deemed unacceptably dangerous, staff 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
Ageratum adenophora	Restricted	Can compete with recruiting *N. Angulata* var. *angulata*
Ageratina riparia	Restricted	Can compete with recruiting *N. Angulata* var. *angulata*
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.
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 and controlled. There was an ICA on firebreak road that was eradicated in 2014.

Taxa	Distribution	Notes
Cenchrus setaceus	Restricted	Scattered populations at entrance of Makua Valley (L.Ohikilolo) and Keaau Valley. None found within managed WCAs, but due to invasive capability should be controlled wherever seen.
Coffea arabica	Widespread	While common in Koiahi gulch, *C. Arabica* distribution has expanded into areas east of Koiahi gulch. We need to conduct surveys to understand how widespread it has become. Will need to control around rare taxa. It should be a priority for early detection and rapid control.
Falcataria moluccana	Scattered	Scattered throughout the valley, but not present in managed WCAs.
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. Incision Point Application (IPA) is effective.
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.
Leucaena leucocephala	Widespread	Common in the MU, this is a target whenever seen near native forest patches. It is best controlled with Triclopyr in a 40% mix or with IPA aminopyralid.
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.
Passiflora edulis	Scattered	Widespread throughout the MU.
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. Possible Tectacoccus release.
Schinus terebinthifolius	Widespread	Widespread across the MU, *S. terebinthifolius* becomes the dominant vegetation as the ridges climb in elevation.
Spathodea campanulata	Scattered	While this tree has a wide distribution, it is not common in the MU. It should be treated wherever seen. IPA trials were completed. IPA wasn't 100% but IMZ was best performer.
Syzygium cumini	Widespread	With its thick bark, *S. cumini* is difficult to control. Chainsaw girdling and Triclopyr application are most effective. Another method that is going to be trialed is drilling into the tree and adding glyphosate. 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. Mapping the area via aerial images will help in understanding if *T. ciliate* is widespread or not. IPA with aminopyralid or imazapyr are effective.
Triumfetta semitrilobata	Widespread	This shrub should be controlled around rare taxa and along trails.
Megathyrsus maximus	Scattered	Formerly *Urochloa maximum*. This grass has a very high burn index. Any patches in/near native forest patches are a high priority for control.

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 Lower Makua.

Taxa Considerations for Restoration Actions:

Native Taxon	Growth Habit	Outplant/SDT	Notes
Abutilon incanum	Shrub	Outplant	Grow from seed. Sporadic germination?
Bidens cervicata	Herb	Outplant	Grow from seed. Need more collections. Candidate for seed orchard.
Carex wahuensis	Sedge	Outplant	Grow from seed. Good ground cover until larger canopy species can establish
Diospyros spp.	Tree	Outplant	Grow from seed. Slow growing tree but hardy.
Dodonaea viscosa	Shrub	Outplant	Grow from seed. Fast growing shrub/ small tree.
Eragrostis variabilis	Grass	Outplant	Grow from seed. Good groundcover until larger canopy species can establish. Candidate for seed orchard.
Erythrina sandwicensis	Tree	Outplant	Grow from seed. Drought/full sun tolerant.
Heteropogon contortus	Grass	Outplant	Grow from seed. Drought/full sun tolerant. Need collections.
Hibiscus arnottianus	Tree	Outplant	Grow from seed.
Microlepia strigosa	Fern	Outplant	Grow from spore. Good groundcover until larger canopy species can establish. Plant in 18" spacing or tighter for weed suppression.
Myrsine lanaiensis	Tree	Outplant	Grow from seed. Need collections.
Myoporum sandwicensis	Shrub	Ouplant?	Can grow from seed, but Naio thrips present challenge.
Polyscias sandwicensis	Tree	Outplant	Grow from seed. Need collections.
Psydrax odorata	Tree	Outplant	Need to grab snatchlings if desired. Slow growing but hardy. Fruit often bored.
Santalum ellipticum	Shrub	Outplant	Grow from seed. Companion plant in container.
Sapindus oahuensis	Tree	Outplant/ Seedsow	Grow from seed. Seed recalcitrant. Slow growing but large footprint once established. Seedsows possible especially if cleaned and soaked prior to sow.
Scaevola taccada	Shrub	Outplant	Grow from seed if possible. Need collections.
Sida fallax	Herb	Outplant	Grow from seed. Sporadic germination.
Waltheria indica	Herb	Outplant/Seedsow	Grow from seed. Need more collections. Candidate for seed orchard.

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. Weeding may improve native recruitment now that the area surrounding these rare plants is fenced. 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 invasive ferns can be hand pulled or clipped and dripped 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 plants/base of cliff in hopes of fostering recruitment. There are a few *N. angulata* at the foot of the cliffs. Weeding may improve native recruitment now that the area surrounding these rare plants is fenced. 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 foliar herbicide sprays.

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: 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-07, due to the presence of native-dominated forest nearby. This WCA contains large intact dry-land forest stands of *E. sandwicensis* and *Diospyros* spp. and is a candidate for future outplantings of *H. brackenridgei* subsp. *mokuleianus.*

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 have occured in an area known as “Banana gulch”, where populations of *Melanthera tenuifolia, Nototrichium humile*, and *Neraudia angulata var. 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. In 2022 the site was monitored for any remaining outplanted *N. angulata* var. *angulata* (MMR-E), however, none were found. It has been deemed not suitable for future rare plant outplantings and weeding priorities within the fence will be reduced. Additional weeding efforts have been focused along the trails within this WCA. Continued non-native canopy removal may help native seedlings get re-established. 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. Continuing off the grassy ridges toward the gulch bottoms there is a border of *P. cattleianum* that limits grass ingress upslope of the gulch.

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 population of *N. humile* (MMR-I) is outplanted within a small fence at the back of a slot gulch. This gulch habitat is similar to the one in Ohikilolo-07 where a population of *N. humile* (MMR-H, MMR-D) and *N. angulata* (MMR-D) are. Staff have not been back to rare plant sites to monitor, however it seems unlikely to be a suitable area for future ouplantings. Continued non-native canopy removal may help native seedlings re-establish in the gulches. Large 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. Unfortunately access to this WCA is limited due to its remote location. It is almost halfway between the makua firebreak road and the Lower Makua Campsite/LZ. Much of the WCA is native, especially along the Blue trail. Plans to do restoration work in mostly native habitat along the trail would be beneficial to maintain diversity in the dryland forest. Opportunities for targeted *T. ciliata* sweeps are possible, however, since most of the WCA does not promote good habitat for common or rare plant reintroductions, priority for weed control in this WCA is low.

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*, *M. azedarach*

Notes: This is one of the largest WCAs in Makua, and contains one of the largest populations of INRMP and SAR species. Due to 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* (historic), and *B. sandwicensis*. Additional native plants present in this area include *D. sandwichensis*, *P. odoratum*, *Sapindus oahuensis*, *Nestegis sandwicensis*, and the rare *Alphitonia ponderosa*. 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 *T. 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. This WCa has potential for restoration and common reintroductions.

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: Containing the most intact native dry-land forest patches within the MU, this WCA has an abundance of common, INRMP, and SAR species such as *O. compta*, *A. ponderosa* and *M. tenuifolia*. Although the highest concentrations of *Alectryon macrococcus* var. *macrococcus* reside here, they have steadily declined possibly due to rat predation, disease, and the black twig borer (*Xylosandrus compactus*) and are probably no longer existing. The high number of rare taxa in this WCA make it a priority for weeding and restoration. Future efforts will focus on sweeps up towards steep cliffs, due to the close proximity to Campsites/LZs. Large, monotypic stands of *P. cattleianum* will be avoided, and weeding will focus on chainsaw girdling and herbicide application of *P. cattleianum* that is intermixed with natives. 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. A scope in March 2022 was conducted six years after the last weed control effort and showed a surprising amount of weed suppression. In the canopy large *P. cattleianum* were dead and native trees were filling in (*D. hillibrandii*, *M. polymorpha*). The understory remained mostly bare dirt, with few instances of weeds (*A. adenophera*, *A. hispidulum* and *P. cattleianum*). Weed control efforts in areas such as these would require minimal effort and maintenance while preserving biodiversity in native areas.

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 the only confirmed *C. ibidis* population within the MU, as well as rare and endangered taxa such as, *A. macrococcus* var. *macrococcus* (historic), *Pteralyxia macrocarpa*, *A. ponderosa*, and *Ctenitis squamigera.* 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.* Selective control of *P. cattleianum* will occur to prevent light gaps and weed incursion in the understory. The priority for this WCA is to concentrate weeding efforts in the flat area below *A. ponderosa*. Two LZs in this WCA (Arch Camp and Upper Lower Makua) have been discontinued. Upper Lower Makua LZ could be used in the future to access Elepaio territories.

WCA: MMRNoMU-09 (Elepaio 15 LZ)

Veg Type: Dry forest

MIP Goal: None

Targets: *G. robusta, S. campanulata, T. ciliata*, *M. minutiflora*, *M. maximus*

Notes: This LZ was created to assist the monitoring of Elepaio in the gulches upslope. This small area is rarely used and is an infrastructure WCA to track weed efforts to clear the trail and LZ. 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 will be performed.

WCA: MMRNoMU-13 (Makua Eucalyptus LZ)

Veg Type: Dry forest

MIP Goal: None

Targets: *G. robusta, S. campanulata, T. ciliata*, *M. minutiflora*, *M. maximus*

Notes: This LZ was created to assist the monitoring of Elepaio in the gulches upslope. This small area is rarely used and may be discontinued if not needed to access Elepaio. Future weeding actions will not be scheduled in this WCA, but will be used to track any incidental weeding that occurs.

Small Vertebrate Control

Species: *Rattus rattus (*Black Rat), *Mus musculus* (House Mouse), *Herpestes auropunctatus* (small Indian mongoose), Felis catus (domesticated cat),

Threat level: High

Seasonality/Relevant Species Biology: Year round.

Management Objectives:

- Provide rodent control to Elepaio territories that have been observed in the area.
- Continue to monitor managed taxa in the area for demonstrated damage from rodents (NotHum, NerAng)

Strategy and Control Methods:

- Small rodent control grids Elepaio territories.
- Monitor rare plant populations and note any rodent damage.

Discussion:

Currently no rodent control is conducted for rare plant populations, only control for Elepaio. However, total rodent control along with UXO restriction make the installation of an MU grid unpractical.

The status of Elepaio and snail numbers are unknown until proper surveys are completed. The snail population (AchMus MMR-J) was last monitored in 2000, but there is common belief that there are no snails left. Elepaio numbers have increased since the last survey in 2009. A survey in March 2022 discovered two pairs, and a single male. However, because of time constraints the crew was unable to survey the area entirely, but there is reason to believe that more pairs exist in the valley. Since the discovery of these pairs, an A24 grid was installed 3/21/2022 around one of the territories (9 traps), while the other remains unprotected for now. When new pairs are observed, small A24 grids will be installed in their territory. Tracking tunnels will not be employed as they need to be monitored on a regular basis.

Future management for small vertebrates in Lower Makua is to install small A24 grids around Elepaio territories. The Goodnature A24 is our programs primary rodent control tool. With the addition of a slug deterrent lure in an automatic lure pump, the checking interval is once every 6 months.

Slug Control

Species: *Deroceras leave, Limax maximus*

Threat level: Unknown

Seasonality/Relevant Species Biology: Wet season

Management Objectives:

- Annual census monitoring of *Nototrichium humile* seedling recruitment following fruiting events.

Strategy and Control Methods:

- Define Slug Control Areas (SLCAs) around rare plant locations. Prior to any control, complete the Pre-Application Survey Protocol; see below. A buffer of at least 5 meters from vulnerable plants is recommended. 10 meters is optimal.
- Calculate amount of Ferroxx needed to treat SLCA. Orient staff to SLCA and train applicators.
- Apply Ferroxx quarterly based on irregularity of visits to Lower Makua and overall dry conditions.
- If rare snails are found in an established SLCA, treatment will be halted. Rare snails will be relocated to the MU snail enclosure, and the Pre-Application Survey Protocol will resume.
- Conduct slug abundance monitoring with baited beer traps. Use data to inform whether control is needed, and/or if it may be seasonal versus annual.

Discussion:

Slug control is conducted at rare plant sites where slugs pose a significant threat to the survivorship of individual plants and/or survivorship of seedlings, where slugs are present, and where native snails are absent.

During annual rare plant monitoring, inspect plants for herbivory, and document potential slug damage and presence on plants. Indications that slugs are responsible include 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). Some rare plant taxa are known to be susceptible to slug damage, and control may be warranted even before any impact is seen.

Another factor to consider is slug abundance and seasonality. Slugs may only be present seasonally, or in low numbers, especially in dry habitats. Control may not be needed at all, or not at certain times of year. At some sites, it may be useful to measure slug abundance using baited beer traps, monitored after two weeks. If the number of slugs captured per trap over two weeks exceeds one slug per trap, slug control may be needed. Beer trap monitoring requires frequent visits, and is just one optional tool to inform control needs and frequency.

Slugs have not been observed feeding on *N. angulata* and *N. humile*. Both taxa occur in habitat frequented by slugs making contact possible. The habitat in Lower Makua is unfavorable for slugs in some areas, however, deep moist gulches where rare taxa exist are favorable slug habitat. In addition, seasonal changes during the summer/dry season may limit slug activity. In the future staff will monitor for slug presence while doing other natural resource management actions in the area to assess any damage. Beer traps will be employed as necessary and Ferroxx will be applied once per quarter if deemed necessary due to the limited number of trips to Lower Makua.

Consult with the Rare Plant Program Coordinator and Invertebrate & Forest Invasive Species Biologist to determine if slug control is warranted at a particular site. Prior to any control, follow the Pre-Application Survey Protocol:

Pre-Application Survey Protocol:
For control only of slugs and non-native snails via listed, approved molluscicide application in forests, on offshore islands, and in other natural areas to protect threatened and endangered Hawaiian plants. Only Ferroxx AQ® Slug and Snail Bait is approved for use in forest areas in Hawaii. Area must be thoroughly searched by experienced malacologists prior to application of Ferroxx AQ® granules to ensure that non-target native Hawaiian snail species are not impacted. Do not apply in areas where it may come into contact with known

populations of endemic Hawaiian snail species from the following rare families or subfamilies: Amastridae, Achatinellinae and Endodontidae. Bait cannot be applied within 20 m of any tree known to harbor endangered Hawaiian tree snails (*Achatinella* spp.).

1. Conduct thorough day survey of proposed treatment area to include searching trees and all understory vegetation. The ground and rock talus areas will also be search. An effort to identify other snails found and their rarity will be made prior to Ferroxx use.
2. If proposed treatment area is known *Achatinella* spp. site or if *Achatinella* spp. is observed during day survey, then must conduct night survey and remove all *Achatinella* spp. to a snail enclosure/protected area prior to bait use.
3. Area will continue to be surveyed and *Achatinella* spp. translocated to enclosures until all *Achatinella* spp. are removed from the area and at least one survey is conducted where 0 snails are found within area.
4. If *Achatinella* spp. are abundant in large numbers or are found on multiple trips, use of Ferroxx will not be allowed in area.
5. If *Achatinella* spp. are located in the area in the course of other field work, then surveys and relocation efforts will resume.
6. An effort to identify other snails found and determine their rarity will be made prior to Ferroxx use.

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:

- 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:

- 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 human entry points a minimum of once a year. Use samples to track changes in existing ant densities and to alert staff 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 ANRPO to any new introductions.
- Look for evidence of ant tending of aphids or scales on rare plants during annual rare plant monitoring.

Discussion:

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, but there are a variety of species near the pavilion at range control and along the road in the akoko patches. There is the possibility of transferring new ant populations to Lower Makua via sling loads, trucks, personnel. We will continue to monitor for any infestations.

There are no known *Drosophila* spp. present at Lower Makua, however, the host taxon, *Dracaena forbesii* is present in the MU. If *D. montgomeryi* is found in Lower Makua, staff will survey *D. forbesii* sites to determine if ants are present.

Black Twig Borer Control

Species: *Xylosandrus compactus*

Threat level: High

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

Management Objectives

- Monitor *Alectyron macrococcus* var. *macrococcus* and *Flueggea neowraea* survival.

Strategy and Control Methods:

- Annual or every other year census monitoring of *Alectyron macrococcus* var. *macrococcus* and *Flueggea neowawraea* populations. Note any damages due to BTB.

Dissussion:

Heavy decline of *F. neowawraea* and *A. macrococcus* due to *X. compactus* has been difficult to manage. Heavy watering and fertilization of targeted plants has been successful at reducing BTB damage in agricultural settings, but is not practical on wild plants. There are currently no reintroductions planned, but possible reintroduction sites could include wet gulches or the spring where there is an abundance of water for plants to grow quickly enough to outcompete *X. compactus* damage.

Coconut Rhinoceros Beetle

Species: *Oryctes rhinoceros*

Threat level: Low

Seasonality/Relevant Species Biology: Immature stages are in the soil, while matures are above ground and able to fly

Management Objectives:

- Determine if CRB range has increased into Makua Valley

Strategy and Control Methods:

- UV light trap
- Visual damage on any *pritchardia spp*

Discussion:

There are eight pheromone traps established around the entrance of Makua Valley. Staff are unsure if there is a breeding population of *O. rhinoceros* in Makua or if individuals are coming from a known breeding site in Makaha. Nineteen coconut trees growing around range control were cut down to limit host plants for *O. rhinoceros*, however, coconut is not the only known host. *O. rhinoceros* poses a threat to *P. kaalae*, which occur in the Upper Makua MU (Ohikilolo Ridge). Staff are working with partners to do trials with other native taxa that may be at risk to *O. rhinoceros*.

Two CRB light traps were installed at Lower Makua. Light lures were chosen instead of pheromone lures because of the uncertainty of the level of attractant of the pheromone at certain distances. The decision to use light lures would limit the probability of attracting *O. rhinoceros* to the back of the valley where *P. kaalae* exist nearby. One trap was installed at the main campsite LZ and the other was installed at Luna-Skeet LZ. If either of these traps detect *O. rhinoceros*, localized control will begin to limit spread.

CRB trap locations

Image Redacted
Sensitive Information
Available Upon Request

ARMY NATURAL RESOURCES PROGRAM O'AHU

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 within the fuel break with native species.
- Reduce fuel loads in forest patches by controlling grasses.

Past Fires Map

Image Redacted
Sensitive Information
Available Upon Request

<u>Discussion:</u>

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. The Army's general protocol for 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.

No live-fire training has occurred in Makua in the past twenty 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.

ANRPO 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. ANRPO will support fire-fighting with helicopters and staff. In WCAs, grass patches will be controlled and no canopy weeding will be done on the edge of the grass/forest line to suppress grass incursion into forested areas. *Cenchrus setaceus* is an invasive, highly flammable species that is present along Ohikilolo ridge and in neighboring Keaau on private land. It is a high risk to managed taxa, Identifying and controlling *C. setaceus* as a target taxa will continue to be a high priority.

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), fuel suppression via planting of common natives (such as *Dodonea viscosa* or *Osteomeles anthyllidifolia*).

Ecosystem Restoration Management Plan
MIP Year 19-23 Oct. 2022-Sept. 2027
OIP Year 16-20 Oct. 2022-Sept. 2027
MU: Pualii North and Pualii No MU

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, ANRPO, OPEPP, OSEPP

Acreage: 25 acres

Elevation Range: 1800-2775 ft.

Description: Pualii North 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 cliffs 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 Pualii North consists of a non-native dominated southern aspect (mostly *Eucalyptus* sp. and *Schinus terebinthifolius*) and a mixed native and non-native northern aspect. The lower slope and gulch bottom of the north aspect 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 limited to the area immediately around the *H. oahuensis* reintroduction. Below the fence, South Pualii gulch is largely unmanaged and highly degraded. The forest composition is similar to North Pualii with much fewer native canopy species. Previously, a single mature *Urera kaalae* was located along with historic populations of *Achatinella* and *Amastra.* Management is limited to target species sweeps every three years.

Infrastructural resources include two 250 gallon water catchments and tanks on adjacent ridges atop North and South Pualii and a landing zone at the crestline above South Pualii . A small PU fence in the adjacent Napepeiauolelo Gulch to the south, with similar habitat to Pualii North, is not a part of the MU. The small PU fence once contained a wild *Hesperomannia oahuensis* population but currently, a small patch of *Dissochondrus biflorus* (a Species of Concern) is the only rare taxon still in the Napepeiaoolelo fence. There is no current plan to do further management of the Napepeiaoolelo PU fence, its proximity to Pualii North and the former *H. oahuensis* population are the only reason for mention in this MU plan.

Pualii North MU is accessed via Kunia road, through the Kunia Loa Farm Lots in the south and the northern start of the Honouliuli Contour Road. The 25-acre fence was installed by The Nature Conservancy in 2006. Numerous rare plant reintroductions were conducted 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 Pualii North MU gulch bottom for reintroductions of *Urera kaalae*, *Sicyos lanceoloideus,* 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., *Antidesma platyphylum*, *A. pulvinatum, Rauvolfia sandwichensis, Bobea* spp*.,* and *Santalum freycinetianum*. Understory includes: *Alyxia oliviformis, Bidens torta, Coprosma* spp., and *Microlepia strigosa*
NOTE: For MU monitoring purposes vegetation type is mapped based on theoretical pre-disturbance vegetation. Alien species are not noted.	

Terrain and Vegetation Types at 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

Gulches and MUs at Pualii

Image Redacted
Sensitive Information
Available Upon Request

MIP/OIP Rare Resources

Organism Type	Species	Pop. Ref. Code	Population Units	Management Designation	Wild/ Reintroduction
Plant	*Hesperomannia oahuensis*	PUA-A	Pualii North	MFS	Reintroduction
Plant	*Phyllostegia mollis*	PUA-A*	Pualii North	MFS	Reintroduction (failed)
Plant	*Flueggea neowawrea*	PUA-A*	Pualii North	GSC	Reintroduction (failed)
Bird	*Chasiempis ibidis*	NA	NA	None	Consistently observed, no management designation
Arthropod	*Drosophila montgomeryi*	PUA-A	Pualii North	MFS	Wild, possibly extirpated

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

Other Rare Taxa at Pualii North

Organism Type	Species	Status
Plant	*Abutilon sandwicense*	Endangered (TNC reintroduction)
Plant	*Asplenium unisorum*	Endangered
Plant	*Asplenium dielfalcatum*	Endangered
Plant	*Bobea sandwicensis*	Endangered
Plant	*Cenchrus agrimonioides* var. *agrimonioides*	Endangered (wild and TNC reintroduction)
Plant	*Dracaena forbesii*	Endangered
Plant	*Delissea waianaeensis*	Endangered (TNC reintroduction)
Plant	*Dissochondrus biflorus*	Rare on island
Plant	*Geniostoma kaalae*	Endangered
Plant	*Exocarpus geudichaudii*	Endangered
Plant	*Gardenia brighamii**	Endangered (TNC reintroduction)
Plant	*Lobelia yuccoides*	Endangered
Plant	*Neraudia melastomifolia*	Endangered
Plant	*Phyllostegia parviflora* var. *lydgatei*	Endangered*
Plant	*Sideroxlon polynesicum*	Vulnerable (from South Pualii)
Plant	*Solanum sandwicense*	Endangered (TNC reintroduction)
Plant	*Schiedea ligustrina*	Species of Concern
Plant	*Schiedea pentandra*	Endangered
Plant	*Sicyos lanceoloidea*	Endangered (wild and reintroduced, OPEPP managed)
Plant	*Stenogyne kanehoana**	Endangered (TNC renitroduction)
Plant	*Stenogyne kaalae* var. *kaalae*	Species of Concern
Plant	*Tetramolopium lepidotum* var. *lepidotum*	Endangered (TNC renitroduction)
Plant	*Urera glabra*	Vulnerable (ANRP CN planting)
Plant	*Urera kaalae*	Endangered (wild* and reintroduction, OPEPP managed)
Snail	*Achatinella concavospira**	Endangered
Snail	*Achatinella mustelina**	Endangered
Snail	*Auriculella ambusta*	Species of Concern
Arthropod	*Drosophila flexipes*	Vulnerable (Sapindus host)

*= Extirpated (10 years or less)

Rare Resources at Pualii North

Reintroduced stand of *Abutilon sandwicense*

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.


Hesperomannia oahuensis

Locations of Rare Resources at Pualii North and Pualii NoMU

Image Redacted
Sensitive Information
Available Upon Request

Threats to MIP/OIP MFS Taxa

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2022
Ungulates	All	Across MU	Pig scat observed inside fence on 3/9/22, all snares in the area reset.
Rodents	All	Localized control around *Hesperomannia oahuensis*	Trap grid maintained regularly, increased from 12 traps to 25. Additionally, D-50 to be hand broadcast yearly from March/April to August, starting April 2022.
Ants	*Drosophila* sp.	Control in North Pualii gulch, within fence	No current control, flies absent on all recent surveys.
Weeds	All	Rare taxa sites primarily, across MU secondarily	Regular maintenance required several times per year.
Fire	All	No control	Reduce fuel loads, especially grass along access trails/fence line
Black Twig Borer	*Flueggea neowawrea*, *Abutilon sandwicense*	No control	No control necessary at this time. All *F. neowawrea* outplants have died. ANRPO currently does not manage *A. sandwicense* in this MU.
Slugs	*Hesperomannia oahuensis*	Affected rare taxa sites only	Monitor rare plants for damage; no control currently

Threat	Rare Taxa Affected	Management Strategy	Current Status, 2022
Coconut Rhinoceros Beetle	Unknown, possible threat to *Dracena forbesii*	No Control	A trap on the Honouliuli contour road at the Pualii trailhead consistently catches, known large infestation in Kunia farm Lots.
Jackson's Chameleon	*Drosophila* sp., *Achatinella* sp.	No control	No control necessary at this time for *Drosophila* sp. All *Achatinella* sp. have been moved or no longer extant.

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.
- 2010-2014: ANRPO reintroduces *Hesperomannia oahuensis, Flueggea neowrawrea, Delessia waianaensis,* and *Phyllostegia mollis* to Pualii . *P. mollis* reintroductions all fail to recruit and die, *F. neowrawera* and *D. waianaensis* slowly die-off but *H. oahuensis* reintroduction thrives.
- 2013- First mature *H. oahuensis* observed.
- 2013-2014: ANRPO surveys Pualii for *Drosophila* sp., 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.
- 2014-2015: OSEPP translocated most of the *A. concavospira* snails to the Palikea snail enclosure.
- 2015: *Urera glabra* outplanted in gulch, low survivorship after first year. First *H. oahuensis* fruit/seed collected from hand pollinated plants at site
- 2015: Rodent control initiated at *H. oahuensis* reintroduction with 12 Victor snap traps and 4 A24 repeating traps.
- 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.
- 2016-18: Goats detected along crestline and in South Pualii . DOFAW allows snare groups along crest outside fence.
- 2017: Victor snaps removed and 8 more A24 traps added for a total of 12.
- 2019: *Urera glabra* planted for *Drosophila* stabilization. Common taxa planting collaboration between Outreach and Blue Team in northern gulch later in year. Again, poor survival and most dead within one year.
- 2020: Pig sign observed in South Pualii gulch below *Hesperomannia*, snares set and pig caught four months after initial observation.
- 2020: TNC catchment above *H. oahuensis* reintroduction observed collapsed on visit for monitoring and subsequently repaired.

- 2018-2021: Three anecdotal observations of native birds (amakihi and apapane) visiting *Hesperomannia* flowers. Pollinator monitoring initiated in 2021 using ten game cameras and playback system through flowering season.
- 2021: Rat cache of *Hesperomannia* flowers/immature fruit observed, subsequent game camera observations confirm flower predation by rats.
- 2022: 13 additional A24s added around *H. oahuensis* and seasonal D-50 application initiated (15 lbs applied 5-7 days apart, April to October based on observed flowering time)
- 2022: Pollinator monitoring equipment redeployed during *H. oahuensis* flowering/fruiting. Significant interactions observed on game camera footage of native honeycreepers visiting *H. oahuensis* flowers.

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:

- Exclusion of all ungulates from MU via fencing. The PUA-A fence was completed in 2006
- Conduct quarterly fence checks and monitor as needed after extreme weather events.
- Note any pig sign while conducting day-to-day actions within fenced MU.
- If any pig activity is detected, work with Ungulate Biologist to implement removal strategy.

Discussion: Pigs are somewhat frequent visitors outside the fence and small individuals have taken advantage of gaps under the fence to access the unit. Skirting near the gulch crossing just below the *H. oahuensis* planting was lifted by an uprooted tree and has been repaired.

Goat activity had been high along the crestline and into South Pualii in the past. This lead to seeking and getting DOFAW approval for snare groups set immediately outside the unit between 2016 and 2018. Around this time, there were sightings of domestic goats within the Honouliuli Forest Reserve, presumably from the Kunia Loa Farm Lots. Significant numbers of goats have also been observed in Lualualei, the network of drainages to the west of Pualii North MU. Should an increase in goat activity be observed, especially near the *H. oahuensis* planting, permission to snare outside the MU may be sought again.

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. The addition of a hypalon barrier similar to that installed at other problematic gulch crossings in other MUs is being considered for this site.

Ungulate Management Map

Image Redacted
Sensitive Information
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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 taxa, small size of the fenced area, and the overall degraded status of MU.

Surveys

Potential Vectors: 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, campsites, 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 fieldwork. Map and complete Target Species form to document sighting.
- 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 STAFF do not frequently work in the Pualii North MU, with the exception of the *H. oahuensis* flowering season. The South Pualii LZ (see Ungulate Management Map) will be monitored quarterly, unless it isn't used in a given quarter.

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.

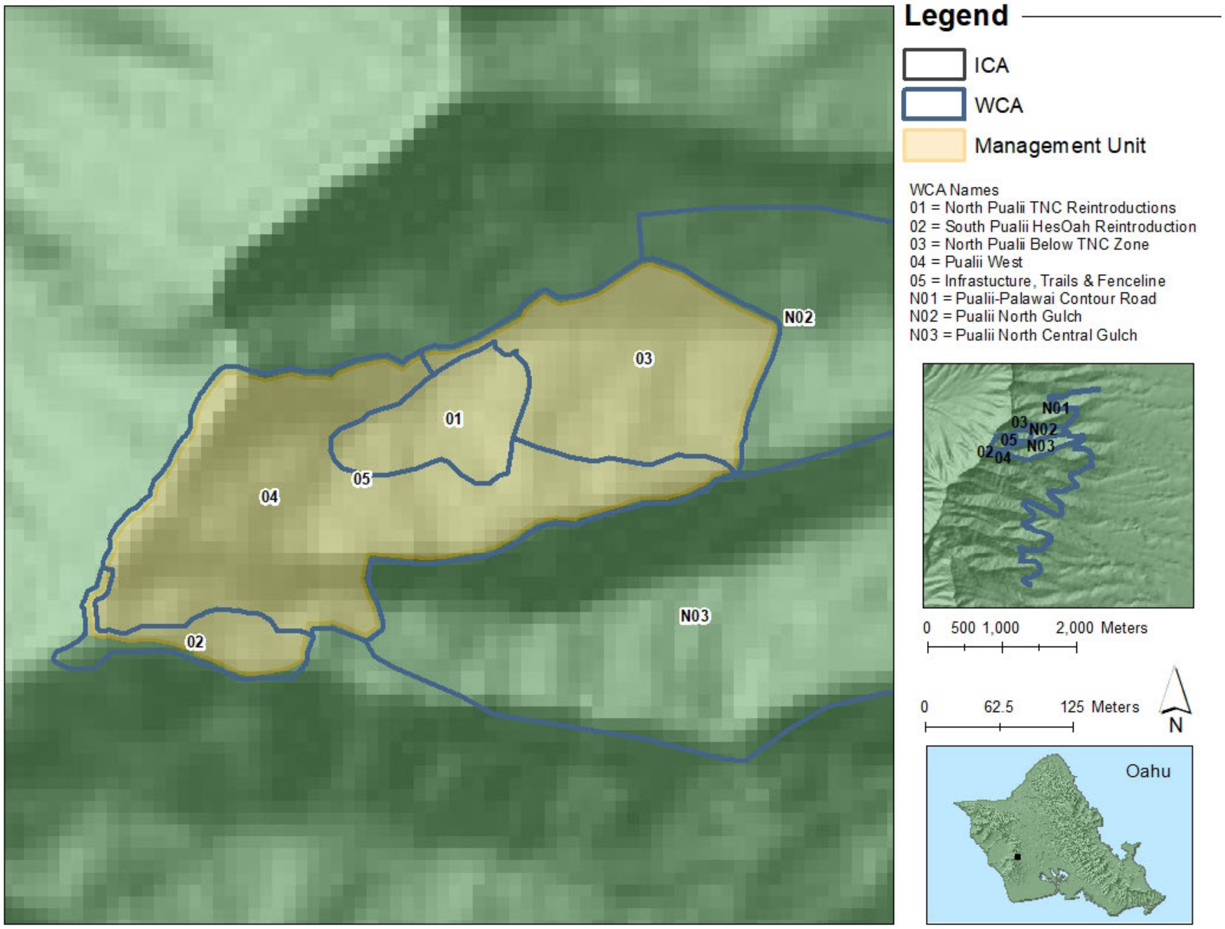
Strategy and Control Methods:

- 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.

Discussion:

Sphaeroptis cooperii, formerly designated as an incipient taxa in Pualii North MU, has been downgraded from ICA to target species. *S. cooperi* spores likely travel considerable distances on the wind and it is well established in unmanaged areas as well as in cultivation in areas adjacent to Pualii North MU. Although the PualiiNorth-SphCoo-01 ICA has been discontinued, plants encountered during the course of other fieldwork should be noted, mapped, and controlled to prevent further establishment in the MU.

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.

Discussion:

Weeding actions in Pulii North are focused on improving managed rare plant sites and at maintaining habitat that could house future reintroductions of managed taxa. Sites in the gulch are weeded annually while the WCA around the *H. oahuensis* reintroduction is scheduled twice annually. This site is often weeded more often due to the frequency of visits for pollination/collection during the flowering season.

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

Summary of Target Taxa

Taxa	Distribution	Notes
Angiopteris evecta	Scattered	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	Widespread	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	Restricted	Not widespread, occasionally found in patches throughout the MU.
Christella spp.	Restricted	Concentrated around the gulch bottom/trails in disturbed areas. Control as needed along trails and in reintroduction areas.
Ehrharta stipoides	Restricted	Widespread along crestline and South Pualii ridgeline but not elsewhere in MU. Control along fence line near reintroduction area and LZ. Take GPS points when observed outside of known core areas in MU. Decon footwear and gear prior to leaving known infestations to avoid spread.
Erigeron karvinskianus	Widespread	Widespread across MU. Control near reintroduction areas and wild endangered plant locations.
Eucalyptus spp.	Restricted	Large trees in gulch. Control near native dominated areas using IPA.
Grevillea robusta	Widespread	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 application of Aminopyralid (Milestone) was effective in controlling *Grevillea robusta*.
Heliocarpus popayanensis	Restricted	Not common in MU as area is a bit dry for this large tree species. Zero tolerance within WCAs.
Melinus minutiflora	Widespread	This grass invades open areas, especially fence lines, and has a high fire index, elevating fire risk. Control when grass prohibits staff to thoroughly inspect the fence.
Oplismenus hirtellus	Widespread	Dominant grass in the gulch 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	Restricted	Known to create monotypic stands in mesic forests. Occasionally found in fence. Zero tolerance within WCAs.
Passiflora edulis	Restricted	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	Restricted	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, potential release site for biocontrol *Tectococcus ovata*.
Psidium guajava	Widespread	Widespread throughout the MU but only in localized patches. Control in native dominated areas.
Rivina humilis	Widespread	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.

Taxa	Distribution	Notes
Rubus rosifolius	Widespread	Control in native dominated areas and near rare resources.
Schefflera actinophylla	Widespread	Scattered throughout the MU as saplings and recruiting across widespread area. It is a priority for control whenever found. IPA with 100% Range Pro effective on large trees.
Spathodea campanulata	Scattered	Scattered individuals across MU. Few large mature individuals found. Priority for control in native dominated areas given active recruitment across MU.
Sphaeropteris cooperi	Scattered	Found, mostly, in southern gulch below *H. oahuensis* reintroduction. Formerly an ICA now this taxa is being controlled as a target taxa to be removed on sight.
Syzygium cumini	Widepsread	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	Scattered	Scattered mature individuals, but recruiting across widespread area. Priority for control.
Triumfetta semitriloba	Scattered	Not common in MU. It thrives in disturbed areas. Pull during weed control efforts and along trails, LZ, and fence lines.
Megathrysus maxima	Widespread	Zero tolerance within WCAs and along fence lines, trails, and DZs and LZs.

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	Growth Habit	Outplant/SDT	Notes
Acacia koa	Tree	Outplant	Outplant if no mature trees on site. Recruits grow rapidly.
Antidesma pulvinatum	Tree	Outplant	Grow from seed. Seeds recalcitrant.
Bidens torta	Herb	Seedsow	Known to grow from seed sows.
Carex meyenii	Sedge	Outplant	Groundcover species for shadier areas
Carex wahuensis	Sedge	Outplant	Good groundcover until larger canopy species can establish
Ceodes spp.	Tree	Outplant/ Seedsow/ Transplant	Grow from seed. Recalcitrant. Can seedsow or transplant.
Cibotium chamissoi	Fern	Outplant	Grow from spore. Tree fern.
Cyperus polystachyos	Sedge	Seedsow	Excellent groundcover until larger canopy species can establish. Seedsows highly effective.
Dianella sandwicensis	Herb	Outplant, Division	Good groundcover until larger canopy species can establish. Divisions possible in wetter areas.
Dodonaea viscosa	Shrub	Outplant	Grow from seed. Fast growing shrub/small tree.
Doodia kunthiana	Fern	Outplant	Grow from spore. Groundcover for shadier areas.
Eragrostis grandis	Grass	Outplant	Good groundcover until larger canopy species can establish
Metrosideros polymorpha	Tree	Outplant	Grow from seed. Major component of forests.
Microlepia speluncae	Fern	Outplant	Grow from spore. Larger fern, but more delicate than *M. strigosa*. Plant in shade or moist soils.
Microlepia strigosa	Fern	Outplant, Division	Grow from spore. Good groundcover until larger canopy species can establish. Plant with 18” spacing or tighter for weed suppression.
Mysine lessertiana	Tree	Outplant	Grow from seed. Tends to recruit directly under mother tree.
Pipturus albidus	Tree	Seedsow	Known to grow from seed sows. Good early establishment. Trim around year two making gaps for larger canopy

Native Taxon	Growth Habit	Outplant/SDT	Notes
			species.
Pittosporum spp.	Shrub	Outplant	Grow from seed. Has established quickly in other restoration areas and fruits heavily.
Planchonella sandwicensis	Tree	Outplant/ Seedsow	Grow from seed. Slow growing. Seeds recalcitrant.
Psydrax odorata	Tree	Outplant	Need to grab snatchlings if desired. Slow growing, but hardy. Fruit often bored.
Sapindus oahuensis	Tree	Outplant, Seedsow	Grow from seed. Slow growing but has large footprint once established. Seedsows possible, especially if cleaned, clipped and soaked prior to sow.
Scaevola gaudichaudiana	Shrub	Outplant, Seedsow	Grow from seed. Tends to recruit in disturbed areas.
Urera glabra	Tree	Outplant	Grow from seed if possible. Drosophila host plant.

WCAs: Pualii North-01 North Pualii, (*Planchonella* stand and adjacent reintroduction gulch)

Veg Type: Dry-Mesic Forest

OIP/MIP Goal**:** 50% or less alien cover (rare taxa in WCA, none MFS).

Targets: Alien canopy trees at edges of WCA and alien understory weeds in gulch and *Planchonella* stand.

Notes: This WCA contains a fairly stable and intact native forest patch. Alien canopy has been largely removed from this WCA. Continued effort needed at the boundaries of this WCA for *Casuarina* sp. at top, western edge of gulch near *Asplenium unisorum* and northwestern edge along *Ceoides brunoniana* patch near fence line to crestline. There are numerous *G. robusta, Eucalyptus* sp., and *S. terabinthafolius* bordering the *Planchonella* stand. Control of these and other alien canopy recruits (including *T. orientalis, S. actinophylla)* through sweeps in this WCA is conducted annually. Understory control of understory/grass species such as *R. rosifolius, E. karvinskianus M. maxima, P. suberosa, B. asiatica*, and other weeds will be conducted one to two times per year.

WCA: Pualii North -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 targeting *S. cooperi*.

Notes: This is a high priority WCA because of the success of the *H. oahuensis* reintroductions there. Site maintenance for the rare taxa as well as expansion for future plantings will be the focus of weeding effort in this WCA. *Psidium cattleianum* and *S. terebinthifolius* largely removed from the accessible portions of this WCA. Continue *S. terebinthifolius* control along bottom edge of WCA to avoid trees getting too large and ripping out slope. The soil is extremely loose on the steep slopes of this WCA and staff should stay on established trails to avoid causing increased erosion at the site. Continue grass control (*M. maxima*, *M. minutiflora*, *P. conjugatum*, and *E. stipoides*) in reintroduction area, along fence line, and area to the south. Thick patches of *E. stipoides* may be, in conjunction with other threats, suppressing *H. oahuensis* recruitment. Staff are considering the best method for replacing this grass species, possibly through aggressive planting of native ground covers and grasses (*E. grandis, C. wahuensis*). Continue *C. hirta* control and other understory weeding to increase open ground opportunities for rare plant recruitment.

Some TNC rare plant reintroductions are still persist in the area (primarily *Cenchrus agriminiodes* var. *agriminiodes* and *Delessia waianaensis*) as well as MFS *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. Annual visits are needed to ensure that these incipient species do not reappear. There is a water catchment available for grass control as well as reintroduction watering. Due to the presence of *E. stipoides* in this WCA, staff should thoroughly decontaminate gear prior to leaving the area.

WCA: Pualii North-03 (North Pualii, North facing slope, gulch bottom area below PUA-01 to lower fence bottom)

Veg. Type: Dry-Mesic Forest

OIP/MIP Goal**:** 50% or less alien cover (rare taxa in WCA).

Targets: Minimal understory alien control (mainly *B. appendiculatum*). Alien canopy control includes *S. terebinthifolius, P. cattleianum*, *Eucalyptus spp.*, *G. robusta*, *T. orientalis*, *S. campanulata*, and *S. actinophylla.*

Notes: This native dominated stand of mesic-dry forest has a mostly open understory and is bordered by the gulch bottom and a planting of Eucalyptus along the lower 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. terebithifolius* and other canopy weed trees as well as some IPA work along the upper elevational border to buffer the native dominated stand below. Most large *T. orientalis* have been controlled but seedlings and saplings continue to be encountered and should be targeted to prevent ongoing recruitment in native dominated areas.

Understory weeding should continue to focus on recruits of alien canopy species while also targeting patches of *B. appendiculatum, C. paraciticus,* and *E. karvinskianus. R. rosifolius* and *P. suberosa* should also be targeted during the course of understory weed control.

Disturbed areas in the gulch bottom where large trees have fallen are chronically weedy, with patches of grass occurring in the more exposed areas. Common plantings in these areas have also fared poorly due to large slabs of rock both exposed and subsurface that seem to have restricted new plantings access to water. Future restoration actions may benefit from seed sows instead of plantings. Any patches of *M. maximus* in these areas will be controlled to reduce fuel; aggressive restoration of these areas may not be feasible.

WCA: Pualii North-04

Veg. Type: Dry-Mesic Forest

OIP/MIP Goal**:** 50% or less alien cover (no rare taxa in WCA).

Targets: Alien canopy control of *S. terebinthifolius*, *Eucalyptus* spp., *G. robusta*, *T. orientalis*, *S. actinophyla, S. campanulata*, and *P. cattleianum*.

Notes: This WCA is in the steep portions above Pualii North-01 and consists largely of *S. terabinthafolius.* There are no managed taxa in this WCA and no plans for future reintroductions here making it a low priority for weed control. Sweeps for target alien canopy are limited due to the steep terrain at the top and sides of this WCA.

WCA: Pualii North-05 Infrastructure WCA

Veg. Type: Dry-Mesic Forest

OIP/MIP Goal**:** Maintain fence line and trails for STAFF access.

Targets: Alien canopy control along the fence line includes *S. terebinthifolius*, *Eucalyptus* spp., *G. robusta*, *T. orientalis*, *S. campanulata*, *S. actinophylla,* 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. Removing large eucalyptus adjacent to the PUA-A fence in the northern gulch is not feasible. Staff will monitor and clear any tree fall and fix damage to the fence as needed. Continue *S. terebinthifolius* control also along bottom edge of WCA to avoid trees getting too large and ripping out slope. Continue grass control (*M. maximus*, *M. minutiflora*, and *P. conjugatum*) along fence lines and trails.

WCA: PualiiNoMU-01 (Forestry gate to trailhead)

Veg Type: Dry-Mesic Forest

OIP/MIP Goal: NA

Targets: Tree fall/patches of grass obstructing road.

Notes: This WCA extends from the Forestry gate to the parking area/trailhead. The only control actions in this WCA will be aimed at maintaining access to the MU and may include removing downed trees from the access road and spraying grass should patches of *U. maxima* restrict visibility/access.

WCA: PualiiNoMU-02 (Trailhead to MU fence)

Veg Type: Dry-Mesic Forest

OIP/MIP Goal: NA

Targets: Tree fall/patches of grass impeding access to unit.

Notes: This WCA encompasses the access trail from the parking area to the fence at the bottom of the unit. Actions will be similar to Pualii NoMU-01 in that maintaining access to the MU will be the priority. Actions will include removing downed trees from the access trail and spraying grass to ensure trail is useable. Staff regularly collect large amount of *S. oahuensis* near the parking spot that will be used for MU restoration projects. Target taxa sweeps on a five-year interval may help prevent spread of these taxa into the MU but area is low priority.

WCA: PualiiNoMU-03 (Central Pualii Gulch)

Veg Type: Dry-Mesic Forest

OIP/MIP Goal: NA

Targets: *S. terebinthifolius*, *Eucalyptus* spp., *G. robusta*, *T. orientalis*, *S. campanulata*, *S. actinophylla,* and *P. cattleianum*.

Notes: Pualii NoMU-03 encompasses the highly degraded, unfenced gulch below Pualii North-01 down to the Honouliuli Contour Road. This WCA is scheduled for target species sweeps every three to five years. There are no managed taxa sites within the WCA and much of it is too steep to traverse. Large *T. oreientalis* and *S. actinophylla* are visible from the ridge trail and control of these targets could reduce dispersal of these species by birds into the MU.

Small Vertebrate Control

Species: *Rattus rattus* (Black rat), *Rattus exulans*, (Polynesian rat), *Rattus norvegicus* (Norway rat), *Mus musculus* (House mouse), and *Herpestes auropunctatus* (small Indian mongoose)

Threat level: High

Seasonality/Relevant Species Biology: Rodent damage has been seen commonly on *Hesperomannia oahuensis* during all stages of the reproductive period. Caches of flowers and fruit have been observed within the site. Rodent damage has also been seen on stems during extended dry periods and can be fatal.

Management Objectives:

- Protect *H. oahuensis* flowers, fruits, and stems from damage year round, but especially during reproductive season.

Strategy and Control Methods:

- Maintain and improve localized trapping grid around *H. oahuensis* using 20-25 Goodnature A24 traps
- Hand broadcast of Diphacinone-50 twice a month from March/April to July/August, a total of eight applications per season.
- Monitor rare plant populations (*H. oahuensis*), as well as other native species to determine impacts by rodents

Discussion:

Rodent control has been conducted at the *H. oahuensis* reintroduction site year round since 2015 when 12 Victor snaps and 4 Goodnature A24 traps were installed (PUA-A predator site code). In November 2017, the Victor snap traps were removed and 8 additional Goodnature A24 traps were installed bringing the total to 12 onsite. During the 2021 reproduction season, several large caches of *H. oahuensis* flowers and fruit were observed at this site. As a result, nine (9) Victor traps were temporarily installed to help with control that season. In April 2022, the existing A24 grid was increased to 25 traps to try and buffer the site more effectively providing more complete control of rodents. Additionally, 15 lbs. of D-50 will be hand broadcast twice (5-7 days apart) every two months from April to October to further ensure the protection of *H. oahuensis* during the reproductive season.

Rat licking nectar of *H. oahuensis* flower.

Small Vertebrate Management Map

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ARMY NATURAL RESOURCES PROGRAM O'AHU

Slug Control

Species: N/A

Threat level: Low

Seasonality/Relevant Species Biology: Slugs have not been observed to cause negative impact *Hesperomannia oahuensis* but are known to predate members of *Asteraceae*. Limited recruitment of *H. oahuensis* has led to few opportunities to observe slug damage to this species in the field.

Management Objectives:

- During annual rare plant monitoring, look for seedling recruitment and slug herbivory.
- Avoid potential impacts to rare snails.

Strategy and Control Methods:

- Conduct slug abundance monitoring with baited beer traps. Use data to inform whether control is needed, and/or if it may be seasonal versus annual.
- 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 (see protocol below).
- Calculate amount of Ferroxx needed to treat SLCA. Orient staff to SLCA and train applicators.
- FerroxxAQ is applied every 6 weeks. FerroxxAQ is not applied within 20 m of known populations of native snails.
- If rare snails are found in an established SLCA, treatment will be halted. Rare snails will be relocated to the MU snail enclosure, and the Pre-Application Survey Protocol will resume

Discussion:

Currently, there is no implemented slug control in Pualii North MU. Slugs have not yet been observed to negatively affect *Hesperomannia oahuensis,* though they are known to predate other members of the *Asteraceae* family. During annual rare plant monitoring, staff will inspect plants for herbivory. If present, this will be noted and the protocols for creating a SLCA will be followed (see protocol above). Due to the rarity of *H. oahuensis* recruitment, slug control at this site should be considered though direct evidence of predation is lacking.

Pre-Application Survey Protocol:
For control only of slugs and non-native snails via listed, approved molluscicide application in forests, on offshore islands, and in other natural areas to protect threatened and endangered Hawaiian plants. Only Ferroxx AQ® Slug and Snail Bait is approved for use in forest areas in Hawaii. Area must be thoroughly searched by experienced malacologists prior to application of Ferroxx AQ® granules to ensure that non-target native Hawaiian snail species are not impacted. Do not apply in areas where it may come into contact with known populations of endemic Hawaiian snail species from the following rare families or subfamilies: Amastridae, Achatinellinae and Endodontidae. Bait cannot be applied within 20 m of any tree known to harbor endangered Hawaiian tree snails (*Achatinella* spp.). 1. Conduct thorough day survey of proposed treatment area to include searching trees and all understory vegetation. The ground and rock talus areas will also be search. An effort to identify other snails found and their rarity will be made prior to Ferroxx use. 2. If proposed treatment area is known *Achatinella* spp. site or if *Achatinella* spp. is observed during day survey, then must conduct night survey and remove all *Achatinella* spp. to a snail enclosure/protected area prior to bait use. 3. Area will continue to be surveyed and *Achatinella* spp. translocated to enclosures until all *Achatinella* spp.

are removed from the area and at least one survey is conducted where 0 snails are found within area.

4. If *Achatinella* spp. are abundant in large numbers or are found on multiple trips, use of Ferroxx will not be allowed in area.
5. If *Achatinella* spp. are located in the area in the course of other fieldwork, then surveys and relocation efforts will resume.
6. An effort to identify other snails found and determine their rarity will be made prior to Ferroxx use.

Ant Control

Species: Big headed ants (*Pheidole megacephala*)

Threat level: Moderate to High

Seasonality/Relevant Species Biology: Unknown

Management Objectives:

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

Strategy and Control Methods:

- Sample ants at human entry points using the standard survey protocol (Plentovich and Krushelnycky 2009) and *Drosophila* sites once a year (see table below). Use samples to track changes in existing ant densities and to alert ANRPO 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 ANRPO 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
Drosophila restoration area	*Drosophila* are sensitive to high ant abundance

Discussion:

Vials are baited with SPAM, peanut butter and karo syrup. The caps are removed and vials spaced 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.

Surveys of Pualii in 2014 revealed the presence of *D. montgomeryi* in the gulch, where both reintroduced and one wild *Urera kaalae* were located. With the designation of Pualii as a MFS site for this rare fly, ant sampling of the surrounding area was initiated to assess the threat posed primarily by *Pheidole megecephala.*

Surveys revealed that the number of ants was highest in disturbed areas and lowest in shadier, more native areas. It was thought that through restoration of native vegetation including *D. montgomeryi's* primary host, that ant habitat would be reduced and the fly population could be stabilized.

Unfortunately, plantings of both *U. kaalae* and *U. glabra*, as well as many of the other common natives in the gulch failed. *D. montgomeryi* were not observed in Pualii after 2015, though *U. kaalae* reintroductions and their progeny still exist. Since the flies seem to have been extirpated from the MU, no ant control will be conducted and the MFS site for *D. montgomeryi* has been shifted to Ekahanui MU.

Coconut Rhinoceros Beetle

Species: *Oryctes rhinoceros*
Threat Level: Unknown, possible threat to *D. forbesii*

Seasonality/Relevant Species Biology: Unknown

Management Objectives:

- No current management at Pualii North
- There is no current control

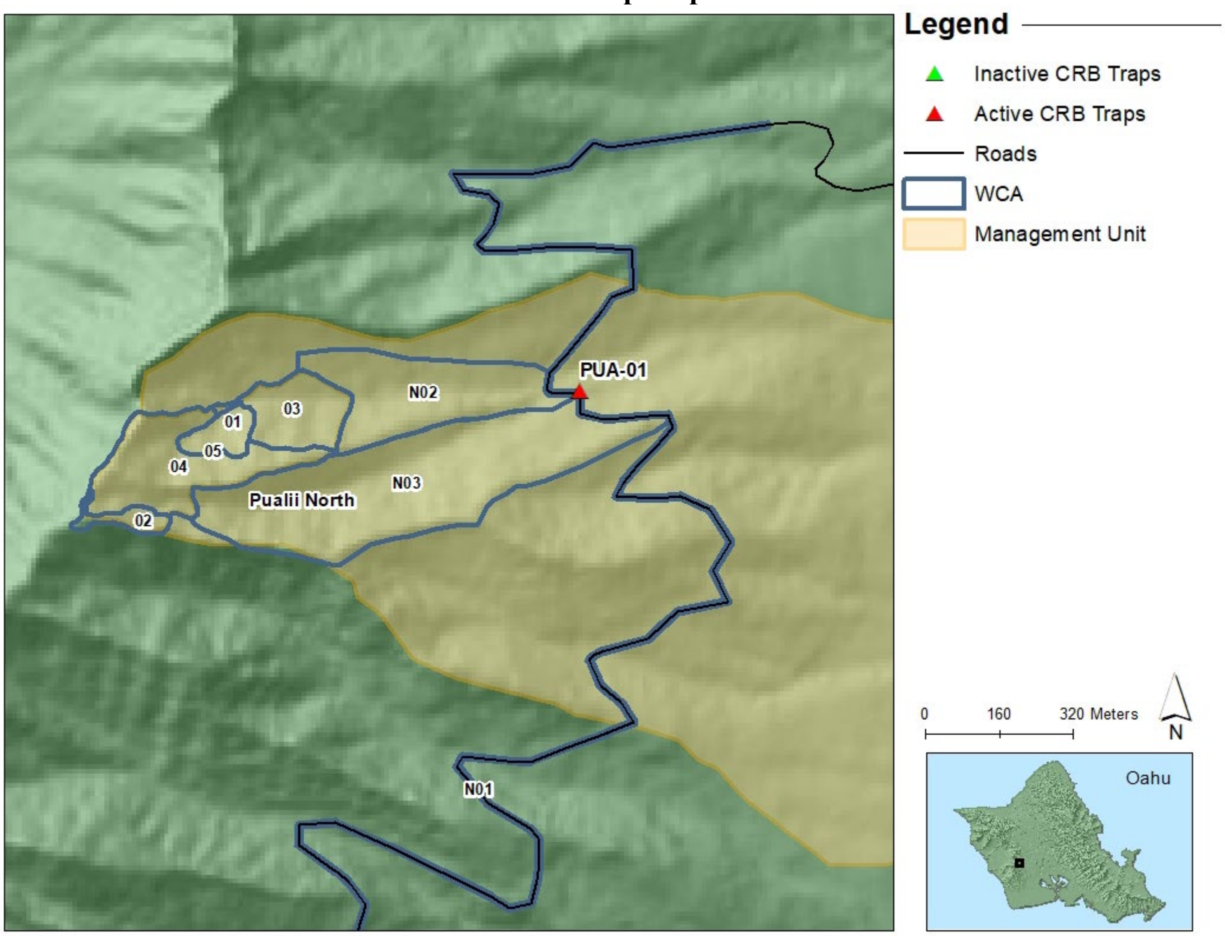
Strategy and Control Methods:

- No current traps deployed within MU
- One pheromone panel trap (PUA-01) along road in Pualii NoMU-01

Discussion:

Oryctes rhinoceros are known to be well established in numerous sites on Oahu, including the Kunia Loa Farm Lots. Pualii North does not contain managed taxa known to be effected by CRB but many endangered *D. forbesii* occur in the MU and are a possible host. Monitoring along the Honouliuli Contour Road is ongoing and beetles are consistently found in the panel trap (PUA-01) at the trailhead. On May 5, 2022, staff found a dead female on the portion of the trail along the ridge crest between Pualii and Lualualei.

CRB Trap Map



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. *Megathyrsus maximus* has a high fire index, and is found along the fence line. This site has 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.
- Target *M. maximus* throughout the MU.

Discussion:

The threat of fire is highest during the summer, but fire may pose a risk at any time if appropriate conditions exist. The most likely ignition source for a fire that may threaten the Management Unit is along Kunia Road. The expansion of agricultural lots closer to the bottom edge of the Honouliuli Forest Reserve as well as recreational hunters may elevate the risk. Keeping fuel loads down along access trails and fencelines is a priority, especially control of large patches of *M. maximus*. There is also potential for ingress to the sensitive *H. oahuensis* reintroduction from Lualualei, should a large fire be ignited. The steep, rocky terrain and prevailing wind direction pushing against it may lower the risk significantly. Should a fire threaten Pualii North, staff familiar with resource locations will aid first responders including HFD and DOFAW in directing efforts.

Monitoring the Phenology of *Chromolaena odorata* to Inform Management of an Incipient and Highly Invasive Species in Hawai‘i

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Abstract

The invasion of nonnative species has negative impacts on ecological processes and ecosystem services, and these impacts are being exacerbated by global trade and climate change. In Hawaiʻi, invasive species, along with associated biodiversity loss and habitat degradation, are the greatest threat to the archipelago's endemic biota. In 2011, *Chromolaena odorata* (Devil's Weed), a globally dispersed invasive species, was first detected in the Kahuku Training Area (KTA) on the Island of O'ahu. Known as one of the world's worst weeds, *C. odorata* is an aggressive colonizer of disturbed environments that, once established, creates dense monotypic stands that prevent the growth and regeneration of other species. Since its discovery in 2011, *C. odorata* has spread to occupy ~1,042 ha in KTA. The objective of this study was to develop a *C. odorata* phenology monitoring program to investigate the correlation between observed phenophases, seed germination, and climate variables to inform integrated weed management (IWM). To address this objective, I monitored the phenology (i.e., phenophases or life cycle events) and plant condition of *C. odorata* every two weeks in KTA for 12 months in five study sites and recorded monthly precipitation and temperature from the closest weather station. In addition, I collected soil samples in each study plot monthly and monitored seedling emergence in the greenhouse over 12 months. Overall, I found that flowering occurred between November – February and fruit set occurred between February – April, with smaller flowering and fruiting events in May – June and June – July, respectively. Monthly precipitation and temperature had strong explanatory power for both overall plant condition and productivity-related phenophases (i.e., flower production and seed drop). In addition, a positive correlation existed between seedling germination and the presence of flowers. Based on this information, chemical and mechanical control should be conducted between August and October to reduce large flowering events beginning in November. Overall, the results of this study will allow for the adjustment and optimization of IWM practices for this species based on phenophases that are more susceptible to weed control methods, as well as informing the use of phenology in controlling and managing invasive species more broadly.

Keywords: climate; integrated weed management (IWM); land management; plant control; restoration

Motivation

The introduction of invasive species has negative impacts on ecological processes, ecosystem services, and local and national economies, and these impacts continue to increase with global trade and climate change (Poland et al., 2021). Their establishment alters the structure and function of native ecosystems and, ultimately, can lead to species extinctions (Poland et al., 2021). Invasive species, along with associated biodiversity loss and habitat degradation, are the greatest threat to Hawaiʻi's endemic flora and fauna (Daehler et al., 2004). Hawaiʻi provides habitat to over 44% of all species on the U.S. endangered and threatened plant species list, with 25% of these species found only in Hawaiʻi. According to Poland et al. (2021), the term invasive species indicates a nonnative species whose presence does or is likely to cause economic or environmental harm, or harm to human health. Understanding how invasive species interact with their environment can help anticipate their impacts, as well as inform protection of native species and habitats at risk (Morais & Freitas, 2015).

In 2011, *Chromolaena odorata*, known as Siam Weed or Devil's Weed, was first detected in the Kahuku Training Area (KTA) on the Island of Oʻahu. Known as one of the world's worst weeds, *C. odorata* is an aggressive colonizer of disturbed environments such as roadsides, abandoned agricultural fields, and degraded forests (Zachariades et al., 2009). Once established, it creates dense monotypic stands that prevent the growth and regeneration of other species, due at least in part to allelopathic qualities (Zachariades et al., 2009). Though not as widely distributed in Hawaiʻi as other, more established invaders, due to *C. odorata*'s invasiveness in other areas globally, it has a very high potential to increase widely outside of its current habitat, making early control critical.

Since its discovery in 2011, *C. odorata* continues to be the top incipient priority for the Army Natural Resources Program-Oʻahu (ANRPO). Currently, ANRPO manages 54 *C. odorata* incipient control areas (ICAs; weed control efforts with the goal of eradication of a particular invasive species) spanning both the Waiʻanae and Koʻolau Mountain Ranges. Each ICA is species-specific and geographically defined. Of the 54 ICAs, 26 are located in KTA, where it has spread to occupy ~1042 ha (Figure 1) and accounted for 54% of time spent on incipient control efforts conducted by ANRPO in the 2021 reporting year (total of 2355 people hours). Despite the resources and time put towards controlling *C. odorata*, due to its large infestation across difficult terrain *C. odorata* continues to spread. To better manage this incipient invasive species, more applied management options are needed to optimize current and future control efforts.

Background

Chromolaena odorata is a fast-growing herbaceous to woody perennial plant in the family Asteraceae (Gautier, 1992). Native to South and Central America, *C. odorata* forms dense tangled bushes up to 2 m high, with the ability to branch and grow on surrounding vegetation to up to 20 m high. Leaves are opposite, ovate-triangular, with serrated margins, and a distinctive 3-vein "pitchfork" pattern. Due to its ability to asexually form viable seeds, also known as apomixis, plants can germinate and set seed within a 12-month period and are able to produce up to 800,000 seeds per individual plant per year (Witkowski & Wilson, 2001). The small seeds are then dispersed long distances by wind, as well as by adhesion to fur, feathers, vehicles, and clothes. Steroids and other toxins produced by the plant make it toxic to livestock and reduce the growth of other surrounding plants via allelopathy (Zachariades et al., 2009).

C. odorata is a serious invasive species in other parts of the world, where it threatens food security and the integrity of ecological systems in West Africa, Asia, and the Pacific. For example, *C. odorata* was introduced into West Africa in the late 1930s in Ghana, and since then has spread to occupy 12 of the 16 countries in Africa, where it is considered one of the worst invasive species as a result of significant impacts to native ecosystems and agriculture (Aigbedion-Atalor et al., 2019). The invasiveness of *C. odorata* is due to its high reproductive capacity and dispersal of propagules, adaptation to growth in a range of soil types and climate conditions (Aigbedion-Atalor et al., 2019), ability to outcompete and prevent the natural regeneration of native plants (Honu & Dang, 2000; Timbilla & Braimah, 2000), and its ability to rapidly invade new areas where it significantly reduces the biodiversity of native ecosystems (Timbilla & Braimah, 2000). As chemical and mechanical control methods are often deemed unsustainable, costly, and ineffective, biological control agents have been released to control *C. odorata* outside of Hawaiʻi. A gall fly species *Cecidochares connexa* (Tephritidae), has been shown to significantly reduce the density of *C. odorata* in Papua New Guinea, Indonesia, and parts of West Africa. *C. connexa* is indigenous from the USA to central South America, and is known to be highly host specific to *C. odorata* (Aigbedion-Atalor et al., 2018). *C. connexa* is currently being tested in Hawaiʻi, with the goal of establishing the first gall fly colony in the coming years to help reduce the density of *C. odorata* in the state.

Though biological control is often seen as the most environmentally friendly and cost-effective way to manage a widely spread invasive species, the combination of one or more control methods that consider the biology or phenology of the target species can lead to more successful control via synergistic effects (Lake & Minteer, 2018). Integrated weed management (IWM) is a sustainable approach to managing invasive species that combines biological, chemical, and mechanical methods in a way that maximizes effectiveness while minimizing costs and environmental impacts (Paynter & Flanagan, 2004). As an adaptive management approach, IWM requires sufficient knowledge of the ecology and phenology of the species and the invaded system to better predict the outcome of control efforts. *C. odorata* has been documented to flower in December to January in the northern hemisphere, and flowering is typically triggered by decreases in rainfall and day length (Zachariades et al., 2009). However, flowering has been observed anecdotally in KTA from January to March, highlighting that region-specific information is needed on *C. odorata* phenology in Hawaiʻi to inform IWM.

Phenology is the study of seasonal activities of organisms (e.g., flowering, leaf flush, etc.) that is central to understanding ecological interactions between species and the ecosystems they inhabit (Denny et al., 2014). Phenology monitoring has many useful applications, including delineating the response of vegetative and reproductive stages to climate and optimizing the timing of management practices. Plant phenology can also help to provide insight on management strategies for opportunistic and competitive invasive species (Hernandez, 2019). For example, a study conducted by Taylor et al. (2020) documented the timing of phenophases of *Verbesina encelioides* (golden crownbeard) on Midway Atoll NWR to improve eradication efforts. Using a general phenology monitoring approach developed by the USA National Phenology Network (USA-NPN), which defines the term phenophase as "an observable stage or phase in the annual life cycle of a plant or animal that can be defined by a start and an end point (Denny et al., 2014)", this phenological monitoring revealed that *V. encelioides* can set seed in as little as 31 days, which was then used to adjust treatment schedules in infested areas to every 30 days. The adjustment of treatment schedules based on phenology data is now an important tool in maintaining low frequency and density of *V. encelioides* across Midway Atoll NWR (Taylor et al., 2020).

Studying the phenology of invasive species can also aid in better understanding the physiological and morphological adaptive strategies that species utilize to capture resources (Morais & Freitas, 2015). A study by Wallace et al. (2016) tracked the phenology of *Pennisetum ciliare* (buffelgrass), an aggressive invasive species in the Sonoran Desert in southern Arizona, USA, to identify periods of reproduction and green-up, where plants are most susceptible to mechanical removal and herbicide application. Herbicide treatments were then optimized to be applied 1-2 weeks following a precipitation threshold when plants are 50% more green. Phenology monitoring can, therefore, help to identify how species will respond to environmental changes, which natural resource managers may then use as indicators to implement control strategies that focus on targeting life cycles most susceptible to control. Therefore, my project focused on understanding the correlation between observed phenophases of *C. odorata* and climate variables to better predict phenology of the species based on readily available climate data.

Objectives

This study sought to investigate how a phenology monitoring program for *C. odorata* can help to better inform the use of IWM to successfully manage this problematic invasive species in Hawai‘i. Specifically, this project addressed three questions: (1) What is the relationship between phenophases of *C. odorata* and climate variables (e.g., current precipitation and temperature)?; (2) What correlations exist between reproductive phenophase outputs of *C. odorata* and its seed germination in the greenhouse?; and (3) What is the relationship between reproductive phenophase output and plant condition?

Methods

I monitored *C. odorata* phenology in KTA for one year from February 2021 to January 2022. KTA is a 9,400 acre military base located on the northern tip of the moku of Koʻolauloa on the island of Oʻahu, Hawaiʻi. KTA has an elevation range between 6 to 640 m, where it stretches from the Koʻolau summit to lower elevations dominated by alien vegetation that experience regular disturbances by military training and recreational use (e.g., motocross). KTA spans multiple ahupuaʻa (i.e., Kaunala, Waialeʻe, Pahipahiālua, ʻŌpana, Kawela, Hanakaʻoe, ʻOiʻō, Ulupehupehu, Punalau, Kahuku, Keana, Māleakahana) with the core infestation of *C. odorata* between Kaunala and Pahipahuālua gulches. Higher elevation soils are mainly composed of Oxisols, while the lower elevations include Ultisols and Mollisols (Hawaiʻi Soil Atlas).

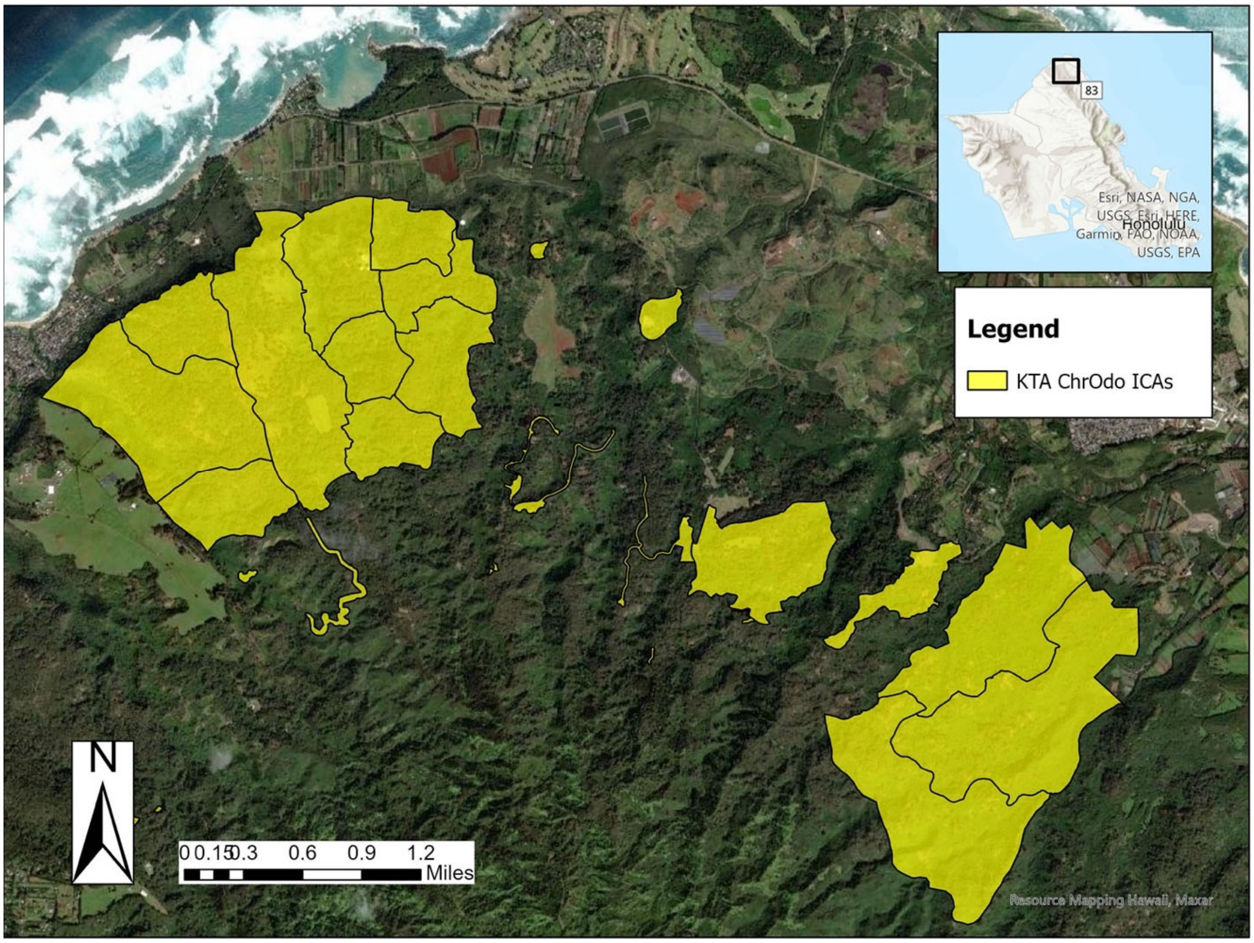


Figure 1. Map of *C. odorata* incipient control areas (ICAs) in Kahuku Training Area. Borders depict individual ICAs.

I selected five 10 x 10 m study plots that were easily accessible and 5 meters away from roads or motocross trails, with a total of 15 individual plants in each plot (*n*=75), located in areas of KTA that consist of highly disturbed nonnative vegetation, such as koa haole (*Leucaena leucocephala*), guinea grass (*Megathyrsus maximus*), ironwood (*Casaurina equisetifolia*), and strawberry guava (*Psidium cattleyanum*). Using standardized phenology monitoring methods developed by the USA-NPN, I documented the onset, duration, and intensity of observed *C. odorata* phenophases (see below) on individual plants in each plot every two weeks for one year.

Greenhouse germination trials

I collected soil samples in each of the five study plots monthly to follow seedling emergence in the greenhouse. Three soil samples were taken from each study plot at a depth of 10 cm using a soil probe and composited within a plot. Composite soil samples from each individual plot were transported to the ANRPO greenhouse and placed in individual soil trays for germination trials. Individual soil trays recieved daily watering and consistent light under a shade cloth. Emerging *C. odorata* seedlings were identified, recorded, and immediately removed from the soil trays for the duration of the study.

USA Standardized Phenology Monitoring Methods

The protocols developed by the USA-NPN are standardized within taxonomic plant groups and utilize phenophases that are easily observable, responsive to seasonal changes, and accurately reflect species life histories (Denny et al., 2014). The observation protocol applies a status monitoring approach, in which observers visit a site at a regular interval to monitor and record the phenological status of marked individuals (Rosemartin et al., 2018).

For my project, I tagged 15 individual plants in each plot, numbered 1 thru 15. During each site visit, I observed the presence, absence, and intensity of each phenophase (i.e., initial growth, leaves, flower or flower buds, open flowers, fruits, ripe fruits, and recent fruit or seed drop). Recording the presence or absence of each phenophase allows for capturing the absence of data when the phenophase is not occurring and during repeat events, in contrast to traditional monitoring of annual "first" events (Rosemartin et al., 2018). According to Rosemartin et al. (2018), the intensity can be described as a "categorical measure indicating the extent to which a phenophase is expressed for an individual plant observed on a given visit (e.g., percentage of flowers open)". Rather than simply recording the presence of open flowers on an individual plant, observing the intensity allows, for example, documentation of the total number of flowers and the proportion of flowers that are open (Denny et al., 2014).

Relationship between Phenophases and Climate Variables

Alongside the documentation of observed phenophases, I recorded the average, low, and high monthly temperature, and total monthly precipitation from the closest weather station to my study plots (Sunset Beach Earth Station); www.wunderground.com). Observing the phenophases of *C. odorata* via an established phenology monitoring program allows for determining the relationship between climate variables and the timing of phenological transitions of *C. odorata*. Once this relationship is established, these models can then be used to produce real-time and short-term forecast maps of the timing of phenological transitions to directly support science-driven management decisions (Crimmins et al., 2017). Predicting when *C. odorata* will undergo a phenological transition in KTA is valuable for the implementation of IWM strategies. For example, optimal timing of management activities such as chemical treatment will benefit from real-time information and short-term forecasts of phenological transitions. To determine how climate in the year that I collected data compared to average climate for my study site, I compared the average, low, and high temperature and total precipitation from 1990-2018 from the Sunset Beach Earth Station to climate conditions in my study year. Statistical analysis using the Cumulative Distribution Function (CDF) in R ver. 4.0.4 (R Core Team, 2021) determined that my study year climate variables were characteristic of the 28-year averages.

Reproductive Phenophase Output and Plant Condition

I identified reproductive phenophase output as the average occurrence of each reproductive phenophase (i.e., Flowers/Flower Buds, Open Flowers, Fruits, Ripe Fruits, Seed Drop). This was calculated by dividing each occurrence over the total number of site visits to obtain an average percentage. Alongside the documentation of phenophases, I also recorded the plant condition for each individual plant during each scheduled monitoring visit. Plant condition was determined as Poor (1), Moderate (2), and Healthy (3).

Data Analysis

I used a Generalized Linear Model (GLM) to assess the relationship between phenophases and current temperature and precipitation. To assess the relationship between seed germination and reproductive phenophase output, I calculated the average number of seedlings that emerged per study plot and utilized Linear Regression. I also used Linear Regression to assess the relationship between reproductive phenophase output and average plant condition. All statistical analysis was performed using R ver. 4.0.4 (R Core Team, 2021) with a significance level of $\alpha = 0.05$.

Results

Phenological activity of C. odorata in KTA

The presence of leaves and initial growth occurred year-round in KTA for *C. odorata* (Figure 2). Flowering had a bimodal distribution, occurring between November – February, and to a somewhat smaller scale in May - June. Fruiting also exhibited a bimodal distribution and occurred in February – April, and a smaller event in June – July. Seed drop occurred between February – July. There was no reproductive activity observed between August – October. Although flowering and fruiting both exhibited a bimodal distribution, Figure 3 demonstrates that the first events of both phenophases had the greatest intensity, followed by a much smaller intensity scale in the second event. This may be due to only a handful of plants exhibiting either a late flowering event or another occurrence of flowering, followed by fruiting.

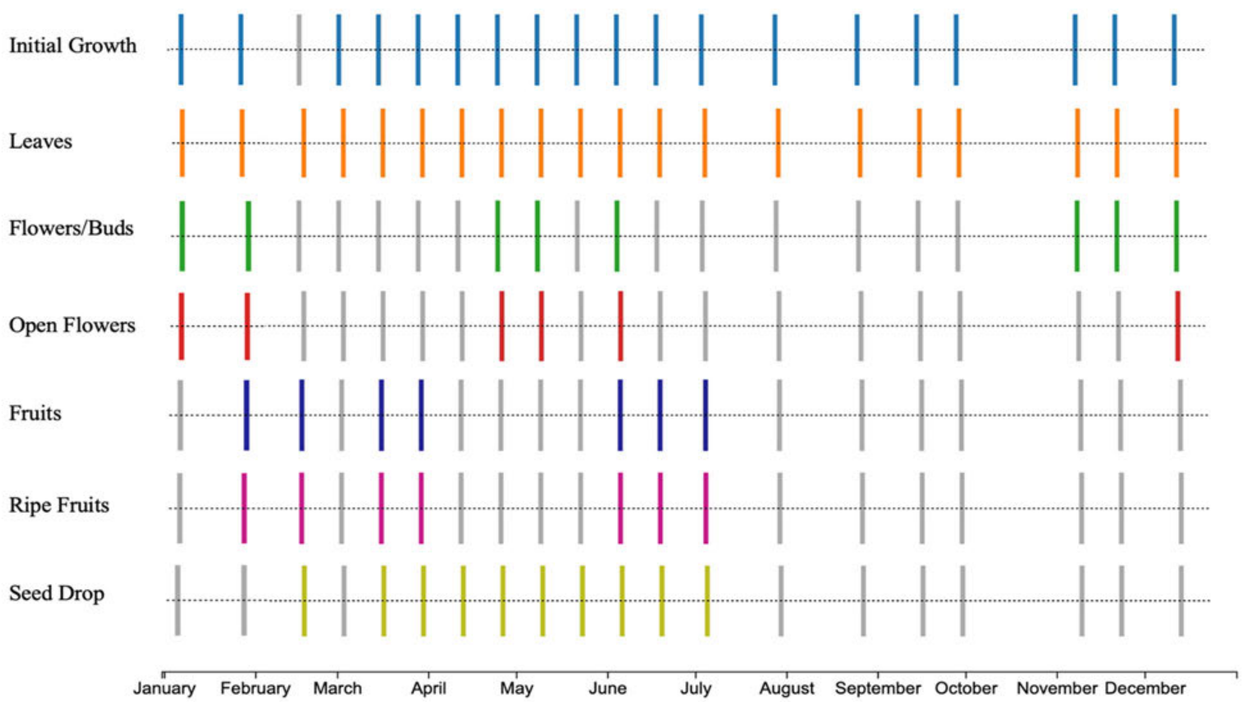


Figure 2. Phenological activity (presence/absence) for *C. odorata* in Kahuku Training Area, observed from February 2021 to January 2022. Colored bars represent the presence of observed phenophases, whereas gray bars represent the absence of phenophases.

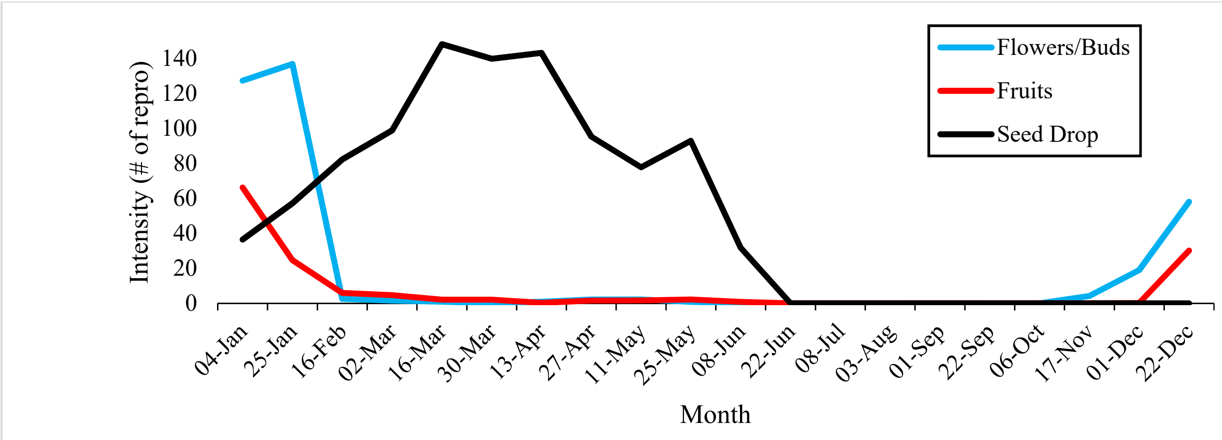
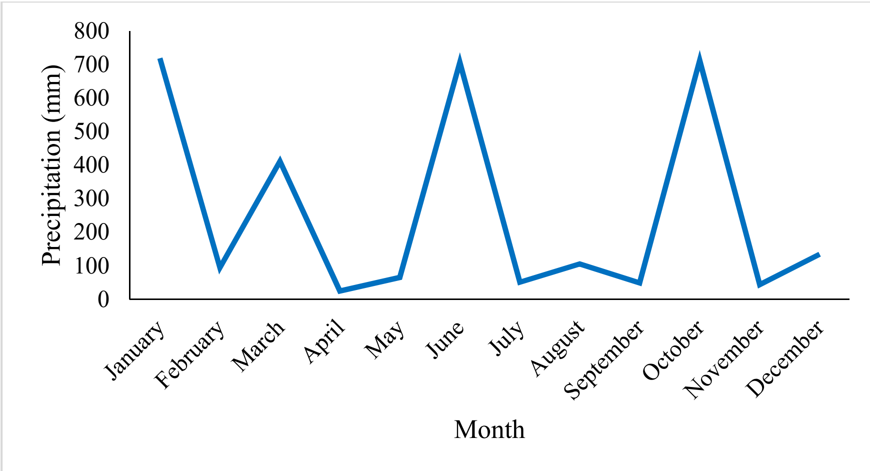


Figure 3. Average intensity of reproductive phenophases for *C. odorata* in Kahuku Training Area, observed from February 2021 to January 2022.

Relationship between phenophases of C. odorata and precipitation

There was a significant positive relationship between precipitation and Flowers/Buds (Figure 4), Open Flowers, Fruits, and Ripe Fruits phenophases (Table 1). There were a few occurrences of heavy rainfall during the year (Figure 5), that may be correlated with the onset and duration of both flowering and fruiting of *C. odorata*, which occurred from November – July. These rainfall events mainly occurred during the wet season, while the summer months between July – September experienced little to no rainfall and reproductive phenophase activity. These results illustrate that an increase in precipitation may trigger the onset and duration of both flowering and fruiting of *C. odorata* in KTA.



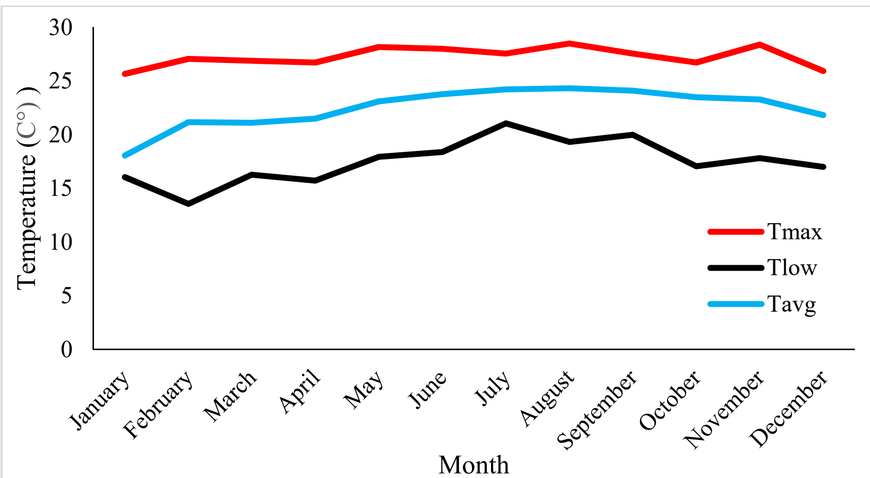


Figure 4. Total monthly precipitation (mm) and monthly high, low, and average temperatures (C°) recorded from the Sunset Beach Earth Station (February 2021 to January 2022).

Relationship between phenophases of C. odorata and temperature

There was a significant negative relationship between temperature and reproductive phenophases (i.e., Flowers/Buds, Open Flowers, Fruits, Ripe Fruits, Seed Drop). Based on temperature readings from the Sunset Beach Earth Station, the highest average monthly temperatures ranged between 24.1-24.3°C from July-September. There appears to be a vegetative (growth) stage of *C. odorata* in Hawai‘i that occurs between July-October, where the occurrence of reproductive phenophases are absent (Figures 2 and 3). These results reveal that *C. odorata* has a seasonality, where its vegetative (growth) stage occurs during the dry season, followed by the rainy season where increasing precipitation triggers the onset of flowering.

Table 1. Linear regression analysis results for relationships between phenophases and climate variables ($\alpha = 0.05$).

	Phenophase	ß	Std Error	Z value	p value
Precip	Flowers/Buds	0.002	0.0002	7.168	<0.001
	Open Flowers	0.004	0.0004	11.48	<0.001
	Fruits	0.0005	0.0002	2.28	<0.05
	Ripe Fruits	0.0005	0.0002	2.07	<0.05
$\mathbf{T_{avg}}$	Flowers/Buds	-0.763	0.0465	-16.39	<0.001
	Open Flowers	-1.063	0.0647	16.44	<0.001
	Fruits	-0.419	0.0364	-11.52	<0.001
	Ripe Fruits	-0.404	0.0367	-11.02	<0.001
$\mathbf{T_{low}}$	Flowers/Buds	-0.449	0.0451	-9.98	<0.001
	Open Flowers	-0.445	0.0565	-7.87	<0.001
	Fruits	-0.972	0.0699	-13.91	<0.001
	Ripe Fruits	-0.903	0.0664	-13.59	<0.001
	Seed Drop	-0.317	0.0342	-9.252	<0.001
$\mathbf{T_{high}}$	Flowers/Buds	-2.009	0.1211	-16.6	<0.001
	Open Flowers	-3.211	0.2561	-12.54	<0.001
	Fruits	-0.496	0.0782	-6.35	<0.001
	Ripe Fruits	-0.484	0.0798	-6.066	<0.001
	Seed Drop	0.432	0.0638	6.78	<0.001

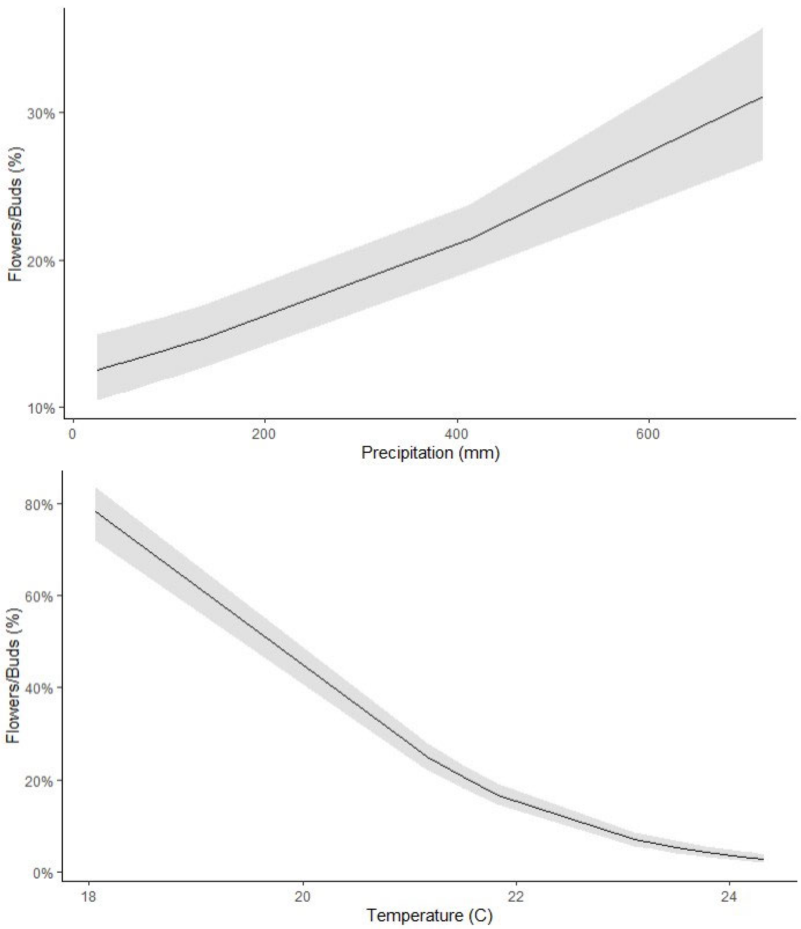


Figure 5. Predicted values (marginal effects) from the Generalized Linear Model illustrating the relationship between Flowers/Buds phenophase and Temperature (C°), and Flowers/Buds phenophase and Precipitation (mm).

Relationship between reproductive phenophase output and average plant condition

Results showed that there was a significant positive relationship between the reproductive phenophase output and average plant condition (Table 2). Healthier plants exhibited reproductive phenophases longer than less healthy plants during the year (Figure 6). These results may be due to habitat characteristics in study plots that are more suitable to *C. odorata*, which in turn allowed plants to reproduce at a higher intensity and longer period.

Relationship between reproductive phenophase output and seed germination

There was a significant positive relationship between the average seedling germination and Flowers/Flower Buds (ß=0.137, F=5.792, $p<0.05$) and Open Flowers (ß=0.139, F=11.78, $p<0.001$) phenophases (Table 2). Although there was a significant positive relationship, results may be inconclusive due to a small number of seedlings that emerged in the greenhouse. The slope of the relationship for Flowers/Buds and Open Flowers was ß=0.14, which is very low and indicates that an increase in reproductive phenophase output only had a marginal impact on seedling germination.

Table 2. Linear regression analysis results for the relationship between average plant condition and reproductive phenophase output, and the relationship between seedling germination and reproductive phenophase output ($\alpha = 0.05$).

	Reproductive Phenophase	ß	F statistic	p value
Average Plant Condition	Flowers/Buds	0.273	20.32	<0.001
	Open Flowers	0.188	16.83	<0.001
	Fruits	0.199	6.43	<0.05
	Ripe Fruits	0.2102	7.08	<0.01
	Seed Drop	0.224	4.02	<0.05
Seedling Germination	Flowers/Buds	0.137	5.79	<0.05
	Open Flowers	0.139	5.79	<0.001

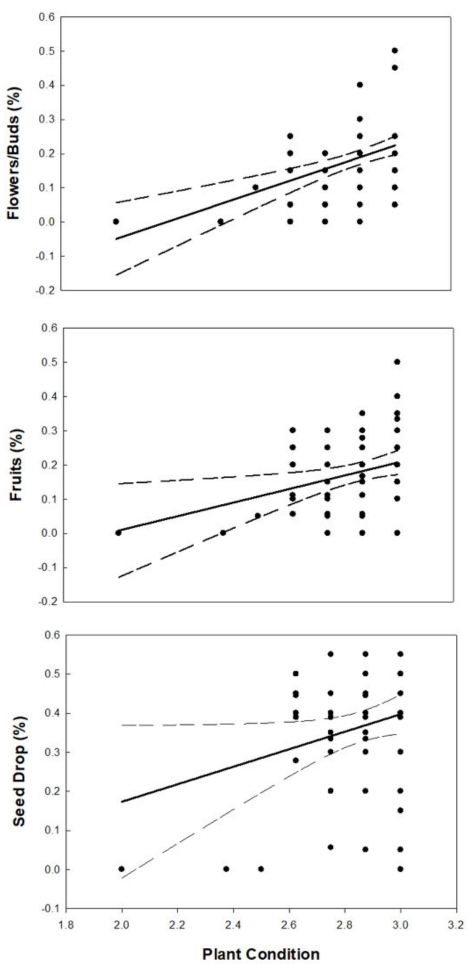


Figure 6. Relationship between reproductive phenophase output (%) and average plant condition. Increasing plant condition indicates healthier plants.

Discussion

This study sought to investigate how a phenology monitoring program for *C. odorata* can help to better inform the use of IWM to successfully manage this highly invasive species in Hawaiʻi. I focused on understanding the relationship between observed phenophases of *C. odorata* and climate variables to better predict the phenology of the species based on readily available climate data. After monitoring the phenology of *C. odorata* in KTA for one year, I found that flowering and fruiting had a bimodal distribution. Flowering occured from November – February, and May – June, while Fruiting occurred from December – April, and May – July. Seed drop occurred from February – July, followed by no reproductive activity occurring from August – October. Although there was a bimodal distribution of flowering and fruiting, Figure 3 highlights that the first event of both phenophases had the greatest intensity, followed by a much smaller event. This may be due to only a handful of plants flowering and fruiting twice in the same season or occurring at a later event. Future monitoring should look further into this bimodal distribution to determine if results are consistent or if there is only one main flowering and fruiting event.

Relationship between observed phenophases of C. odorata and climate variables

I found that there was a significant positive relationship between precipitation and the phenophases of Flower/Buds, Open Flowers, Fruits, and Ripe Fruits. Results demonstrate that precipitation events are associated with the onset and duration of flowering. During the study period, October experienced a high amount of total monthly precipitation (Figure 5). This large rainfall event was then followed by the onset of flowering that occurred in November. Another rainfall event occurred in January (Figure 5), where the intensity of both Flowers/Buds and Fruits were highest (Figure 3). According to Gautier (1993), *C. odorata* flowers in the dry season, triggered by decreases in both day length and rainfall. Although there was a large rainfall event that occurred in June, which was then followed by no reproductive activity, my results suggest that flowering of *C. odorata* in Hawaiʻi may be triggered by the onset of precipitation caused by the rainy season. Future monitoring of *C. odorata* should continue to analyze this relationship further to determine what the precipitation threshold is to initiate reproductive phenophases, and if the species here truly behaves differently than in other parts of the world where it is more intensely studied.

I also found that there was a significant negative relationship between average monthly temperature and the phenophases of Flowers/Buds, Open Flowers, Fruits, and Ripe Fruits. These results may be associated with the vegetative stage that *C. odorata* exhibited from August – October, where no reproductive phenophases occurred. During the study year, July – September experienced the highest average monthly temperatures, demonstrating how the increase in temperature may be associated with the decrease in occurrence of reproductive phenophases.

Although climate in this study year was in line with the past 28-year average, it would be useful to continue monitoring the phenology of *C. odorata* in Hawaiʻi to identify how the species may react to changing climate and individual events, such as early seasonal precipitation or high temperatures. Shi et al. (2021) found that warming facilitated the success of *C. odorata* placed in a series of artificial multispecies communities. Consistent with prior studies that have identified how invasive species have a higher stress tolerance, plasticity, and resource utilization efficiency than native species, this prior study demonstrated that warming enhanced *C. odorata* invasiveness and decreased the productivity of the native community (Shi et al., 2021). Although my project did not look at the relationship between climate change and invasiveness, future studies will be able to incorporate my baseline study of the phenology of *C. odorata* in Hawai‘i to better predict how the species will behave under changing climates.

By understanding how climate variables such as precipitation and temperature interact with plant phenology, natural resource managers can better predict how species will behave and be able to adjust treatment schedules to optimize control efforts. Based on my results, I suggest that ANRPO and other conservation organizations that manage *C. odorata* should adjust their treatment schedules to be conducted from August – October, where reproductive phenophases are not occuring and before flowering begins. Currently, control schedules are based on the goal of treating each ICA at least twice a year, and by other external factors such as staff time and access into KTA. By controlling *C. odorata* from August – October, it would not only reduce treatment from twice a year to only once a year, but also prevent the spread of seeds and reduce the overall density by controlling plants before they flower and reproduce.

Relationship between reproductive phenophase output and seedling germination

I found that there was a significant positive relationship between reproductive phenophase outputs and seedling germination. Although my results were significant, they were also associated with a low slope, demonstrating that reproductive phenophase output only had a marginal impact on seedling germination. This may be due to the low number of seedlings that germinated in the greenhouse during the study period. Future studies should record seedling emergence in each study plot during phenophase monitoring visits to allow resource managers to identify which phenophase is associated with significant seedling emergence. This will allow for a better understanding of germination predictions to improve the timing of seedling management. For example, if seedling emergence was high during a specific phenophase, it would allow resource managers to adjust their treatment schedules based on the known phenology of *C. odorata* in Hawai‘i.

Future monitoring of C. odorata in Hawai‘i

Phenology data can facilitate the success of natural resource management goals and support informed decision making (Enquist et al., 2014). It allows managers to improve their understanding of species interactions and optimized windows for chemical and mechanical control. For example, Jucker et al. (2020) wanted to understand the seasonal variation in the growth phenology of stinking passionflower (*Passiflora foetida*) in Northern Australia and identify the optimal time window for management. The authors found that there was a rapid increase in mean leaf size following two rainfall events. This information was then used to create an adaptive management plan by applying the most effective combination of treatment methods two months after a large rainfall event, when stinking passionflower was at its peak in terms of vegetative growth.

Although my project studied the phenology of *C. odorata* in Hawaiʻi for one year, there remains a need for coordinated, long-term monitoring and research of key environmental variables as this species is currently found in areas in the state that differ in climate, soils and vegetation. For example, monitoring phenology is a key indicator of climate change impacts (Enquist et al., 2014). Long-term monitoring will improve understanding of how *C. odorata* will respond to seasonal variations and further inform adaptive management plans. Future studies may continue monitoring phenology and identify which phenophases are most suscpetible to chemical and mechanical control. This will allow for the adjustment of treatment schedules that will allow for the optimization of both staff time and resources in controlling *C. odorata.*

The information presented here will also be useful for informing the future release of the biocontrol *C. connexa* in Hawaiʻi. Aigbedion-Atalor et al. (2018), who studied the success of *C. connexa* in Ghana, observed a low density of *C. connexa* in the dry season. This was not unexpected because of the susceptibility of the gall fly to dry climatic conditions that had previously been reported. However, the persistence and recovery of *C. connexa* over the period of the study indicated that the agent is capable of surviving through the dry season in Ghana (Aigbedion-Atalor et al., 2018). Based on suggested adjustments of treatment schedules to optimize efforts to control *C. odorata*, future IWM strategies should take into account both the phenology of *C. odorata* and observed behavior of the biocontrol. For example, herbicide treatments should be conducted between August – October, where reproductive phenophases are not occurring and possibly when *C. connexa* will be in low densities.

Only one-third of biocontrol programs for invasive species are successful (Buckley et al. (2004). Other management options are, therefore, needed, such as IWM, which emphasizes the use of several complimentary control measures. In a study conducted by Buckley et al. (2004), the authors used models of increasing complexity to determine the most successful parameters for controlling an invasive shrub (*Mimosa pigra*), in tropical Australia. The models demonstrated that biocontrol alone is only successful at low levels of small scale disturbance and seedling survival, and would take decades to reduce a stand to <5% site occupancy (Buckley et al., 2004). The most successful IWM strategy was an application of herbicide in year one, mechanical and fire control in year two, herbicide in year three, and biocontrol along the edges of the invasion (Buckley et al., 2004). By integrating biological control with other treatments, such as chemical and mechanical control, management can not only significantly reduce the cost of managing *C. odorata*, but reduce the spread and density of the species in KTA and across Hawaiʻi.

Conclusion

Studying the phenology of invasive species is a key strategy to better understanding seasonal life history events such as germination, growth, and reproduction that can strongly determine a species ability to utilize resources and reproduce (Godoy & Levine, 2014). By improving knowledge and literacy of phenological data and research, it will help land managers achieve their goals of invasive species control by identifying points in the life cycle of species at which they are most susceptible to control, while protecting habitats that are at risk (Morais & Freitas, 2015). My project, which implemented a phenology-based monitoring program of *C. odorata* to better understand the relationships between phenophases and climate variables, will improve the use and integration of both invasive species management and IWM in Hawai'i. During my project, I was able to successfully add *C. odorata* onto the USA-NPN's Nature's Notebook species list. This will allow other scientists or volunteer observers to input their phenophase observations of *C. odorata* into USA-NPN's database, which will provide valuable long-term data for understanding phenological responses around the world. Not only will phenological data of *C. odorata* be more readily available to others but serve as an example on how studying the phenology of invasive species can directly support natural resource decision making.

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O'AHU INVASIVE SPECIES COMMITTEE

Survey and Control of *Chromolaena odorata* in the Kahuku Training Area, Oʻahu, Hawaiʻi Progress Report October 1, 2021—March 31, 2022

Flowering and seeding *C. odorata* plants.

Summary of Project Objectives:

The aim of this project is to contain *Chromolaena odorata,* commonly called devil weed, within the Kahuku Training Area (KTA). Containment at KTA will reduce the threat of this species spreading to natural areas that may contain protected species. With other funds, control operations toward eradication are taking place at locations outside of KTA where *C. odorata* has been found.

Chromolaena odorata is a state-listed noxious weed that is toxic to livestock, people, and other plants. It is widespread on Guam and other Pacific territories and under control programs in Australia and several African countries. It poses a threat to natural and agricultural systems due to its ability to form dense thickets and crowd out native plants. It is a threat to ranching because of its toxicity to livestock. Current populations of *C. odorata* are located at several locations across Oʻahu: the Kahuku Training Area, Kahana State Park, ʻAiea, Pūpūkea, and Malaekahana. Isolated plants have been found in Mākaha, Lanikai, and Hauʻula.

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 KTA and that *C. odorata* was introduced to KTA because of military activities.

At KTA, OISC conducts sweeps of designated subunits and flags patches with a high density of plants that are most efficiently treated with a power or aerial spray. These patches are called "hotspots" and are treated at a later date by the Army Natural Resources Program. This method allows consistent monitoring of devil weed treatments to ensure that areas that may need re-treatment are noted and any new infestations mapped. OISC's responsibilities are:

- Surveying and monitoring treatment of subunits 3,4,7,8 and 10 within the Alpha 1 Range of Kahuku Training Area (KTA). This includes state land leased by the military and used by the public as a motocross recreational area on the weekends. Figure 1 shows where the subunits are within KTA.
- Flagging areas as "hotspots" for follow-up treatment by Army Natural Resources Program. Hotspots are defined as areas with more than five mature plants within a 10m area that would be inefficient to treat without a power sprayer or an aerial spray.
- Monitoring hotspot treatment and recording amount of re-growth after treatment.
- Removing outlier *C. odorata* outside of hotspots.
- Treating re-growth inside previously treated hotspots if this can be accomplished without delaying surveying (otherwise area is flagged for follow-up treatment by Army Natural Resources Program).
- Communicating results of all monitoring through a Google Docs spreadsheet.
- Conducting outreach to the community regarding the threats of *C. odorata*

Project Accomplishments: October 1, 2021—March 31, 2022

OISC conducted three multi-day trips to control *C. odorata*. During the worktrips the crew:

- Conducted survey sweeps over 593 ground acres.
- Marked hotspots with flagging or something equivalent for later aerial or ground treatment by Army Natural Resources Program staff.
- Treated a total of 513 mature and 1,017 immature plants.
    - It should be noted that these numbers are not a reflection on the total amount of plants detected or that actually exist within the subunits OISC and Army Natural Resources Program manage, just the total that were treated by OISC staff.

Staff with freshly removed devil weed.

In addition to the important field work conducted over the reporting period, OISC's outreach staff maintained steady engagement with community members, partners, and other stakeholders. The Public Outreach Coordinator created and presented a digital poster about OISC's citizen science volunteer devil weed control program at the California Invasive Pest Conference (Cal-IPC). The OISC outreach team also conducted a site visit with the Hawaiʻi Motocross Association (HMA) at KTA, creating online GIS maps for volunteer data tracking and assisted with signage and identification of important hotspot locations.

Challenges:

The most challenging aspect specific to this reporting period has been the cancellations of our December 2021 and January 2022 camp trips due to heavy rains and thunderstorms. These cancellations delayed the completion of the second round of surveys for FY21 and delayed the start of the FY22 first round of surveys. Despite the uncooperative weather, OISC conducted two camping trips in February and March. The first round of FY22 surveys is expected to be completed in May and the second round is on track to be completed by October. The map below (*Figure 3*) illustrates survey area completed for both the second round of FY21 and the first round of FY22.

Another challenge we continue to face is the increasing active hotspots. Although OISC only detected three new hotspots during the reporting period, this is the highest amount of new hotspots since 2017. The graphs below (*Figures 1 & 2*) demonstrate a rise in active hotspots to the highest levels snice we began recording hotspot data in 2012. Active hotspots increased to a total of 69, up from 59 the previous year and 19 total in 2012. Inactive hotspots, which had been increasing up until 2018, have started to again recede. Although we are confident in our ability to render hotspots inactive, this species spreads so quickly that it has become difficult to reduce the number of active hotspots in the absence of helicopter treatment for inaccessible populations. These graphs also do not include the other hotspots controlled by ANRP or new infestations discovered in different parts of KTA.

C. odorata is now too widespread across the Oʻahu to eradicate island-wide. OISC continues working with ANRP and other partners to prepare for an eventual biocontrol release that will aid in the control of this species and hopefully allow stakeholders to get ahead of the invasion front.

Table 1: OISC *Chromolaena odorata* Work Effort Summary at Kahuku Training Area October 1, 2021—March 31, 2022

Location	Acres Surveyed	Mature Plants Treated	Immature Plants Treated	Total Plants Treated	Effort (Hours)
KTA Subunit 3 & 7	593.61	513	1,017	1,530	1,190

DEFINITIONS

New = A newly identified hotspot defined as containing five or more mature and/or greater than 150 immature, less than five mature but really old and set seed more than once, or less than five mature but outlying area. Spray needed to address seed bank.
Active high = Existing hotspot with at least one mature plant old enough to set seed at least once and/or at least 30 immature detected. Spray needed to address seed bank.
Active low = Existing hotspot with fewer than 30 immature plants, or containing a small number of newly mature plants that has not set seed. In general, less than two years since 'active high.' Spray typically needed on at least the first year classified as low to address seed bank.
Inactive = Existing hotspot at least two years after an 'Active high' or NEW designation with 'Active low' criteria. An exception for earlier designation would be if fewer than five immature detected with no previous history of spray treatment and following one year of 'Active low'. Spray not needed.
Unknown = No data available.

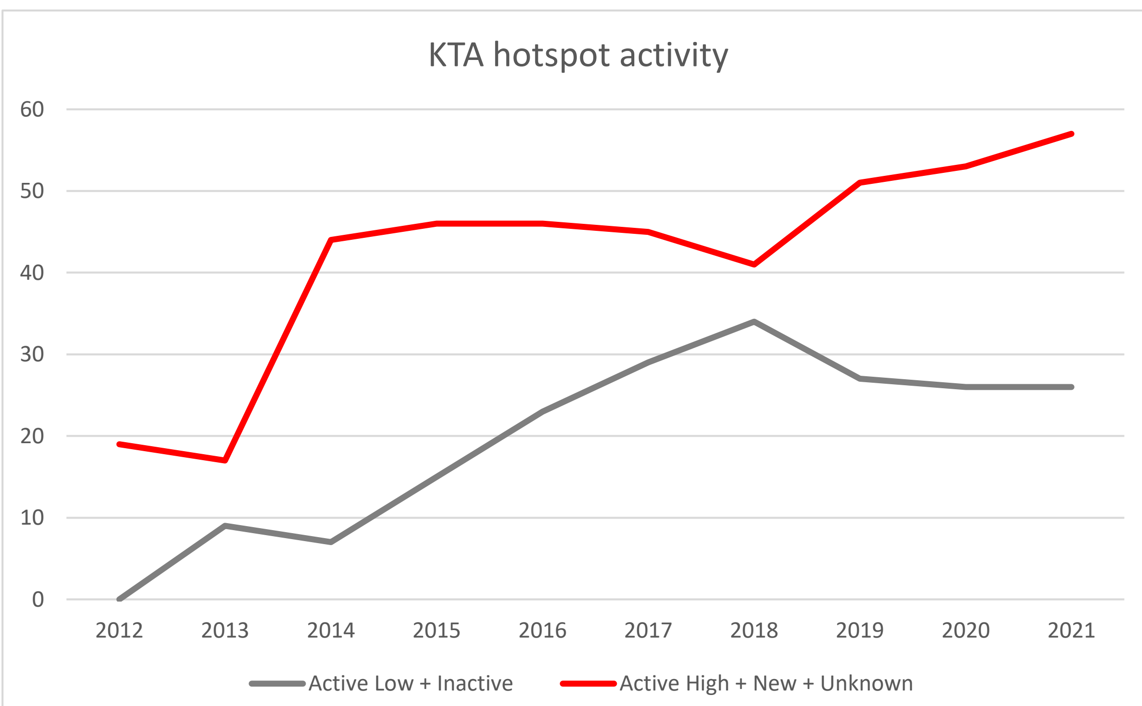
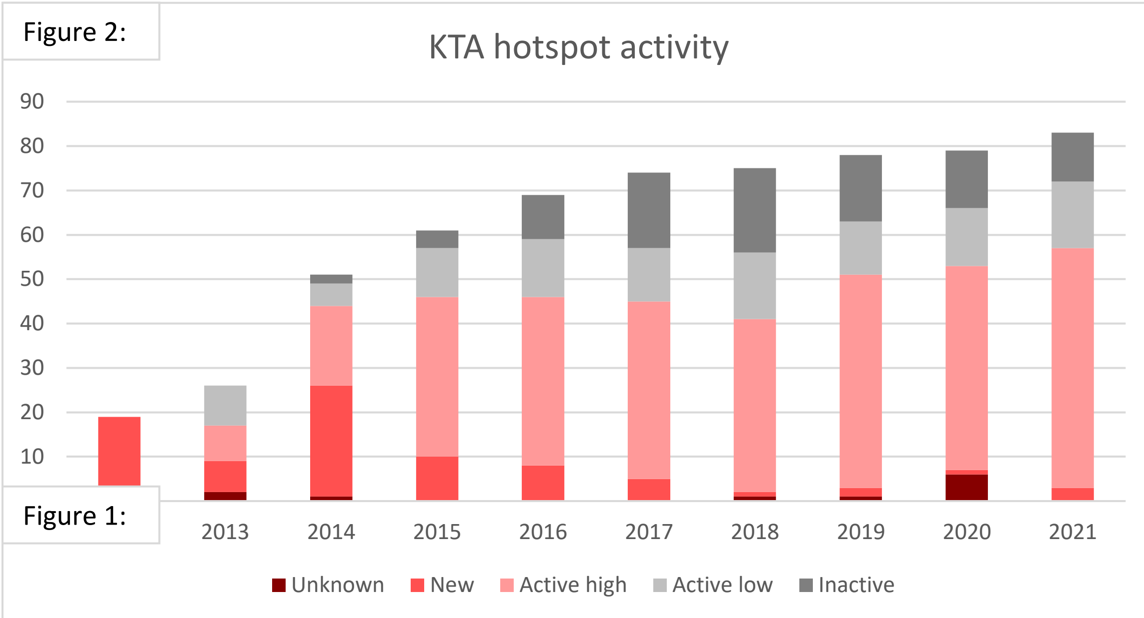
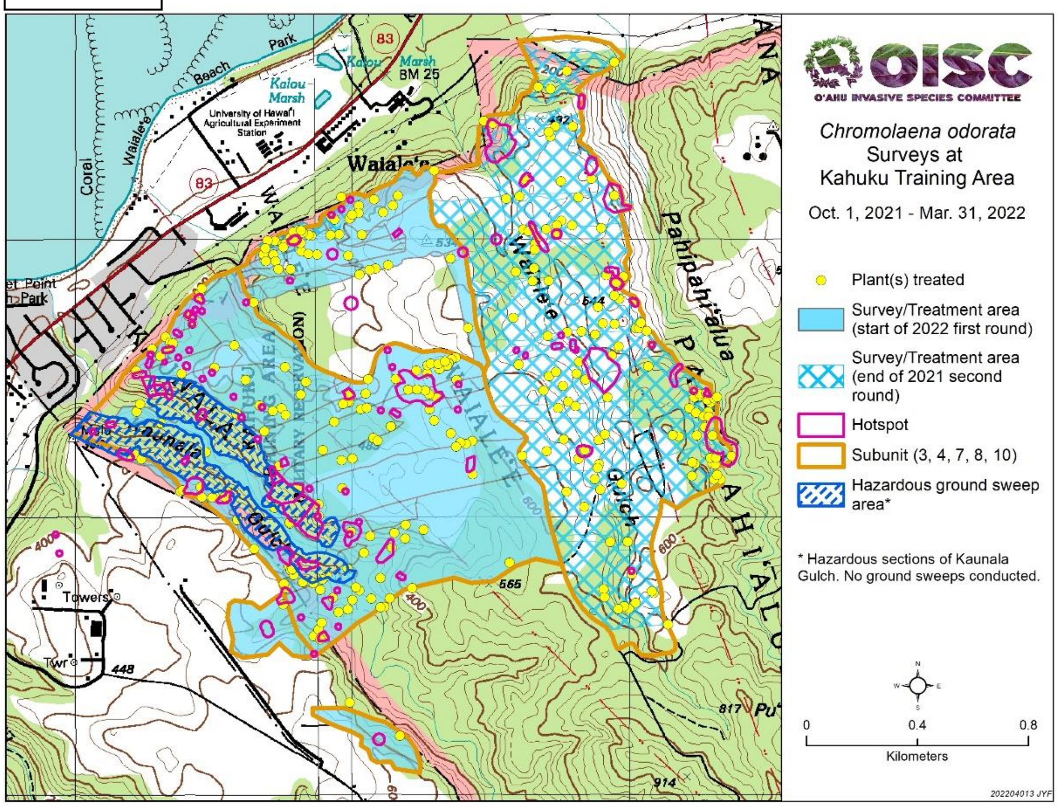


Figure 2:



Figures 1-3: KTA Hotspot Activity (Figures 1 & 2); OISC *Chromolaena odorata* Work Effort in Kahuku Training Area October 1, 2021 – March 31, 2022:

Figure 3:



Data Management and Coordination:
During the reporting period, OISC staff entered observations for each hotspot into the Google Docs Hotspot Spreadsheet. The GIS Specialist quality controlled data from the field entered into the database and the spreadsheet. She also worked with Army Natural Resources Program staff to ensure the hotspot spreadsheet makes sense to both organizations. OISC also submits monthly time reports detailing time spent in the field and office pertaining to these funds. Internally, OISC staff enters survey and control data monthly to ArcGIS and the OISC database with rigorous quality control measures to ensure data accuracy. Volunteers collect data via the free mobile application AllTrails and all data is reviewed by outreach staff before finalization.

C. ODORATA ACTIVITES SUPPORTED WITH OTHER FUNDS:

Outreach and Education regarding C. odorata outside of the Kahuku Training Area (KTA)
OISC maintains a robust outreach program that works to educate the community about the threats of invasive species and what actions community members can take to help fight the spread and harmful effects of invasive species. Since March of 2020, in-person outreach has been limited and volunteer outings continue to be prohibited per university mandates. OISC quickly adapted all outreach virtual activities, conducting presentations via zoom and creating digital outreach tools in order to maintain our presence in the community.

Despite these pandemic challenges, outreach staff have been able to establish the “Devil Weed Crew” citizen volunteer group as a substitute for volunteer outings to survey and control for *C. odorata* along trails adjacent to KTA. Outreach staff facilitate this program through an active Facebook group that has grown to 54 members. Devil Weed Crew members submit data via the AllTrails mobile phone application and OISC reviews data for accuracy before incorporating that data into our database.

During the reporting period, outreach staff tracked 21 requests for identification guides and volunteers removed 170 mature and 441 immature devil weed plants from Oʻahu watersheds over 319 acres of surveyed trails. Volunteers are directed to OISC’s YouTube channel where the staff have created four video tutorials along with the field guide that is mailed to participants after signing up for the program. These videos include virtual guides for species identification, a case study of invasive species as they pertain to agriculture, a field orientation video, and a species botanical breakdown. Staff also provided ranchers with a digitized information packet at the annual meeting for the Hawaiʻi Cattlemen’s Association, maintained a substantial social media footprint with three posts per month that averaged a reach of 940 accounts per post.

Surveys and Control for *C. odorata* outside of the Kahuku Training Area (KTA)
OISC conducted 63 acres of ground and aerial surveys outside of KTA, controlling 661 mature and 4,324 immature plants. Unfortunately, much of the surveys need to be done on private property and acquiring access permission is time-consuming; therefore, there are still areas that may contain *C. odorata* but have not been surveyed.

Specific to the Kahana Valley population, OISC treatments continue to effectively reduce devil weed populations. Field crews conducted a 1.39 acre precision-point aerial application in late 2021, in addition to 52.68 acres of ground survey in late 2021 and early 2022. The steady downward trend in hotspots indicates a successful progression to regional eradication in this location.

DEFINITIONS

New = A newly identified hotspot defined as containing five or more mature and/or greater than 150 immature, less than five mature but really old and set seed more than once, or less than five mature but outlying area. Spray needed to address seed bank.

Active high = Existing hotspot with at least one mature plant old enough to set seed at least once and/or at least 30 immature detected. Spray needed to address seed bank.

Active low = Existing hotspot with fewer than 30 immature plants, or containing a small number of newly mature plants that has not set seed. In general, less than two years since 'active high.' Spray typically needed on at least the first year classified as low to address seed bank.

Inactive = Existing hotspot at least two years after an 'Active high' or NEW designation with 'Active low' criteria. An exception for earlier designation would be if fewer than five immature detected with no previous history of spray treatment and following one year of 'Active low'. Spray not needed.

Unknown = No data available.

Figure 3:

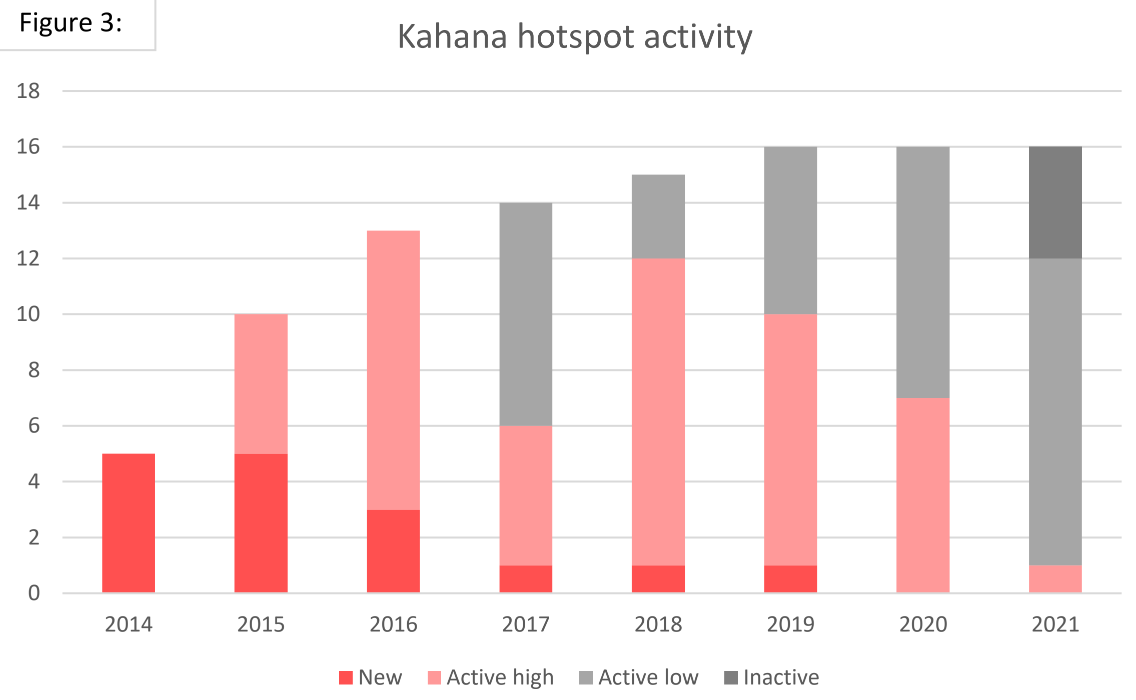


Figure 4:

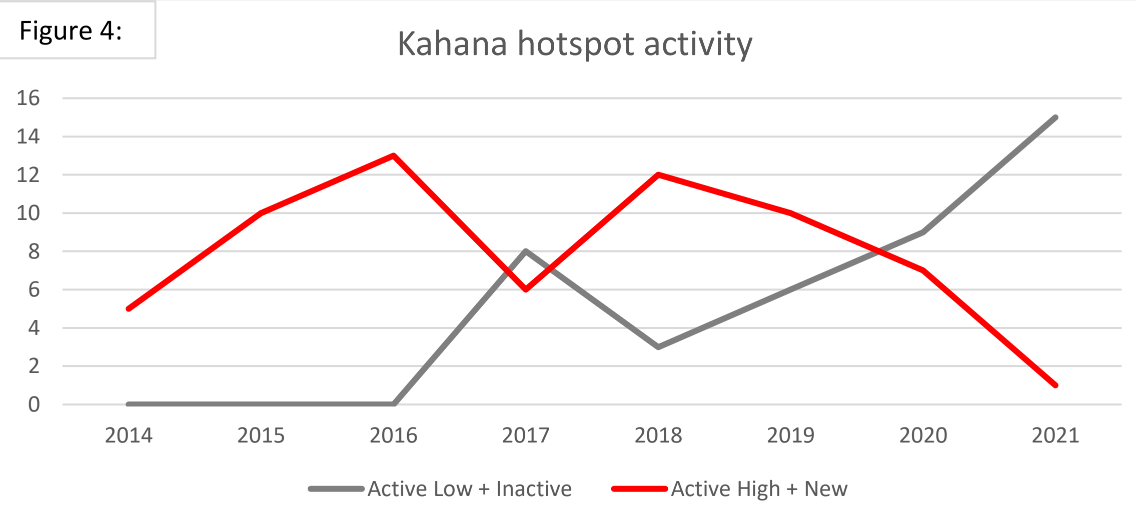


Table 2: OISC *Chromolaena odorata* Work Effort Summary on non-KTA lands. October 1, 2021 – March 31, 2022:

Watershed	Ground Acres Surveyed	Aerial Acres Surveyed	Mature Plants Treated	Immature Plants Treated	Total Plants Treated	Effort (Hours)
ʻAiea	8.92	0	653	3,551	4,204	81.75
Kahana	99.63	1.39	8	773	781	313.25
Total	**61.61**	**1.39**	**661**	**4,324**	**4,985**	**395**

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.

Survey and Control of *Chromolaena odorata* in the Kahuku Training Area, Oʻahu, Hawaiʻi

Annual Progress Report
to
The Army Natural Resource Program (ANRP)

October 1, 2021—September 30, 2022

OISC staff member overlooking communities we protect from devil weed below Kahuku Training Area (KTA).

Summary of Project Objectives:
The aim of this project is to contain *Chromolaena odorata,* commonly called devil weed, within the Kahuku Training Area (KTA). Containment at KTA will reduce the threat of this species spreading to natural areas that may contain protected species. With other funds, control operations toward eradication are taking place at locations outside of KTA where *C. odorata* has been found.

Chromolaena odorata is a state-listed noxious weed that is toxic to livestock, people, and other plants. It is widespread on Guam and other Pacific territories and under control programs in Australia and several African countries. It poses a threat to natural and agricultural systems due to its ability to form dense thickets and crowd out native plants. It is a threat to ranching because of its toxicity to livestock. Current populations of *C. odorata* are located at several locations across Oʿahu: the Kahuku Training Area, Kahana State Park, ʿAiea, Pūpūkea, and Malaekahana. Isolated plants have been found in Mākaha, Lanikai, and Hauʻula.

Between 2006 and 2009, botanical surveys of all publicly accessible roads on Oʻahu were conducted by OISC's Oʻahu Early Detection program. *C. odorata* was not found during these surveys. This means that it is unlikely *C. odorata* was introduced somewhere else and dispersed onto KTA. *C. odorata* is a widely dispersed pest on the island of Guam, and units from Hawaiʻi sometimes train in Guam. The seeds are wind dispersed and readily attach to clothing. One plant can produce approximately 800,000 seeds a year. Given these factors, it is highly likely the pathway of introduction was military activities. The Biological Opinion for military activities on Oʻahu requires the Army to respond immediately to incipient weeds brought in via training operations. What is currently known about *C. odorata* supports the assumptions that the center of the population is the Kahuku Training Area (KTA) and that *C. odorata* was introduced to KTA because of military activities.

At KTA, OISC conducts sweeps of designated subunits and flags patches with a high density of plants that are most efficiently treated with a power or aerial spray. These patches are called "hotspots" and are treated at a later date by the Army Natural Resources Program. This method allows consistent monitoring of devil weed treatments to ensure that areas that may need re-treatment are noted and any new infestations mapped. OISC's responsibilities are:

- Surveying and monitoring treatment of subunits 3,4,7,8 and 10 within the Alpha 1 Range of Kahuku Training Area (KTA). This includes state land leased by the military and used by the public as a motocross recreational area on the weekends. Figure 3 shows where the subunits are within KTA.
- Flagging areas as "hotspots" for follow-up treatment by Army Natural Resources Program. Hotspots are defined as areas with more than five mature plants within a 10m area that would be inefficient to treat without a power sprayer or an aerial spray.
- Monitoring hotspot treatment and recording amount of re-growth after treatment.
- Removing outlier *C. odorata* outside of hotspots.
- Treating re-growth inside previously treated hotspots if this can be accomplished without delaying surveying (otherwise area is flagged for follow-up treatment by Army Natural Resources Program).

- Communicating results of all monitoring through a Google Docs spreadsheet.

Project Accomplishments: October 1, 2021—September 30, 2022

OISC conducted three multi-day trips to control *C. odorata*. During the worktrips the crew:

- Conducted survey sweeps over 1,603 acres.
- Marked hotspots with flagging or something equivalent for later aerial or ground treatment by Army Natural Resources Program staff.
- Treated a total of 1,203 mature and 3,552 immature plants. It should be noted that these numbers are not a reflection on the total amount of plants detected or that actually exist within the subunits OISC and Army Natural Resources Program manage, just the total that were treated by OISC staff.

***C. odorata* plant exhibiting odd coloration, staff hand for scale.**

OISC's outreach staff has maintained steady engagement with community members, partners, and other stakeholders over the reporting period regarding devil weed efforts. The Public Outreach Coordinator created and presented a digital poster about OISC's citizen science volunteer devil weed control program at the California Invasive Pest Conference (Cal-IPC). Later in the year, OISC launched "The Devil Weed Crew Challenge" to incentivize trail surveys before flowering season. This led to a noticeable increase in survey acres along trails, some adjacent to KTA. Volunteer programs like the Devil Weed Crew supplement rigorous outreach efforts for both social media and in-person events.

The OISC outreach team also conducted two site visits to KTA. Staff conducted one visit with the Hawai'i Motocross Association (HMA) to create online GIS maps for volunteer data tracking and assist with identification and signage of important hotspot locations. Coordinated by ANRP, OISC participated in another visit to KTA to scout for suitable control sites and seek general guidance for release of the galling fly *Cecidochares connexa* from Australian biocontrol experts. Staff from OISC partners agencies were also present, including individuals from the Hawai'i Department of Agriculture (HDOA) and the Hawai'i Department of Forestry & Wildlife (DOFAW).

Challenges:
Inclement weather, a range fire, access issues, and a Covid-19 outbreak within OISC cancelled a record high (6) camping operations for OISC at KTA over the reporting period. Survey sweeps began in October and November 2021, but our camping operations for December 2021 and January 2022 needed to be cancelled for inclement weather and issues related to Covid-19 respectively. In May 2022, OISC reverted from camping operations to day trips due to range-access issues and a June 2022 camp was cancelled due to a fire. Two scheduled camping

operations in August 2022 needed to be cancelled due to RIMPAC activities taking place on range. Despite these setbacks, OISC was able to fulfill all expected outcomes by rescheduling trips and sending more staff than originally planned on most camping operations throughout the reporting period as Covid-19 restrictions continued to loosen.

Another challenge we continue to face is the increasing active hotspots. The graphs below (*Figures 1 & 2*) demonstrate a rise in active hotspots to the highest levels snice we began recording hotspot data in 2012. Active hotspots continued a gradual increased from the previous year and inactive hotspots, which had been increasing up until 2018, have started to plateau. Although we are confident in our ability to render hotspots inactive, this species spreads so quickly that it has become difficult to reduce the number of active hotspots in the absence of helicopter treatment for inaccessible populations. These graphs also do not include the other hotspots controlled by ANRP or new infestations discovered in different parts of KTA.

Several shapefiles are included with this report, including points of interest not related to C. odorata. These points include trash piles, military debris, and razor wire. These items make traversing the area more difficult and dangerous so we have included photos and points for ANRP reference.

C. odorata is now too widespread across the island to eradicate island-wide. OISC's core mission is to eradicate species island-wide and it is no longer feasible to do that on Oʻahu for this species. Since there is a biocontrol that has already been tested for host-specificity and released with good results elsewhere, OISC and partner agencies will continue to work together with ANRP in order to get the agent approved for release on Oʻahu. After discussions with ANRP staff, OISC will be shifting strategies to an approach more focused on outreach and control along likely pathways of contamination (roads and trails) rather than widespread survey and control throughout the subunits of Alpha One.

Staff collecting *C. odorata* plant fragments, flowers, and seeding bodies while removing large clusters of *C. odorata* from KTA.

DEFINITIONS
New = A newly identified hotspot defined as containing five or more mature and/or greater than 150 immature, less than five mature but really old and set seed more than once, or less than five mature but outlying area. Spray needed to address seed bank.
Active high = Existing hotspot with at least one mature plant old enough to set seed at least once and/or at least 30 immature detected. Spray needed to address seed bank.
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Inactive = Existing hotspot at least two years after an 'Active high' or NEW designation with 'Active low' criteria. An exception for earlier designation would be if fewer than five immature detected with no previous history of spray treatment and following one year of 'Active low'. Spray not needed.
Unknown = No data available.

Table 1: OISC *Chromolaena odorata* Work Effort Summary at Kahuku Training Area October 1, 2021—September, 2022

Timeframe	Location	Acres Surveyed	Mature Plants Treated	Immature Plants Treated	Total Plants Treated	Effort (Hours)
10/1/20-3/31/21	KTA Subunit: 3, 4, 7, 8, 10	594	560	1,068	1,628	1,190
4/1/21-9/30/21	KTA Subunit: 3, 4, 7, 8, 10	1,009	643	2,484	3,127	1,487
10/1/20-9/30/21	KTA Subunit: 3, 4, 7, 8, 10	1,603	1,203	3,552	4,755	2,677

Figures 1 & 2: *C. odorata* Hotspot Activity at KTA

DEFINITIONS
New = A newly identified hotspot defined as containing five or more mature and/or greater than 150 immature, less than five mature but really old and set seed more than once, or less than five mature but outlying area. Spray needed to address seed bank.
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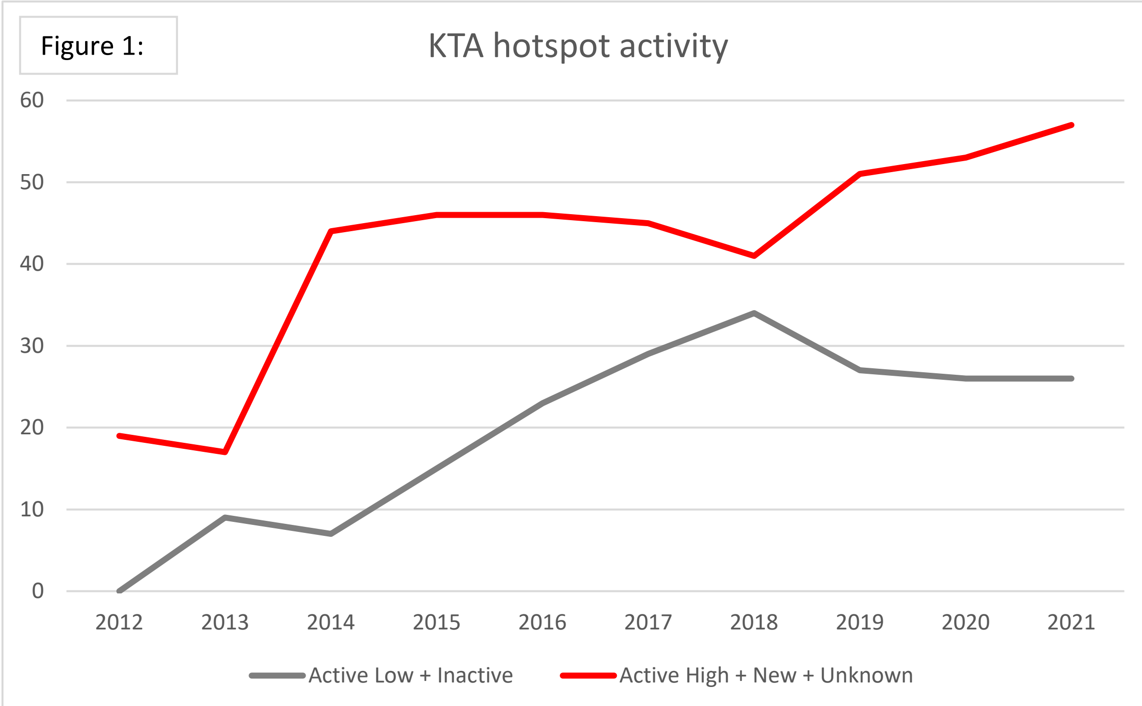


Figure 1:
KTA hotspot activity
60
50
40
30
20
10
0
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Active Low + Inactive
Active High + New + Unknown

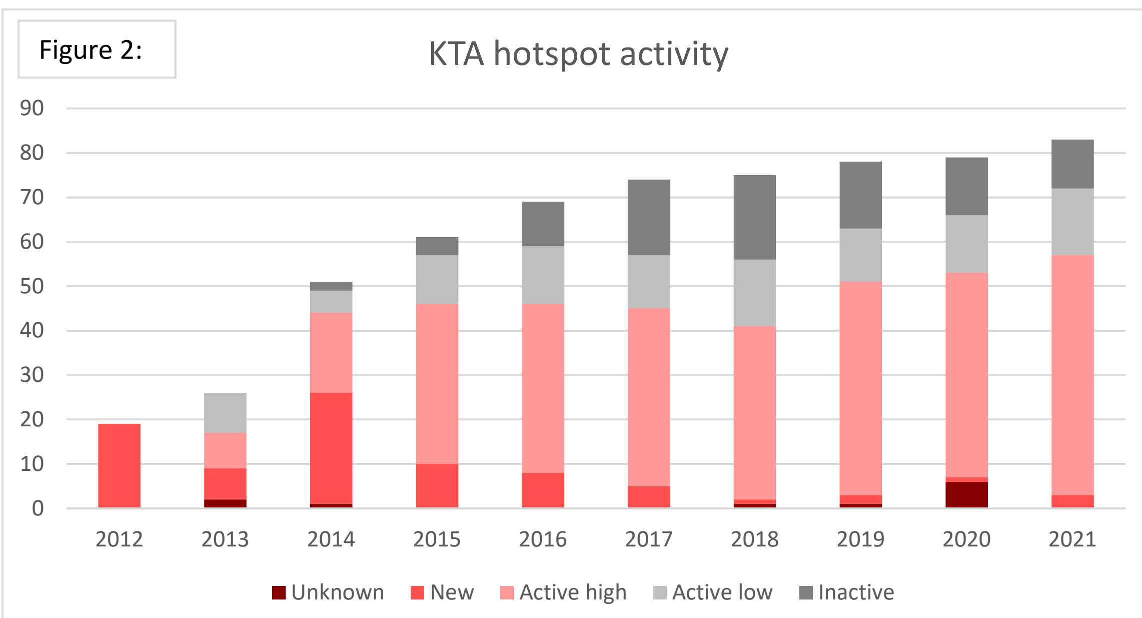
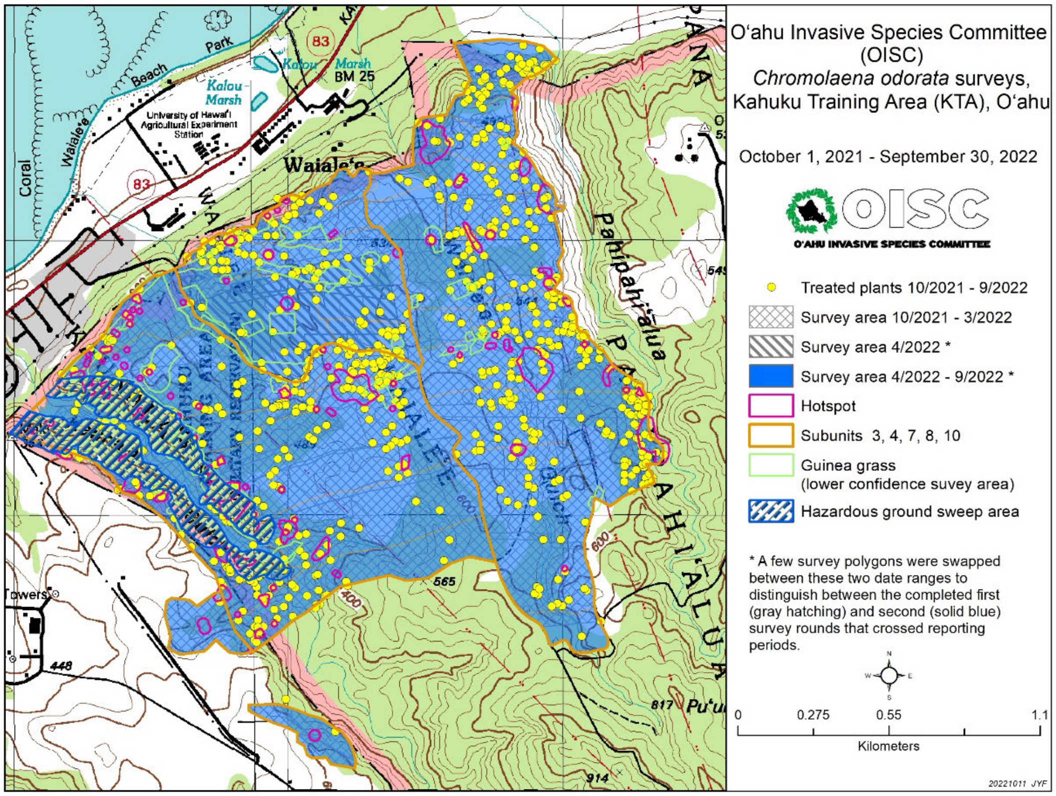


Figure 2:
KTA hotspot activity
90
80
70
60
50
40
30
20
10
0
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Unknown
New
Active high
Active low
Inactive

Figure 3: OISC *Chromolaena odorata* Work Effort in Kahuku Training Area
October 1, 2021 – September 30, 2022



Data Management and Coordination:
During the reporting period, OISC staff entered observations for each hotspot into the Google Docs Hotspot Spreadsheet. The GIS Specialist quality controlled data from the field entered into the database and the spreadsheet. She also worked with ANRP staff to ensure the hotspot spreadsheet makes sense to both organizations.

Staff decontaminating work vehicles from potential *C. odorata* contamination.

C. ODORATA ACTIVITES SUPPORTED WITH OTHER FUNDS:

Surveys and Control for *C. odorata* outside of the Kahuku Training Area (KTA)
OISC conducted 63 acres of ground and aerial surveys outside of KTA, controlling 661 mature and 4,324 immature plants. Unfortunately, much of the surveys need to be done on private property and acquiring access permission is time-consuming; therefore, there are still areas that may contain *C. odorata* but have not been surveyed.

Specific to the Kahana Valley population, OISC treatments continue to effectively reduce devil weed populations. Field crews conducted a 1.39 acre precision-point aerial application in late 2021, in addition to 52.68 acres of ground survey in late 2021 and early 2022. The steady downward trend in hotspots indicates a successful progression to regional eradication in this location.

Outreach and Education regarding *C. odorata* outside of the Kahuku Training Area (KTA)
OISC maintains a robust outreach program that works to educate the community about the threats of invasive species and what actions community members can take to help fight the spread and harmful effects of invasive species. Since March of 2020, in-person outreach has been limited and volunteer outings continue to be prohibited per university mandates. OISC quickly adapted all outreach virtual activities, conducting presentations via zoom and creating digital outreach tools in order to maintain our presence in the community.

Despite these pandemic challenges, outreach staff have been able to establish the Devil Weed Crew (DWC) citizen volunteer group as a substitute for volunteer outings to survey and control for *C. odorata* island-wide. Outreach staff facilitate this program through an active Facebook group that has grown to 60 members. DWC members submit data via the AllTrails mobile phone application and OISC reviews data for accuracy before incorporating that data into our database. Volunteers are also directed to OISC's YouTube channel where the staff have created four video tutorials along with a field guide that is mailed to participants after signing up for the program. These videos include virtual guides for species identification, a case study of invasive species as they pertain to agriculture, a field orientation video, and a species botanical breakdown.

During the reporting period, outreach staff provided 75 devil weed identification guides by request and DWC volunteers removed 200 mature and 763 immature devil weed plants from Oʻahu watersheds. Members of the DWC surveyed 460.43 miles across 21 unique Oʻahu trails. OISC's outreach team also provided ranchers with a digitized information packet at the annual meeting for the Hawaiʻi Cattlemen's Association, maintained a substantial social media footprint with three posts per month that averaged a reach of 940 accounts per post, conducted a site visit to the Pūpūkea-Paumalū State Park Reserve with the Maui Invasive Species Committee Public Relations and Education Specialist, and participated in an interview with Conservation Dogs of Hawaiʻi for a Civil Beat article titled, "Sharp-Nosed Dogs." OISC also provided two community presentations reaching 46 individuals, two school presentations reaching 42 students, and attended three in-person outreach events reaching 390 individuals, all specific to devil weed control efforts.

Table 2: OISC *Chromolaena odorata* Work Effort Summary on non-KTA lands
October 1, 2021 – September 30, 2022:

Watershed	Ground Acres Surveyed	Aerial Acres Surveyed	Mature Plants Treated	Immature Plants Treated	Total Plants Treated	Effort (Hours)
‘Aiea	8.92	0	653	3,551	4,204	81.75
Kahana	99.63	1.39	8	773	781	313.25
Total	**61.61**	**1.39**	**661**	**4,324**	**4,985**	**395**

Figures 4 & 5: *C. odorata* Hot Spot Activity Outside of KTA

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New = A newly identified hotspot defined as containing five or more mature and/or greater than 150 immature, less than five mature but really old and set seed more than once, or less than five mature but outlying area. Spray needed to address seed bank.
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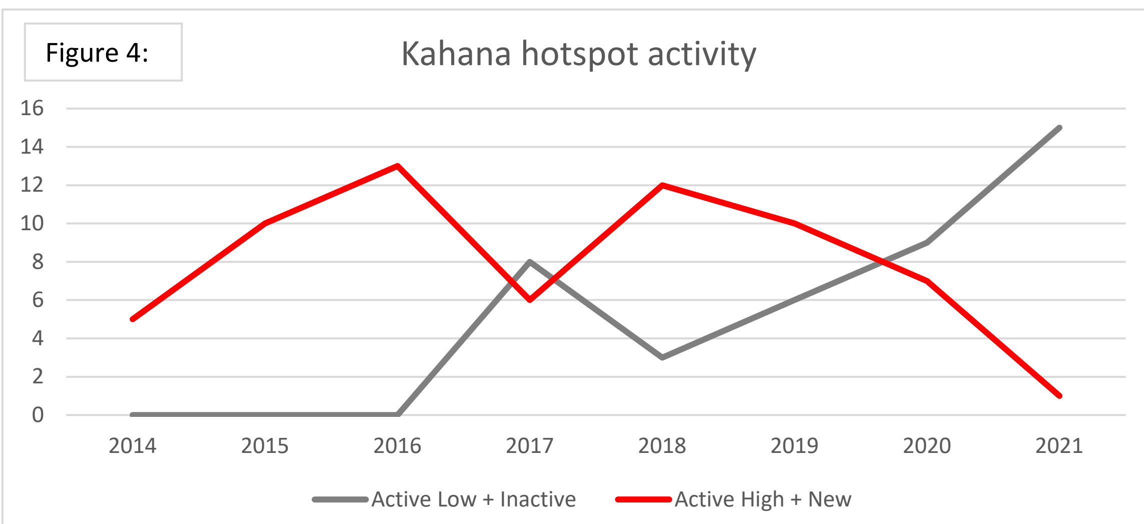

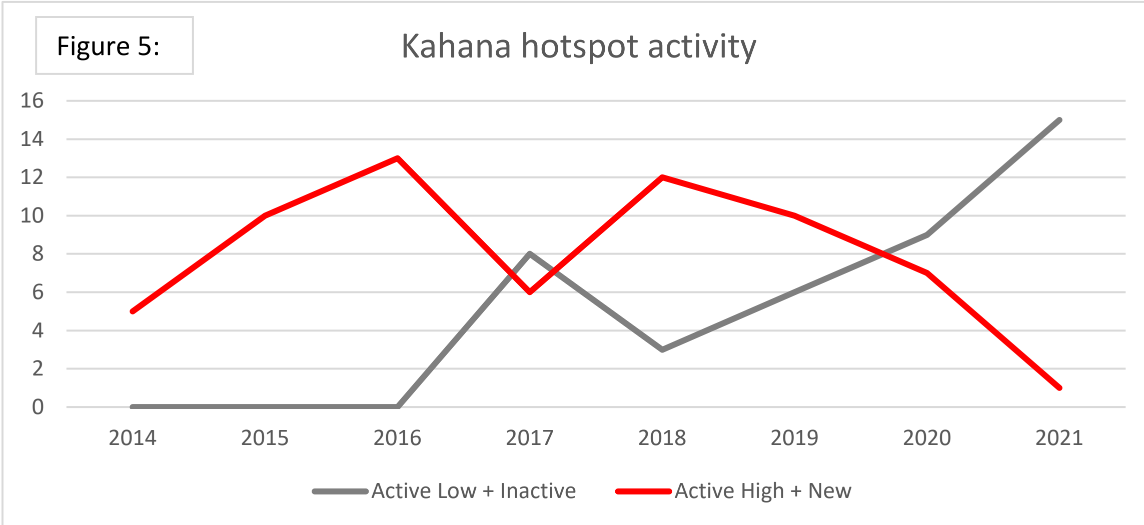

Staff from OISC partner agencies ANRP, HDOA, and DOFAW pose at KTA with Australian biocontrol experts.

Compliance:
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9th Annual O'ahu Weed Management & Restoration Workshop

May 5th, 2022 | Agenda

8 am OPENING

Weed Management

8:10 ***Cenchrus echinatus* Eradication on Nihoa**
Rachel Rounds | US Fish and Wildlife

8:25 **Aerial Control Methods for Forest Invaders**
Nate Dube | O'ahu Invasive Species Committee

8:40 **Introduction to the Statewide Noxious Invasive Pest Program (SNIPP)**
Richard Pender & Danielle Frohlich | SWCA Environmental Consultants

8:55 ***Chromolaena Odorata* Detection Dog Program: From Proof-of-Concept to Operational**
Kyoko Johnson | Conservation Dogs

9:10 **Lessons Learned from Aerial Invasive Fern Mapping Techniques Across Large Landscapes**
Emma Yuen & Dylan Davis | HI Native Ecosystems Protection & Mgmt

9:20 **Rapid ʻŌhiʻa Death Update**
JB Friday & James Harmon | UH Extension & HI Native Ecosystems Protection & Mgmt

9:35 **Pesticide Training Needs Survey**
Melissa Kunz | UH Extension

BREAK

Restoration

9:55 **Intensive Vegetation Management**
Missy Valdez, Chris Lum, Petelo Maosi | Army Natural Resources Program on O'ahu

10:20 **What limits natural regeneration in koa restoration forests, and how do we get around it?**
Stephanie Yelenik | US Forest Service

10:35 **Small-scale, High-intensity Forest Restoration Using Manual Weed Control & Outplanting**
JC Watson | Ko'olau Mountains Watershed Partnership

10:50 **10 Years of Restoration in Waiʻanae**
Yumi Miyata | Waiʻanae Mountains Watershed Partnership

11:05 **Hydrogel Granules: Novel Method for Native Tree Reforestation in Degraded Soil Conditions**
Frankie Koethe & Brad Suenishi | Ko'olau Mountains Watershed Partnership

11:20 **Utilizing Stemflow Collars on Non-Native Plants to Capture Water for Restoration Activities**
Amy Tsuneyoshi, Jamie Tanino, and Judy Journeay | Honolulu Board of Water Supply

11:35 **Plant Propagation Spreadsheet**
Paul Zweng | ʻŌhulehule Forest Conservancy

LUNCH BREAK

Community

12:20 **Mobilizing the Masses - Community Engagement in Conservation**
Presentations followed by facilitated JamBoard discussion

- **Growing a Community Restoration Project**
  Jason Preble, Tyrone Montayre, Ryan Chang | Protect & Preserve Hawaii
- **Mālama Puʻuloa Community Engagement & Empowerment**
  Sandy Ward | Hui o Ho'ohonua

Tools

1:30 **Leveling Up the Weed Spreadsheet**
Presentation followed by facilitated discussion
Clay Trauernicht & Jane Beachy | UH Extension & Army Natural Resources Program on O'ahu

2:30 **CLOSING & PAU**

ARMY NATURAL RESOURCE PROGRAM ON OAHU
MONITORING PROGRAM

KAHANAHAIKI MANAGEMENT UNIT VEGETATION MONITORING, 2021

INTRODUCTION

The Army Natural Resources Program on Oahu (ANRPO) conducted vegetation monitoring at Kahanahaiki Management Unit (MU) in 2021 in association with Implementation Plan (IP) requirements for long term monitoring of vegetation composition and change over time (ANRPO 2008) (Figure 1). The primary objective of MU monitoring is to assess if the percent cover of non-native plant species is less than 50% across the MU, or is decreasing towards that threshold requirement. The secondary objective is to assess if native cover is greater than 50% across the MU, or is increasing towards that threshold recommendation. Kahanahaiki MU vegetation monitoring occurs on a on a three-year interval and took place previously in 2009, 2012, 2015, and 2018 (ANRPO 2009, 2012, 2015, and 2018a). Previous monitoring in 2018 indicated that cover goals were only met for the non-native understory. The MU fence for Subunit I was completed in 1997. The Subunit II fence was completed in 2013, but monitoring plots were not established due to steep terrain and limited plans for active management in that area.

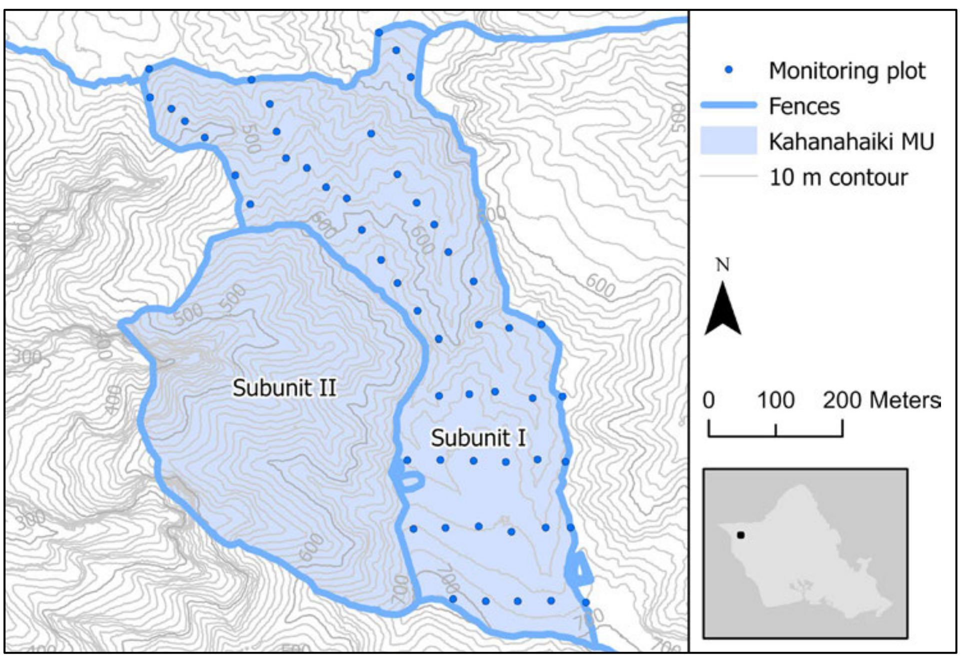

Figure 1: Kahanahaiki MU vegetation monitoring plot locations.

METHODS

In May of 2021, 53 plots along nine transects were monitored in Subunit I of Kahanahaiki MU (Figure 2). Plots measuring 5 x 10 m were generally located every 50 m along transects. Transects were spaced approximately 100 m apart. These same plots were also monitored in 2009, 2012, 2015, and 2018. 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, and overall summary percent cover of non-native and native vegetation in the understory and canopy, 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

Figure 2: ANRPO staff members Joby Rohrer (left, in non-native dominated habitat) and Chelsea Osaki (right, in native dominated habitat) collecting field data at vegetation monitoring plots at Kahanahaiki MU.

(defined as seedlings or saplings < 2 m AGL) data for tree species was recorded beginning in 2012, though observations in 2012 and 2015 (not included in analyses) were incomplete. Monitoring results were compared with data from prior years. Based on IP recommendations, p-values < 0.05 were considered significant, and only absolute cover changes ≥ 10% were recognized. Additional methodology information is detailed in Monitoring Protocol 1.2.1 (ANRPO 2008). All analyses were performed in IBM SPSS Statistics Version 28. These included Friedman's tests with Bonferroni adjusted post-hoc pairwise comparisons and Wilcoxon signed ranks tests for cover and richness data; McNemar's tests for frequency data; and generalized linear modeling (GLM) for the influence of restoration efforts on cover change. For species frequency analyses, comparisons were made between 2009 and 2021 for taxa with ≥ 10% difference in frequency. For species cover analyses, comparisons were made between 2009 and 2021 for taxa with frequencies ≥ 20% in either 2009 or 2021. Median numbers reported do not always correspond to MU-wide trends as reflected by statistical results (median values may remain unchanged despite statistically significant result, or vice versa). P-values represent the likelihood (scaled from 0 to 1) that there is no difference in compared data, where higher values indicate a greater likelihood of no difference occurring.

RESULTS

Understory and canopy cover categories

Management goals of having < 50% non-native understory and canopy and > 50% native understory and canopy cover were only met for the non-native understory (35%) (Table 1). Non-native canopy was fairly high (75% median cover). Native understory and canopy cover remained low (both at

Table 1: Median percent cover of native and non-native vegetation categories in the canopy and understory at Kahanahaiki MU from 2009 to 2021. Categories specifically addressed in management goals are shaded in blue. Statistically significant values for categories that meet the 10% standard for recognized change in cover are in boldface. Arrows indicate increase (↑), decrease (↓), or inconsistent trend (↕) in cover.

	2009	2012	2015	2018	2021	p*	X^2	Years that differed significantly	p (post-hoc)**	Mgmt goal currently met?
Understory										
Native shrubs	7.5	15	7.5	7.5	3	**0.000↓**	26.662	2012-2021 2015-2021	**0.006↓** 0.006↓	
Native ferns	7.5	3	7.5	3	3	0.007↓	14.002	NA		
Native grass/sedges	0	0	0.5	0	0.5	0.405	4.010			
Total native understory	15	25	25	15	15	**0.000↓**	25.159	2012-2021 2015-2021 2015-2018	0.021↓ **0.002↓** **0.024↓**	No
Non-native shrubs	15	25	25	25	15	**0.000↑**	24.190	2009-2015 2012-2015	**0.000↑** 0.026↑	
Non-native ferns	0	0.5	0.5	0.5	0.5	0.000↑	24.070	2009-2021 2012-2021	0.004↑ 0.047↑	
Non-native grass/sedges	0.5	0.5	3	0.5	0.5	0.000↕	27.239	2012-2015 2015-2021 2015-2018	0.001↑ 0.010↓ 0.039↓	
Total non-native understory	25	25	35	25	35	**0.000↕**	27.361	2009-2015 2012-2015 2015-2021	**0.000↑** **0.000↑** 0.010↓	Yes
Canopy										
Native canopy	15	15	15	15	15	0.076	8.450			No
Non-native canopy	45	55	55	55	75	**0.000↑**	34.777	2009-2018 2009-2021 2012-2021	**0.002↑** **0.000↑** **0.024↑**	No
Total canopy	65	95	95	95	95	0.000↑	46.562	2009-2012 2009-2015 2009-2018 2009-2021	**0.001↑** **0.001↑** **0.000↑** **0.000↑**	

*from Friedman's test, asymptotic significance
**from post-hoc pairwise comparisons with Bonferroni adjustment

15%). There were significant changes in percent cover of vegetation since 2009 that met the 10% standard for recognized change in cover. These included cover declines for native shrubs and total native understory, increases for non-native shrubs and canopy as well as total canopy, and inconsistent trends in cover change for total non-native understory (Figure 3). Most pronounced among these was the increase in non-native canopy cover over time since 2009. In 2021, locations of low to high native and non-native understory percent cover were patchily distributed, while high native canopy cover was mostly concentrated in the southern half of the MU, and high non-native canopy cover occurred throughout much of the MU (Figure 4).

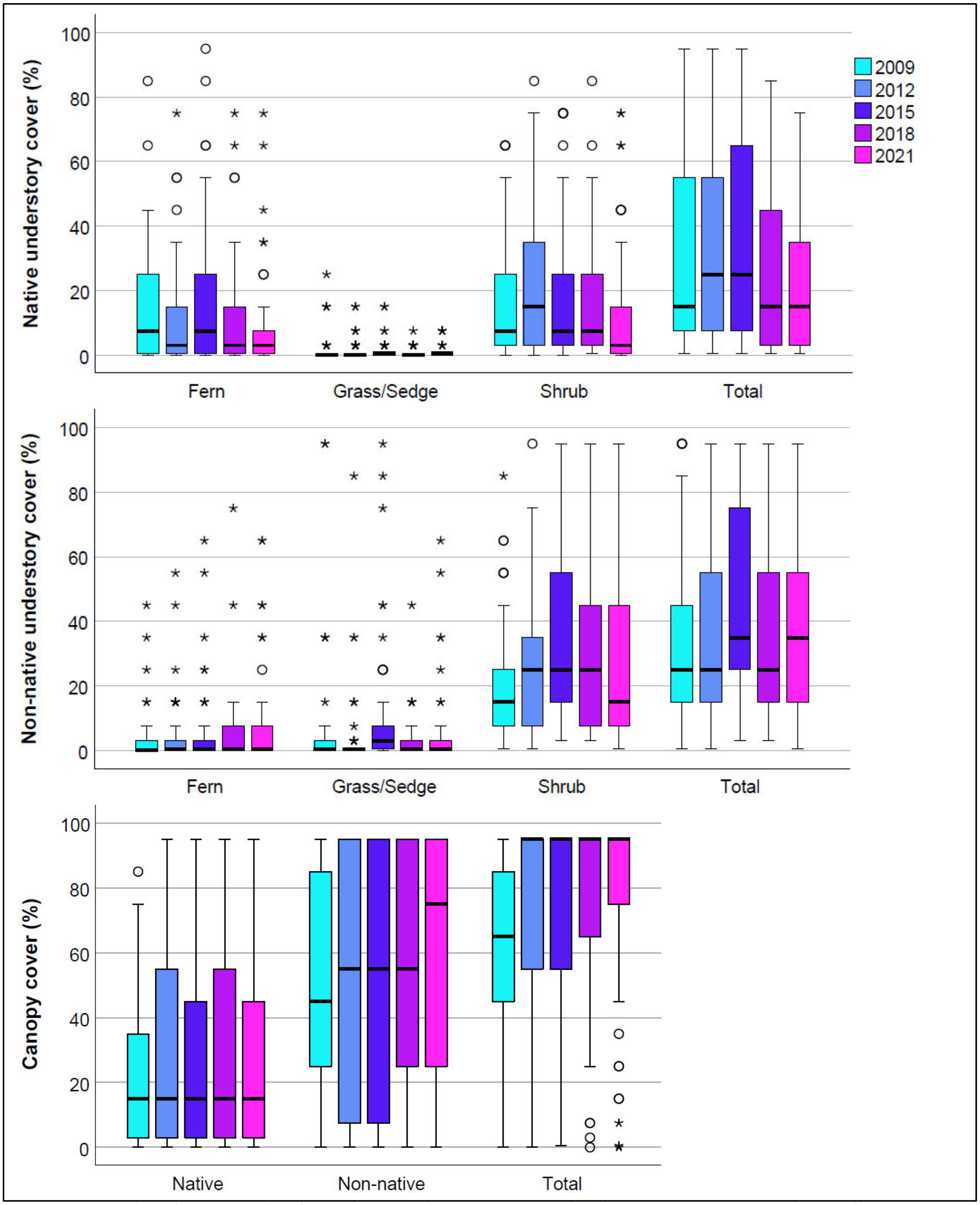

Figure 3: Boxplots for cover of native and non-native taxon categories between years 2009 and 2021 in Kahanahaiki MU. *Note: Boxplots depict the range of values of variable(s). The boxes depict 50% of the data values, and the horizontal line inside the box represents the median value. Very high or low values relative to the shaded box are indicated by circles (1.5 to 3 times the length of the shaded box) and asterisks (> 3 times the length of the shaded box), while the lines extending above and below the shaded box depict the range in values for all remaining data. Circles and asterisks that appear to be in boldface indicate multiple data points for the same values.*

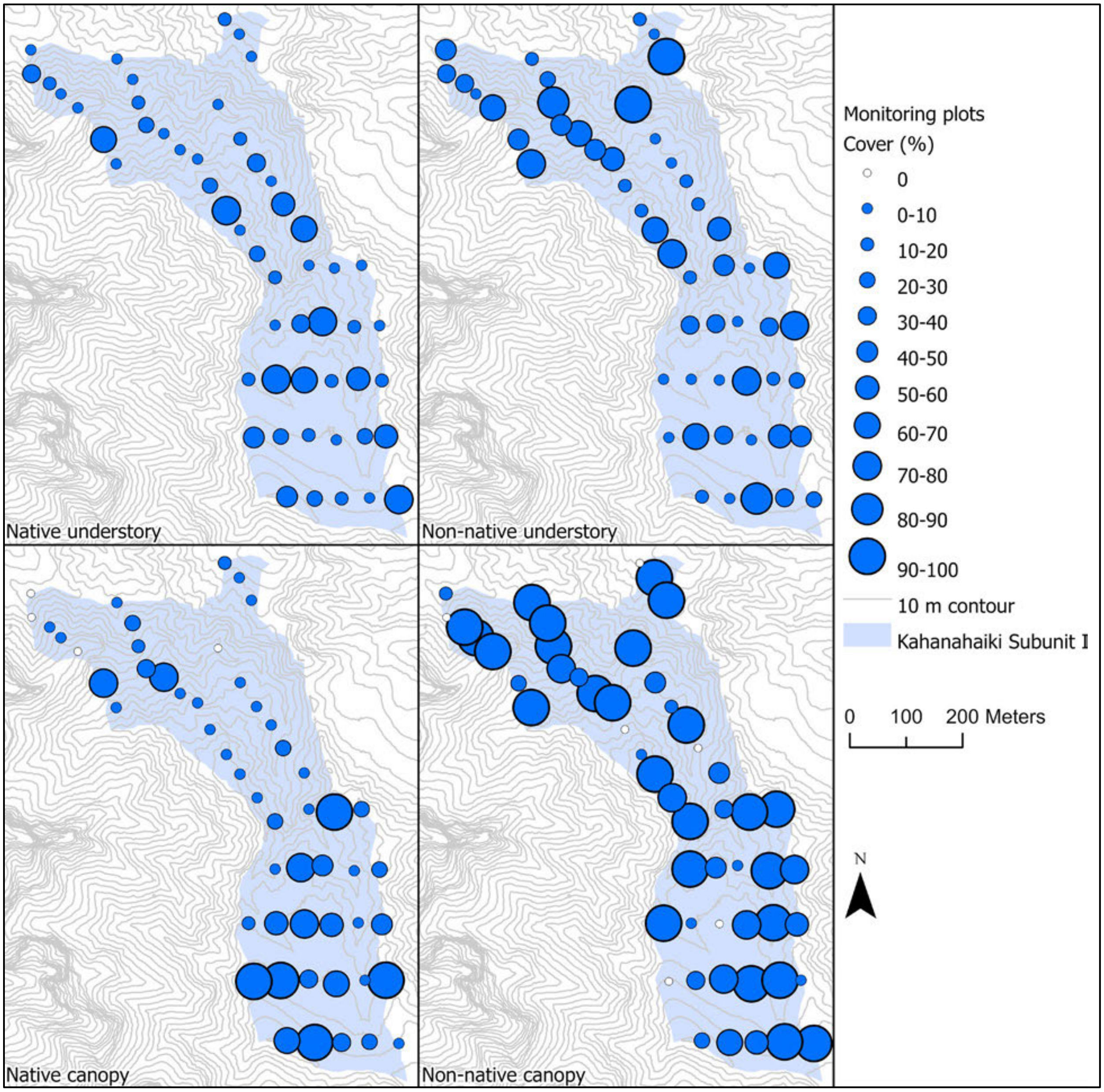

Figure 4: Locations of low to high percent cover of native and non-native understory and canopy vegetation among monitored plots at Kahanahaiki in 2021. Larger circles denote higher percent cover, while smaller circles represent lower cover.

Species richness

During monitoring in 2021, 112 species were recorded in the understory (50% native taxa), and 39 were identified in the canopy (69% native). Locations of high and low species richness for the native and non-native understory and non-native canopy were patchily distributed across the MU, while native canopy richness tended to be higher in the southern half of the MU (Figure 5). The native and non-native understory were tied for the highest overall diversity, with each having 56 taxa documented for the MU (Table 2). The native understory had the highest within plot median richness, while the non-native understory had the largest maximum within plot richness, with 21 species in a single plot. Species richness within plots differed significantly between the years monitored, with increased richness in the non-native understory, and inconsistent trends in the non-native canopy (Table 2 and Figure 6). Notable differences among years in overall diversity for the MU included a gradual increase for the non-native understory.

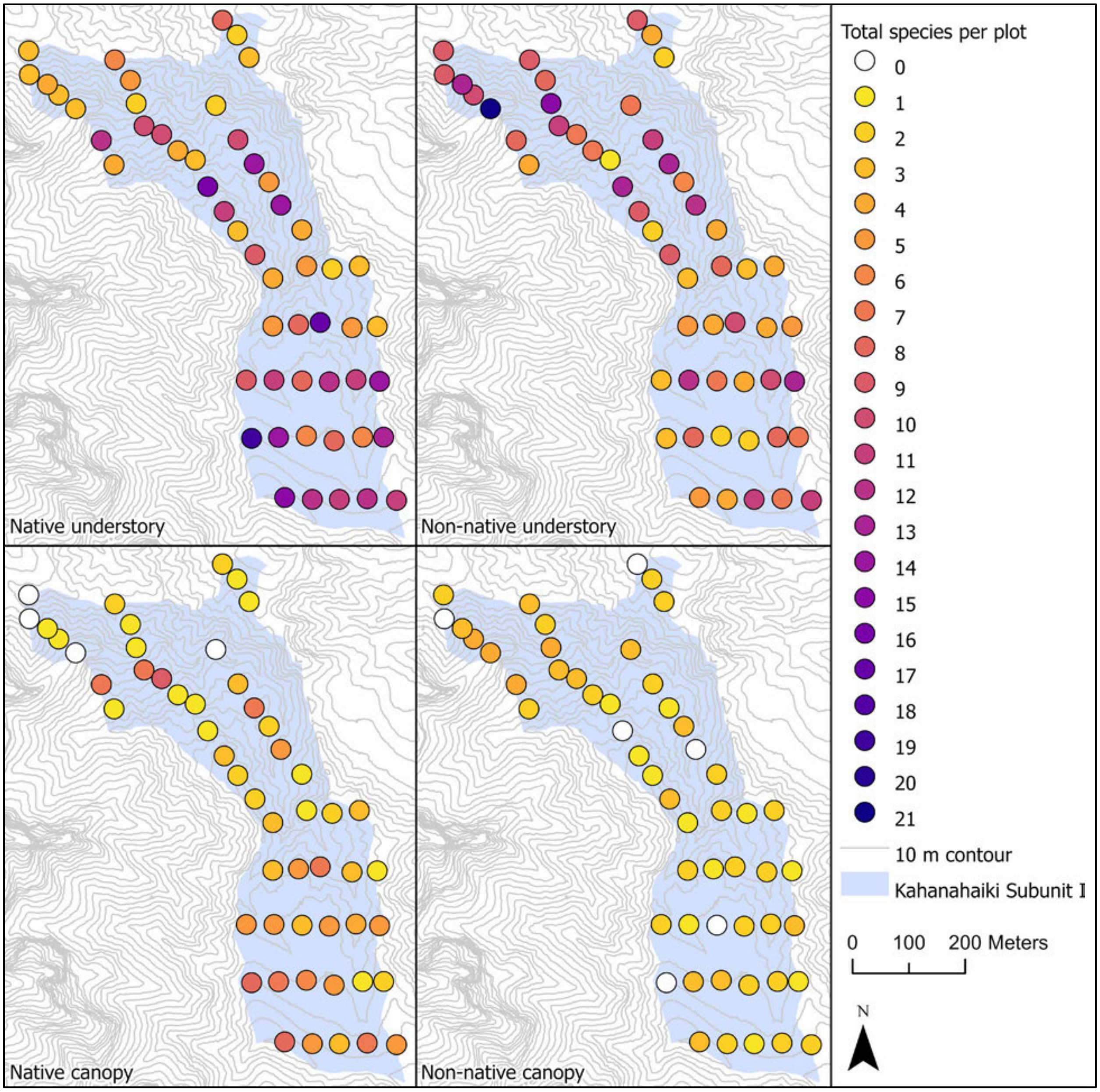

Figure 5: Locations of low to high species richness among plots in the native and non-native understory and canopy in Kahanahaiki in 2021. Color gradients of yellow to purple indicate low to high values, respectively, of the number of species occurring in plots (i.e., yellow indicates low diversity, while purple indicates relatively higher diversity).

Table 2: Kahanahaiki MU understory and canopy species richness from 2009 to 2021. Median species richness per plot during vegetation monitoring is shown by year, with the total number of species recorded among all plots in parenthesis. Statistically significant values (Friedman's test) are in boldface. Arrows indicate increase (↑), decrease (↓), or inconsistent trend (↕) in cover. Post-hoc pairwise comparisons with Bonferroni adjustment did not reveal any years that differed significantly and are not included in the table.

	2009	2012	2015	2018	2021	p*	X^2
Native understory	8 (56)	8 (56)	9 (56)	9 (54)	8 (56)	0.193	6.084
Non-native understory	6 (44)	6 (45)	7 (49)	8 (49)	7 (56)	**0.020**↑	11.670
Native canopy	3 (30)	3 (28)	3 (32)	3 (32)	3 (27)	0.198	6.010
Non-native canopy	2 (10)	2 (9)	2 (12)	2 (15)	2 (12)	**0.041**↕	9.975

*from Friedman's test for differences across all years, asymptotic significance

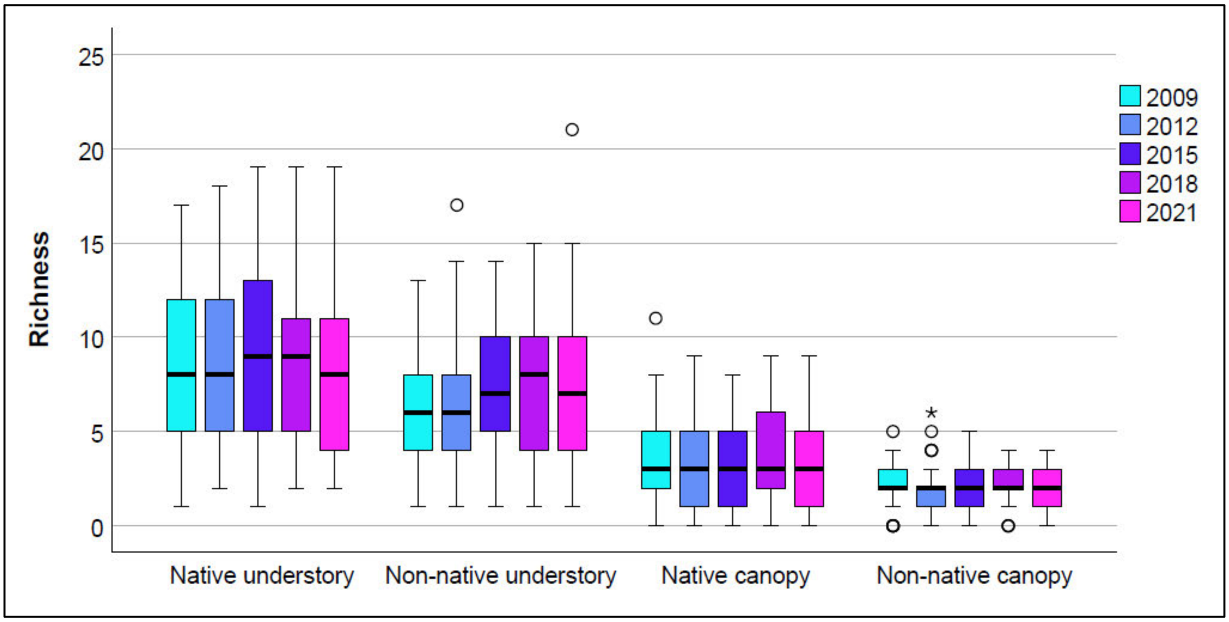

Figure 6: Boxplots for native and non-native richness in the understory and canopy between years 2009 and 2021 in Kahanahaiki MU.

Species frequency

Non-native species that occurred most frequently in plots (present in more than half the plots) in the understory in 2021 included *Psidium cattleianum*, *Clidemia hirta*, and *Schinus terebinthifolius*, while *P. cattleianum* and *S. terebinthifolius* also occurred most commonly in the canopy (Table 3). The most frequent native understory species included *Psydrax odorata* and *Alyxia stellata*, while *P. odorata* also occurred most commonly in the canopy. Two rare taxa were recorded in plots during monitoring in 2021, including *Cyanea superba* subsp. *superba* and *Pritchardia kaalae*, both outplanted. Numerous target weed taxa (taxa of special concern for weed management, ranging from incipient species to those with widespread distributions) (ANRPO 2021a) for Kahanahaiki MU were present in monitored plots in 2021 in either the understory or canopy, though most were those with widespread distributions. One Incipient Control Area (ICA) target, *Acacia mearnsii*, was present in a single plot (in an existing ICA) (Figure 7). Eight limited distribution target taxa were recorded in plots, including *Grevillea robusta*, *Macrotyloma axillare* var. *glabrum*, *Montanoa hibiscifolia*, *Nephrolepis brownii*¸ *Passiflora suberosa*, *Rivina humilis*, *Spathodea campanulata*, and *Toona ciliata*, most of which were in relatively low frequencies (< 8%) with the exception of *P. suberosa*, which was in 38% of all plots collectively in the understory and/or canopy (Figure 8). At least one limited distribution target taxon was present in 45% of the plots. The most notable changes since 2009 included the spread of *P. suberosa* (previously in a small number of plots in the northern half of the MU, but widespread throughout by 2021), and the marked reduction of *G. robusta* (previously widespread, but occurring in only a single plot in the understory in 2021).

Four species (25% native) were newly recorded in plots in 2021, and 25 taxa (56% native) were recorded in prior years but not observed in plots in 2021 (Table 4). Aside from the direct or indirect result of management actions and/or natural processes (weeding, outplanting, dispersal, death, etc.), 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. Misidentifications are possible and/or suspected for some (e.g., *Coprosma longifolia*). Most species that were not recorded in 2021 were uncommon in prior years (frequencies < 6%), as were those newly documented in 2021 (all with frequencies < 4%).

Analysis of frequency change was limited to taxa with at least ten percent change between 2009 and 2021. Among native taxa, there were significant frequency decreases for *Antidesma platyphyllum* and *Cocculus orbiculatus* in the understory and for *C. orbiculatus* and *Kadua affinis* in the canopy, and an increase in *Dianella sandwicensis* in the understory. Among non-native taxa, there were significant frequency increases for *C. hirta*, *P. suberosa*, and *Phlebodium aureum* in the understory and for *P. suberosa* in the canopy, and decreases in *G. robusta* and *S. terebinthifolius* in the understory and *G. robusta* in the canopy (Figure 9). Most notable with respect to the size of the change, consistent trends, and importance within ecosystems among native taxa are the declines in *A. platyphyllum* and *K. affinis*, and the increase in *D. sandwicensis*. Most notable among non-native taxa are the declines in *G. robusta* and the increases in *C. hirta* and *P. suberosa*.

Table 3: Species frequencies over time in the understory and canopy. Taxa are ordered by highest to lowest frequency in 2021. Only taxa with at least 10% change in frequency between 2009 and 2021 were analyzed. Statistical comparisons are between 2009 and 2021 data. P-values obtained from McNemar's tests. Arrows indicate increase (↑) or decrease (↓) in frequency for statistically significant results. Native species are in boldface. ‡Rare taxa. Target weed taxa: *ICA, **LDT.

Taxon	2009	2012	2015	2018	2021	p
Understory						
Psidium cattleianum	92.5	98.1	96.2	96.2	90.6	
Clidemia hirta	69.8	71.7	77.4	88.7	88.7	0.006↑
Psydrax odorata	75.5	79.2	83.0	67.9	66.0	
Alyxia stellata	66.0	64.2	62.3	67.9	62.3	
Schinus terebinthifolius	77.4	71.7	79.2	69.8	60.4	0.049↓
Nephrolepis exaltata* subsp. *hawaiiensis	49.1	50.9	50.9	49.1	49.1	
Blechnum appendiculatum	34.0	37.7	41.5	39.6	45.3	0.070
Microlepia strigosa	34.0	35.8	34.0	37.7	43.4	
Coprosma foliosa	39.6	39.6	47.2	39.6	37.7	
*Passiflora suberosa***	9.4	9.4	18.9	28.3	37.7	0.000↑
Doodia kunthiana	39.6	39.6	39.6	41.5	34.0	
Dianella sandwicensis	18.9	30.2	30.2	37.7	32.1	0.039↑
Metrosideros polymorpha	32.1	34.0	34.0	35.8	32.1	
Lantana camara	34.0	35.8	37.7	39.6	30.2	
Kadua affinis	37.7	34.0	30.2	30.2	30.2	
Melinis minutiflora	28.3	28.3	39.6	30.2	28.3	
Cyclosorus parasiticus	20.8	17.0	18.9	28.3	28.3	
Carex meyenii	32.1	30.2	35.8	24.5	28.3	
Carex wahuensis	20.8	15.1	17.0	24.5	28.3	
Acacia koa	30.2	32.1	41.5	37.7	26.4	
Wikstroemia oahuensis* var. *oahuensis	20.8	20.8	20.8	22.6	26.4	
Rubus rosifolius	13.2	13.2	20.8	30.2	24.5	0.180
Phlebodium aureum	7.5	13.2	9.4	9.4	24.5	0.012↑

Table 3 (continued).

Taxon	2009	2012	2015	2018	2021	p
Understory (continued)						
Oplismenus hirtellus	26.4	24.5	22.6	24.5	22.6	
Diospyros sandwicensis	18.9	24.5	20.8	24.5	20.8	
Bidens torta	20.8	30.2	35.8	15.1	20.8	
Cocculus orbiculatus	37.7	43.4	41.5	26.4	18.9	0.013↓
Conyza bonariensis	11.3	20.8	37.7	22.6	18.9	
Paspalum conjugatum	30.2	22.6	34.0	24.5	17.0	0.118
Cibotium chamissoi	18.9	17.0	18.9	15.1	17.0	
Odontosoria chinensis	18.9	18.9	17.0	20.8	15.1	
Ageratina riparia	17.0	17.0	15.1	18.9	15.1	
Psychotria mariniana	13.2	15.1	11.3	17.0	15.1	
Cyperus hillebrandii* var. *decipiens	11.3	11.3	9.4	13.2	15.1	
Crassocephalum crepidoides	7.5	3.8	13.2	13.2	13.2	
Stachytarpheta australis	18.9	22.6	24.5	18.9	11.3	
Oxalis debilis	3.8	3.8	5.7	11.3	11.3	
Dodonaea viscosa	5.7	7.5	11.3	9.4	11.3	
Deparia petersenii	3.8	3.8	1.9	7.5	11.3	
Ageratum conyzoides	7.5	3.8	5.7	3.8	11.3	
Psilotum nudum	9.4	9.4	17.0	17.0	9.4	
Lepisorus thunbergianus	15.1	15.1	18.9	15.1	9.4	
Cordyline fruticosa	11.3	7.5	9.4	9.4	9.4	
Mesosphaerum pectinatum	3.8	0.0	5.7	7.5	9.4	
*Nephrolepis brownii***	0.0	5.7	7.5	13.2	7.5	
Rockia sandwicensis	5.7	9.4	3.8	11.3	7.5	
*Spathodea campanulata***	1.9	1.9	3.8	11.3	7.5	
Antidesma platyphyllum	22.6	17.0	17.0	9.4	7.5	0.021↓
Andropogon virginicus	3.8	3.8	9.4	9.4	7.5	
Asplenium kaulfussii	13.2	13.2	13.2	7.5	7.5	
Euphorbia multiformis	5.7	7.5	9.4	7.5	7.5	
Nestegis sandwicensis	7.5	9.4	7.5	7.5	7.5	
Pteridium aquilinum	11.3	7.5	7.5	7.5	7.5	
Planchonella sandwicensis	11.3	7.5	7.5	5.7	7.5	
Youngia japonica	1.9	1.9	7.5	5.7	7.5	
Psychotria hathewayi	3.8	5.7	5.7	3.8	7.5	
Cheilanthes viridis	1.9	0.0	0.0	1.9	7.5	
Adiantum hispidulum	3.8	3.8	3.8	0.0	7.5	
Oxalis corniculata	11.3	7.5	7.5	13.2	5.7	
Erechtites valerianifolia	0.0	0.0	5.7	11.3	5.7	
Scaevola gaudichaudiana	13.2	11.3	9.4	9.4	5.7	
Pipturus albidus	1.9	1.9	5.7	7.5	5.7	
Leptecophylla tameiameiae	15.1	7.5	15.1	5.7	5.7	
Cyclosorus dentatus	3.8	7.5	7.5	5.7	5.7	
Diospyros hillebrandii	9.4	5.7	3.8	5.7	5.7	
Dicranopteris linearis	5.7	5.7	3.8	5.7	5.7	
Emilia sonchifolia	1.9	5.7	11.3	3.8	5.7	
Chamaecrista nictitans	1.9	3.8	5.7	3.8	5.7	
Sapindus oahuensis	3.8	1.9	1.9	3.8	5.7	
Aleurites moluccana	1.9	9.4	5.7	1.9	5.7	
*Rivina humilis***	0.0	3.8	1.9	1.9	5.7	
Psidium guajava	5.7	5.7	5.7	9.4	3.8	
Ceodes brunoniana	7.5	1.9	9.4	7.5	3.8	
Asplenium caudatum	7.5	3.8	0.0	5.7	3.8	
Myrsine lessertiana	1.9	3.8	0.0	5.7	3.8	
Buddleja asiatica	0.0	3.8	3.8	3.8	3.8	

Table 3 (continued).

Taxon	2009	2012	2015	2018	2021	p
Understory (continued)						
Castilleja arvensis	0.0	0.0	3.8	3.8	3.8	
Xylosma hawaiiense	5.7	5.7	1.9	3.8	3.8	
Cuphea carthagenesis	0.0	0.0	0.0	0.0	3.8	
Sonchus oleraceus	0.0	0.0	0.0	0.0	3.8	
*Toona ciliata***	0.0	0.0	0.0	0.0	3.8	
*Grevillea robusta***	22.6	11.3	17.0	3.8	1.9	0.000↓
Pluchea carolinensis	0.0	1.9	1.9	3.8	1.9	
Ageratina adenophora	0.0	0.0	1.9	3.8	1.9	
Charpentiera tomentosa	3.8	1.9	0.0	3.8	1.9	
*Montanoa hibiscifolia***	3.8	5.7	1.9	1.9	1.9	
Bobea elatior	1.9	1.9	1.9	1.9	1.9	
Cenchrus agrimonioides* var. *agrimonioides	1.9	1.9	1.9	1.9	1.9	
Desmodium incanum	1.9	1.9	1.9	1.9	1.9	
Macrotyloma axillare var. *glabrum***	1.9	1.9	1.9	1.9	1.9	
*Acacia mearnsii**	0.0	1.9	1.9	1.9	1.9	
Megathyrsus maximus	0.0	0.0	1.9	1.9	1.9	
Pityrogramma austroamericana	0.0	0.0	1.9	1.9	1.9	
Pittosporum glabrum	1.9	1.9	0.0	1.9	1.9	
Rumex albescens	1.9	1.9	0.0	1.9	1.9	
Ceodes umbellifera	0.0	1.9	0.0	1.9	1.9	
***Cyanea superba* subsp. *superba*‡**	0.0	0.0	0.0	1.9	1.9	
Syzygium cumini	3.8	9.4	7.5	0.0	1.9	
Hibiscus arnottianus* subsp. *arnottianus	1.9	7.5	1.9	0.0	1.9	
Melicope oahuensis	7.5	0.0	1.9	0.0	1.9	
Waltheria indica	0.0	0.0	1.9	0.0	1.9	
Emilia fosbergii	3.8	0.0	0.0	0.0	1.9	
Gamochaeta purpurea	1.9	0.0	0.0	0.0	1.9	
Axonopus fissifolius	0.0	0.0	0.0	0.0	1.9	
Cyperus polystachyos	0.0	0.0	0.0	0.0	1.9	
Dryopteris glabra	0.0	0.0	0.0	0.0	1.9	
Eragrostis grandis	0.0	0.0	0.0	0.0	1.9	
Erigeron karvinskianus	0.0	0.0	0.0	0.0	1.9	
Festuca bromoides	0.0	0.0	0.0	0.0	1.9	
Lachnagrostis filiformis	0.0	0.0	0.0	0.0	1.9	
***Pritchardia kaalae*‡**	0.0	0.0	0.0	0.0	1.9	
Sida spinosa	0.0	0.0	0.0	0.0	1.9	
Melinis repens	5.7	3.8	13.2	7.5	0.0	
Passiflora edulis	0.0	7.5	3.8	5.7	0.0	
Elaphoglossum aemulum	3.8	3.8	1.9	1.9	0.0	
Myrsine lanaiensis	3.8	1.9	1.9	1.9	0.0	
Peperomia tetraphylla	1.9	1.9	1.9	1.9	0.0	
Viola chamissoniana* subsp. *tracheliifolia	0.0	0.0	1.9	1.9	0.0	
*Triumfetta semitriloba***	1.9	0.0	0.0	1.9	0.0	
*Angiopteris evecta**	0.0	0.0	0.0	1.9	0.0	
Arundina gramminifolia	0.0	0.0	0.0	1.9	0.0	
Indigofera suffruticosa	0.0	0.0	0.0	1.9	0.0	
Litchi chinensis	0.0	0.0	0.0	1.9	0.0	
Plectranthus parviflorus	0.0	0.0	0.0	1.9	0.0	
Unknown sp.[1]	0.0	0.0	0.0	1.9	0.0	
Korthalsella cylindrica	1.9	1.9	3.8	0.0	0.0	
Cyanthillium cinereum	0.0	1.9	3.8	0.0	0.0	
***Delissea waianaeensis*‡**	0.0	1.9	1.9	0.0	0.0	
Gahnia beecheyi	0.0	1.9	1.9	0.0	0.0	

Table 3 (continued).

Taxon	2009	2012	2015	2018	2021	p
Understory (continued)						
Asplenium macraei	0.0	0.0	1.9	0.0	0.0	
Canavalia galeata	0.0	0.0	1.9	0.0	0.0	
Coprosma longifolia	0.0	0.0	1.9	0.0	0.0	
Panicum nephelophilum	0.0	0.0	1.9	0.0	0.0	
Leucaena leucocephala	5.7	1.9	0.0	0.0	0.0	
*Casuarina equisetifolia**	0.0	1.9	0.0	0.0	0.0	
Santalum freycinetianum* var. *freycinetianum	0.0	1.9	0.0	0.0	0.0	
Stachytarpheta sp.	3.8	0.0	0.0	0.0	0.0	
Doryopteris decipiens	1.9	0.0	0.0	0.0	0.0	
Setaria parviflora	1.9	0.0	0.0	0.0	0.0	
Streblus pendulinus	1.9	0.0	0.0	0.0	0.0	
Canopy						
Psidium cattleianum	79.2	73.6	81.1	84.9	81.1	
Psydrax odorata	64.2	69.8	69.8	75.5	67.9	
Schinus terebinthifolius	71.7	66.0	69.8	73.6	64.2	
Alyxia stellata	43.4	41.5	43.4	50.9	45.3	
Acacia koa	34.0	35.8	37.7	39.6	41.5	
Metrosideros polymorpha	35.8	32.1	32.1	32.1	28.3	
Coprosma foliosa	26.4	22.6	24.5	20.8	22.6	
Aleurites moluccana	15.1	13.2	11.3	15.1	13.2	
Diospyros sandwicensis	13.2	13.2	15.1	13.2	13.2	
Psychotria mariniana	13.2	13.2	11.3	11.3	13.2	
Kadua affinis	22.6	11.3	9.4	13.2	11.3	0.031↓
*Passiflora suberosa***	0.0	0.0	0.0	3.8	11.3	0.031↑
Planchonella sandwicensis	11.3	7.5	9.4	9.4	9.4	
Cordyline fruticosa	7.5	9.4	7.5	9.4	7.5	
Nestegis sandwicensis	9.4	9.4	5.7	9.4	7.5	
Antidesma platyphyllum	11.3	7.5	9.4	9.4	5.7	
Rockia sandwicensis	1.9	3.8	3.8	7.5	5.7	
Diospyros hillebrandii	5.7	5.7	3.8	3.8	5.7	
Santalum freycinetianum* var. *freycinetianum	5.7	3.8	3.8	3.8	5.7	
Pittosporum glabrum	3.8	3.8	0.0	1.9	5.7	
Clidemia hirta	1.9	1.9	0.0	9.4	3.8	
Cibotium chamissoi	1.9	3.8	5.7	5.7	3.8	
Dodonaea viscosa	3.8	3.8	3.8	3.8	3.8	
Hibiscus arnottianus* subsp. *arnottianus	3.8	3.8	3.8	3.8	3.8	
Cocculus orbiculatus	17.0	5.7	1.9	3.8	3.8	0.016↓
Xylosma hawaiiense	7.5	3.8	1.9	3.8	3.8	
Pipturus albidus	1.9	1.9	1.9	3.8	3.8	
Leptecophylla tameiameiae	3.8	1.9	3.8	1.9	3.8	
Psychotria hathewayi	1.9	3.8	1.9	1.9	3.8	
Dicranopteris linearis	0.0	0.0	1.9	1.9	3.8	
Passiflora edulis	1.9	1.9	1.9	3.8	1.9	
Lepisorus thunbergianus	1.9	3.8	0.0	3.8	1.9	
Psidium guajava	5.7	1.9	3.8	1.9	1.9	
Bobea elatior	1.9	1.9	1.9	1.9	1.9	
Eucalyptus urophylla	0.0	0.0	1.9	1.9	1.9	
Lantana camara	0.0	0.0	1.9	1.9	1.9	
Ageratina adenophora	0.0	0.0	0.0	0.0	1.9	
Myrsine lanaiensis	0.0	0.0	0.0	0.0	1.9	
Phlebodium aureum	0.0	0.0	0.0	0.0	1.9	
*Grevillea robusta***	18.9	7.5	13.2	1.9	0.0	0.002↓
Syzygium cumini	5.7	7.5	3.8	1.9	0.0	

Table 3 (continued).

Taxon	2009	2012	2015	2018	2021	p
Canopy (continued)						
Bidens torta	0.0	0.0	3.8	1.9	0.0	
Gynochthodes trimera	1.9	0.0	1.9	1.9	0.0	
Korthalsella cylindrica	0.0	0.0	1.9	1.9	0.0	
*Montanoa hibiscifolia***	0.0	0.0	1.9	1.9	0.0	
Scaevola gaudichaudiana	0.0	0.0	1.9	1.9	0.0	
Charpentiera tomentosa	1.9	1.9	0.0	1.9	0.0	
Pluchea carolinensis	0.0	0.0	0.0	1.9	0.0	
Stachytarpheta australis	0.0	0.0	0.0	1.9	0.0	
Wikstroemia oahuensis* var. *oahuensis	0.0	0.0	0.0	1.9	0.0	
Sapindus oahuensis	1.9	1.9	5.7	0.0	0.0	
Ceodes brunoniana	1.9	0.0	5.7	0.0	0.0	
*Acacia mearnsii**	0.0	0.0	1.9	0.0	0.0	
Canavalia galeata	0.0	0.0	1.9	0.0	0.0	
Streblus pendulinus	0.0	1.9	0.0	0.0	0.0	
Melicope oahuensis	1.9	0.0	0.0	0.0	0.0	
*Spathodea campanulata***	1.9	0.0	0.0	0.0	0.0	

[1]Woody seedling/sapling of unknown taxonomy.

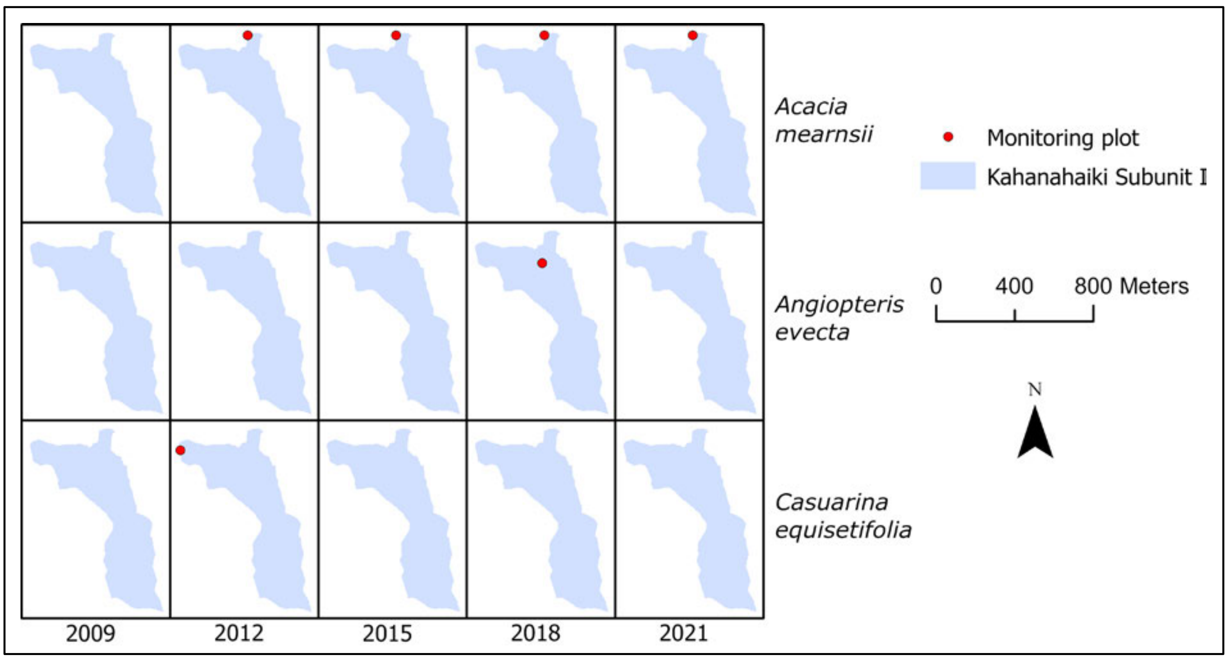

Figure 7: Locations of ICA target taxa in the understory and/or canopy found in monitoring plots at Kahanahaiki Subunit I from 2009 to 2021.

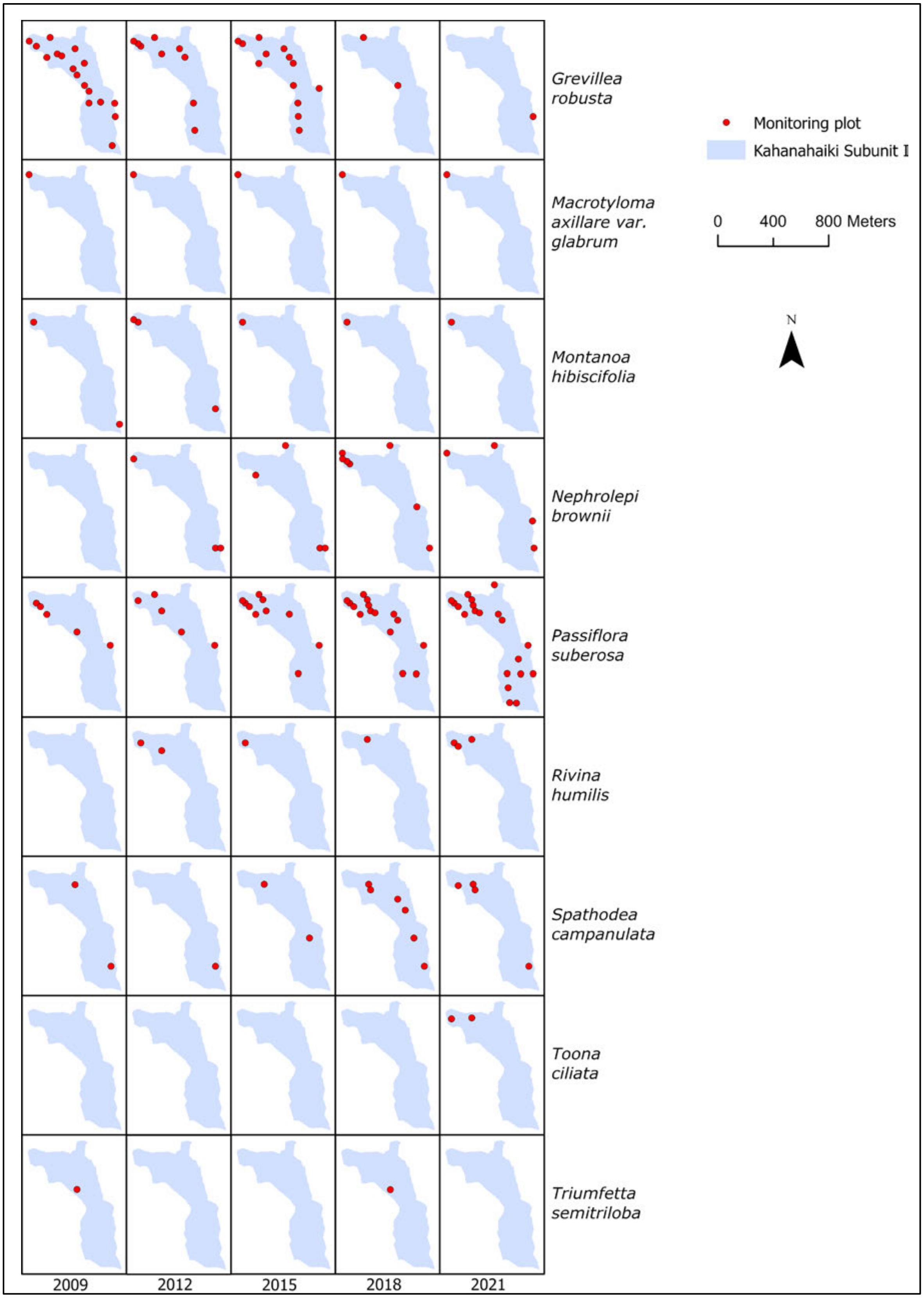

Figure 8: Locations of LDT target taxa in the understory and/or canopy found in monitoring plots at Kahanahaiki Subunit I from 2009 to 2021.

Table 4: Taxa no longer present, and newly recorded, in plots from 2021 Kahanahaiki MU monitoring in the understory and/or canopy. Native taxa are in boldface. Frequency (the percent of plots in which species are present) values are represented. Target taxa: *ICA, **LDT. ‡Rare taxa.

Species not recorded in 2021, but observed in plots previously	2009	2012	2015	2018	New species recorded in plots in 2021	2021
*Angiopteris evecta**	0.0	0.0	0.0	1.9	***Pritchardia kaalae*‡**	1.9
Arundina gramminifolia	0.0	0.0	0.0	1.9	*Sida spinosa*	1.9
Asplenium macraei	0.0	0.0	1.9	0.0	*Sonchus oleraceus*	3.8
Canavalia galeata	0.0	0.0	1.9	0.0	*Toona ciliata***	3.8
*Casuarina equisetifolia**	0.0	1.9	0.0	0.0		
Coprosma longifolia	0.0	0.0	1.9	0.0		
Cyanthillium cinereum	0.0	1.9	3.8	0.0		
***Delissea waianaeensis*‡**	0.0	1.9	1.9	0.0		
Doryopteris decipiens	1.9	0.0	0.0	0.0		
Elaphoglossum aemulum	3.8	3.8	1.9	1.9		
Gahnia beecheyi	0.0	1.9	1.9	0.0		
Gynochthodes trimera	1.9	0.0	1.9	1.9		
Indigofera suffruticosa	0.0	0.0	0.0	1.9		
Korthalsella cylindrica	1.9	1.9	3.8	1.9		
Leucaena leucocephala	5.7	1.9	0.0	0.0		
Litchi chinensis	0.0	0.0	0.0	1.9		
Melinis repens	5.7	3.8	13.2	7.5		
Panicum nephelophilum	0.0	0.0	1.9	0.0		
Peperomia tetraphylla	1.9	1.9	1.9	1.9		
Plectranthus parviflorus	0.0	0.0	0.0	1.9		
Setaria parviflora	1.9	0.0	0.0	0.0		
Streblus pendulinus	1.9	1.9	0.0	0.0		
*Triumfetta semitriloba***	1.9	0.0	0.0	1.9		
Unknown sp.	0.0	0.0	0.0	1.9		
Viola chamissoniana* subsp. *tracheliifolia	0.0	0.0	1.9	1.9		

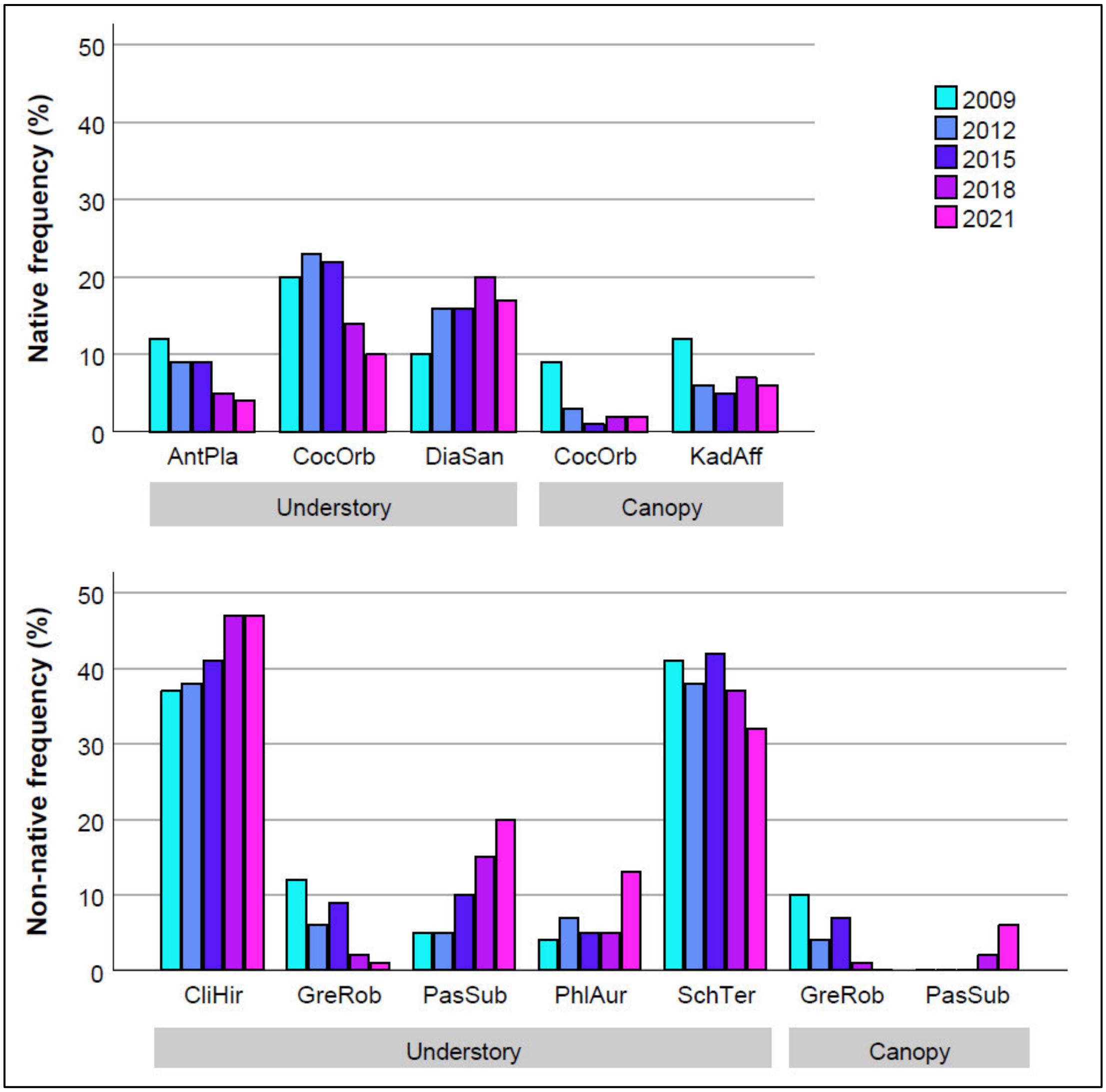

Figure 9: Species frequencies at Kahanahaiki MU between 2009 and 2021, among taxa with significant changes over time. Frequency values represent the proportion of plots in which species are present.

Species cover

Significant cover changes in the understory included declines for three native (*Carex meyenii*, *C. orbiculatus*, and *Nephrolepis exaltata* subsp. *hawaiiensis*) and two non-native (*G. robusta* and *Paspalum conjugatum*) taxa, and increases for one native (*D. sandwicensis*) and three non-native (*Blechnum appendiculatum*, *C. hirta*, and *P. suberosa*) taxa. Significant cover changes in the canopy included increases for two native (*Acacia koa* and *A. stellata*) and one non-native (*P. cattleianum*) taxa (Table 5 and Figure 10). However, for most of those taxa, cover changes were small (primarily ≤ 10% absolute change within plots), and were more a reflection of frequency change than expansive increased cover within plots. Most notable among the changes with respect to sizable differences in cover were the increases for understory *B. appendiculatum* and canopy *A. koa*, *A. stellata*, and *P. cattleianum*, as well as the decreased cover for understory *N. exaltata* subsp. *hawaiiensis*. While there have been some discrepancies over the years in distinctions between *N. exaltata* subsp. *hawaiiensis* and *N. brownii*, most of the plots with decreased cover were not among those with identification discrepancies.

Table 5: Species with significant cover change between 2009 and 2021. Only taxa with > 20% frequency in either 2009 or 2021 were analyzed. Arrows indicate increase (↑) or decrease (↓) in cover. Native species are in boldface.

	p*	Z
Understory		
Blechnum appendiculatum	0.012↑	-2.505
Carex meyenii	0.032↓	-2.140
Clidemia hirta	0.019↑	-2.349
Cocculus orbiculatus	0.008↓	-2.668
Dianella sandwicensis	0.002↑	-3.129
Grevillea robusta	0.002↓	-3.127
Nephrolepis exaltata* subsp. *hawaiiensis	0.000↓	-3.396
Paspalum conjugatum	0.015↓	-2.423
Passiflora suberosa	0.000↑	-3.710
Canopy		
Acacia koa	0.017↑	-2.391
Alyxia stellata	0.004↑	-2.897
Psidium cattleianum	0.000↑	-3.738

*From Wilcoxon signed ranks test, asymptotic significance

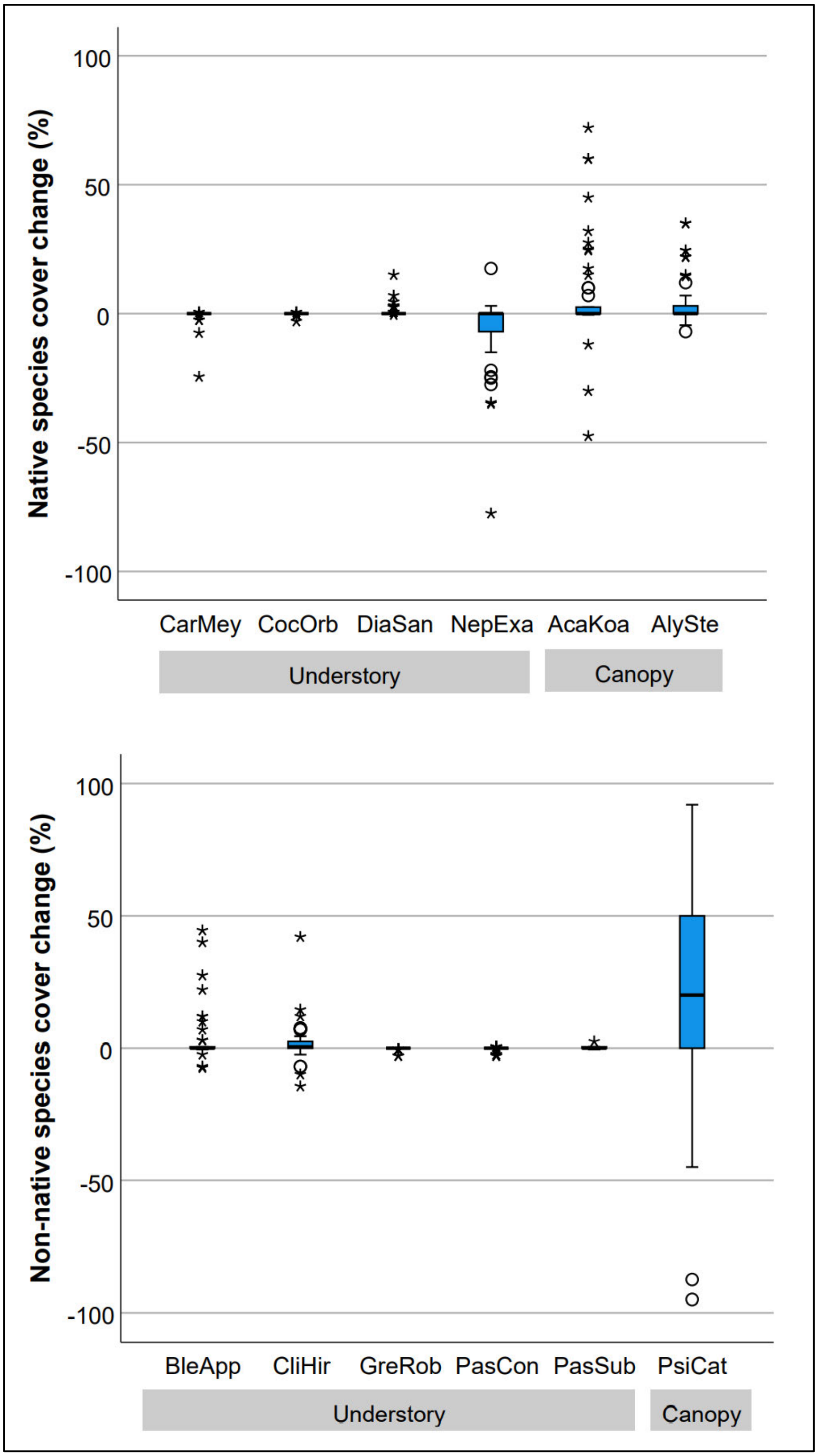

Figure 10: Boxplots of cover change between 2009 and 2021 for taxa with significant changes in percent cover. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change.

Canopy replacement

In 2021, 28 tree taxa (68% native) were found recruiting in the understory (Table 6). *Psidium cattleianum* was the most commonly recruiting tree species, occurring in nearly half of the plots, followed by *S. terebinthifolius* and *P. odorata*, which were recruiting in over one-fifth of the plots. One rare taxon (*P. kaalae*, an outplant) was found recruiting in a single plot. Native tree taxa with no recruitment in the understory were relatively infrequent in the canopy (with frequencies < 6%). One ICA (*A. mearnsii*) and four LDT weed taxa (*G. robusta*, *M. hibiscifolia*, *S. campanulata*, and *T. ciliata*) were found recruiting in plots. Recruitment frequencies within plots for these taxa were < 5%. Recruitment frequency differences between 2018 and 2021 were < 10% for all taxa. 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: Tree species recruitment frequencies from 2018 to 2021. Taxa are ordered by highest to lowest recruitment frequency in 2021. Statistical analyses were not performed as there were no differences > 10%. Native species are in boldface. Target taxa: *ICA, **LDT. ‡Rare taxa.

Species	2018	2021	Species	2018	2021
Psidium cattleianum	51	48	***Nestegis sandwicensis***	2	1
Schinus terebinthifolius	30	22	*Acacia mearnsii**	1	1
Psydrax odorata	22	21	*Grevillea robusta***	1	1
Acacia koa	15	11	*Montanoa hibiscifolia***	1	1
Kadua affinis	11	11	***Psychotria hathewayi***	1	1
Metrosideros polymorpha	10	10	***Hibiscus arnottianus* subsp. *arnottianus***	0	1
Diospyros sandwicensis	11	9	***Melicope oahuensis***	0	1
Dodonaea viscosa	4	5	***Pritchardia kaalae*‡**	0	1
*Spathodea campanulata***	6	4	***Rockia sandwicensis***	5	0
Planchonella sandwicensis	3	3	***Ceodes umbellifera***	1	0
Aleurites moluccana	1	3	*Litchi chinensis*	1	0
Psychotria mariniana	7	2	***Myrsine lanaiensis***	1	0
Myrsine lessertiana	3	2	***Bobea elatior***	0	0
Pipturus albidus	3	2	*Eucalyptus urophylla*	0	0
Antidesma platyphyllum	2	2	***Gynochthodes trimera***	0	0
Diospyros hillebrandii	2	2	***Pittosporum glabrum***	0	0
Sapindus oahuensis	0	2	***Santalum freycinetianum* var. *freycinetianum***	0	0
*Toona ciliata***	0	2	*Syzygium cumini*	0	0
Ceodes brunoniana	4	1	***Xylosma hawaiiense***	0	0
Psidium guajava	4	1			

Vegetation management

Weed control efforts between 2009 and 2021 at Kahanahaiki Subunit I consisted of Weed Control Area (WCA) and ICA weeding (Figure 11). WCA efforts included general ecosystem weeding (over a large portion of the subunit), grass sprays (across roughly half of the subunit), and sweeps for control of targeted taxa, including mature *G. robusta* (across the entire subunit, with all accessible trees treated), as well as *M. hibiscifolia*, *N. brownii*, and *T. semitriloba*. ICA control occurred over a relatively small area. A considerable amount of time (12,824 hours) was spent weeding in the subunit from 2009 to 2021, with 38% of those hours occurring between the 2018 and 2021 monitoring intervals. General ecosystem weeding actions between 2009 and 2021 occurred across 75% of Subunit I, and crossed through 79% of the monitoring plots.

Comparison of cover change in plots that fell within vs. outside of general ecosystem weeded areas (not including target taxa, grass, or ICA control efforts) to discern the impacts of weeding on vegetation cover revealed that the weeding did not significantly influence the native and non-native understory and canopy. However, the widespread targeting of *G. robusta* has clearly impacted that taxon, as it was no longer present in plots in the canopy in 2021, and its significantly reduced presence in the understory was likely attributable to decreased seed rain following control of mature trees. Targeted control of *M. hibiscifolia* appears to have been successful in preventing its further expansion.

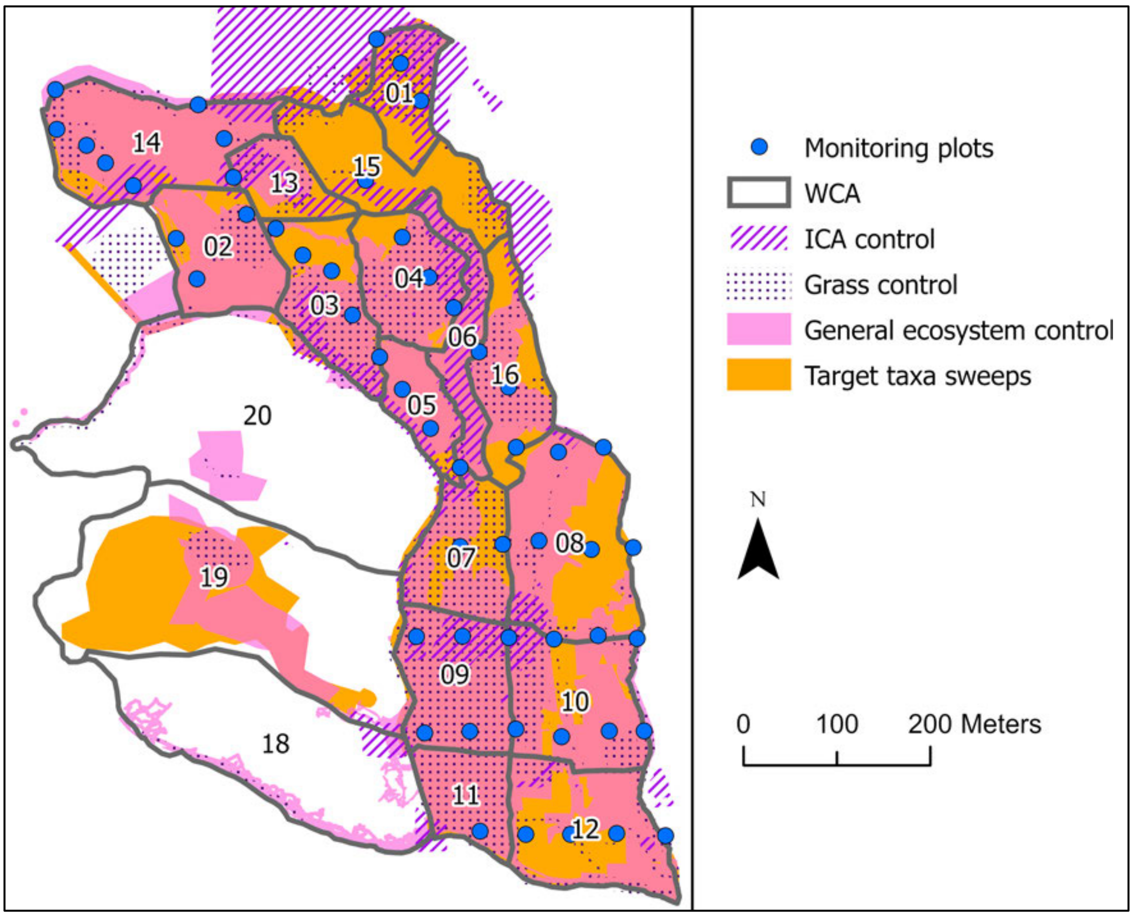

Figure 11: Locations of weed control efforts in relation to monitored plots in Kahanahaiki MU between 2009 and 2021. Weeded areas include WCA (general ecosystem, grass, and target taxa sweeps) and ICA control efforts.

Native vegetation restoration efforts began at Kahanahaiki Subunit I on a small scale in 2008 and expanded over time to include large scale chainsaw removal of non-native canopy (with and without the use of a wood chipper) in several areas along with the restoration of common native plants, including 43 taxa, with 9,629 outplants, 794 divisions, > 205,669 sown seeds, and > 210 transplants. Restoration actions between 2009 and 2021 have occurred across 16% of Subunit I, and crossed through 19% of the monitoring plots (Figure 12).

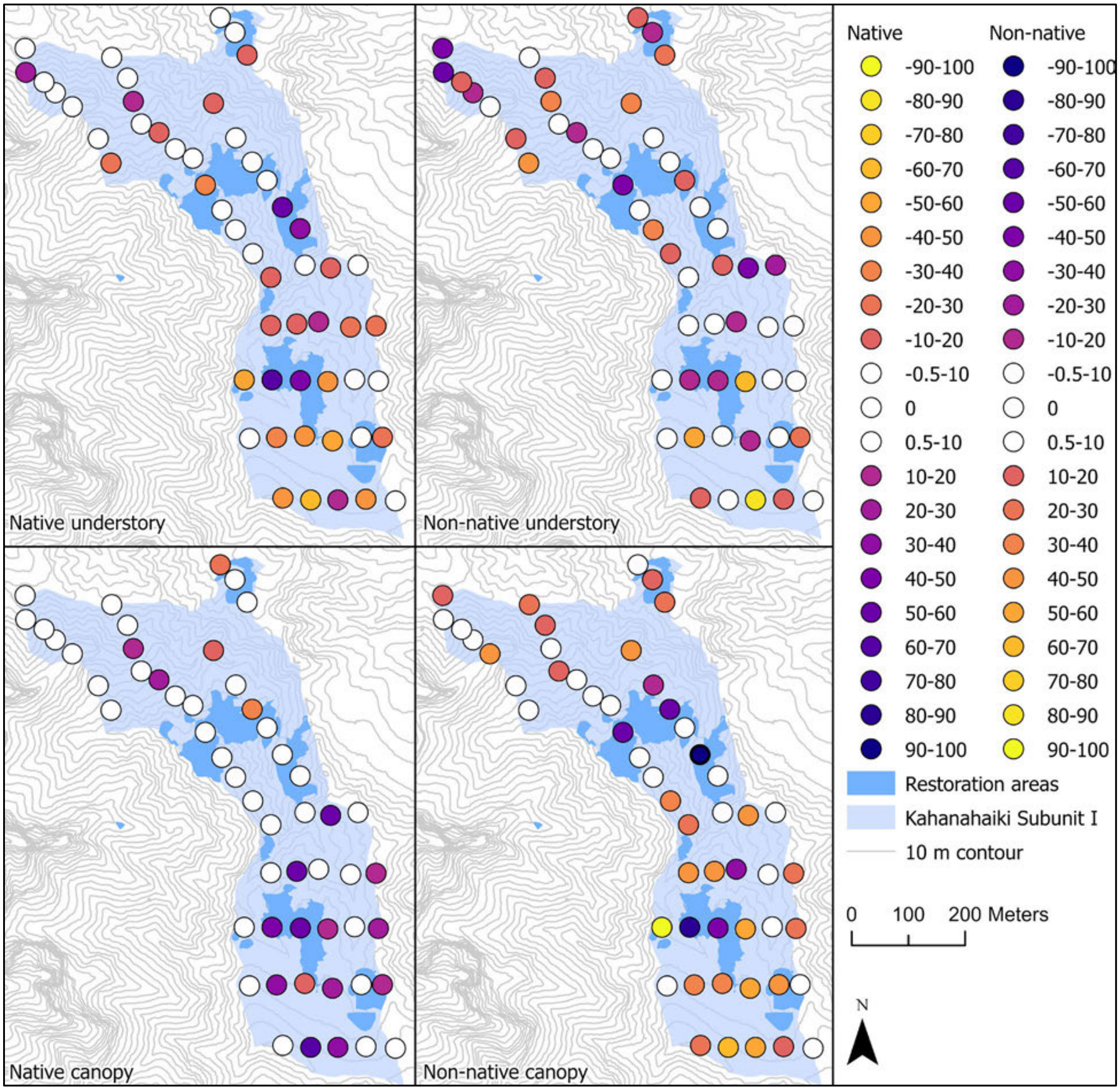

Figure 12: Locations of restoration actions in relation to change in native and non-native percent cover for the understory and canopy vegetation in monitored plots in Kahanahaiki MU between 2009 and 2021. Color gradients are inverted for native and non-native vegetation, such that purple indicates beneficial change, and yellow to pink depicts worsening conditions. Cover change of 0 indicates there was no change in percent cover. Cover change of 0 ± 10% remains uncolored, as absolute cover change of ≤ 10% is not recognized.

Comparison of cover change in plots that fell within vs. outside of restoration areas to discern the impacts of restoration on the native and non-native understory and canopy revealed that the native understory (GLM: $p = 0.035$) and non-native canopy (GLM: $p < 0.000$) were influenced by restoration actions. Native understory cover increased in plots within restoration areas and declined in plots in unrestored areas, while non-native canopy cover decreased in plots within restoration areas and increased in plots in unrestored areas (Figure 13). Analysis from previous monitoring found that native understory cover increased with decreasing non-native cover, and decreased with increasing non-native cover (ANRPO 2018a). Examination of the combined influence of restoration status with non-native canopy cover change on native understory change between 2009 and 2021 further explained the trend, with

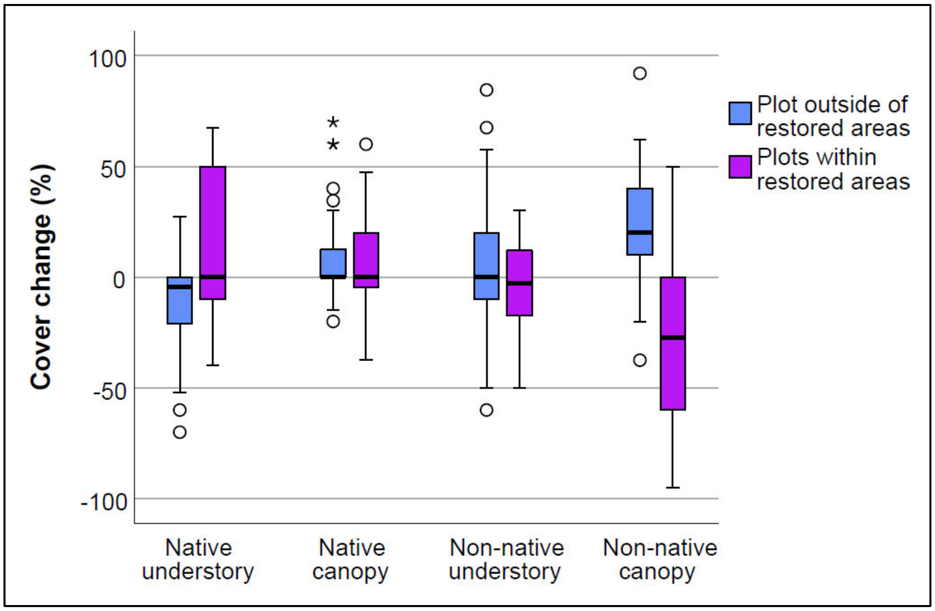

Figure 13: Boxplot of cover change in native and non-native understory and canopy between 2009 and 2021 in plots inside vs. outside of restoration areas. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change.

restoration actions driving the trend of increased native understory in conjunction with decreased non-native canopy (GLM: p = 0.029), and lack of restoration driving the trend of decreased native understory as non-native canopy increases (GLM: p = 0.000) (Figure 14). The influence of restoration actions was also examined with respect to select species that had changes in frequency and/or cover that were thought to be related to restoration efforts (Figure 15 and 16). Understory frequency change for *D. sandwicensis* was influenced by restoration (GLM p = 0.043), though it also increased (but to a lesser extent) in unrestored areas as well. Increased canopy cover was not influenced by restoration actions for *A. stellata* (GLM p = 0.644) or *A. koa* (GLM p = 0.911), as their increases occurred both inside and outside of plots. Increased canopy cover of *P. cattleianum* was significantly influenced by restoration efforts (GLM p = 0.002), as cover decreased in most plots with restoration, but increased in most plots without restoration. This trend largely drove the same pattern of restoration influence on non-native canopy, since that has been the dominant canopy species removed during restoration. Vegetation change is documented at individual restoration sites that demonstrate the beneficial changes that are taking place in those locations. Dramatic reductions in non-native vegetation and increases in native vegetation were documented from photopoints as well as plots recording frequency, richness and cover at the Kahanahaiki Maile Flats chipper restoration site (hereafter referred to as the chipper site) (ANRPO 2021b), and from photopoints at other various restoration sites (Figure 17).

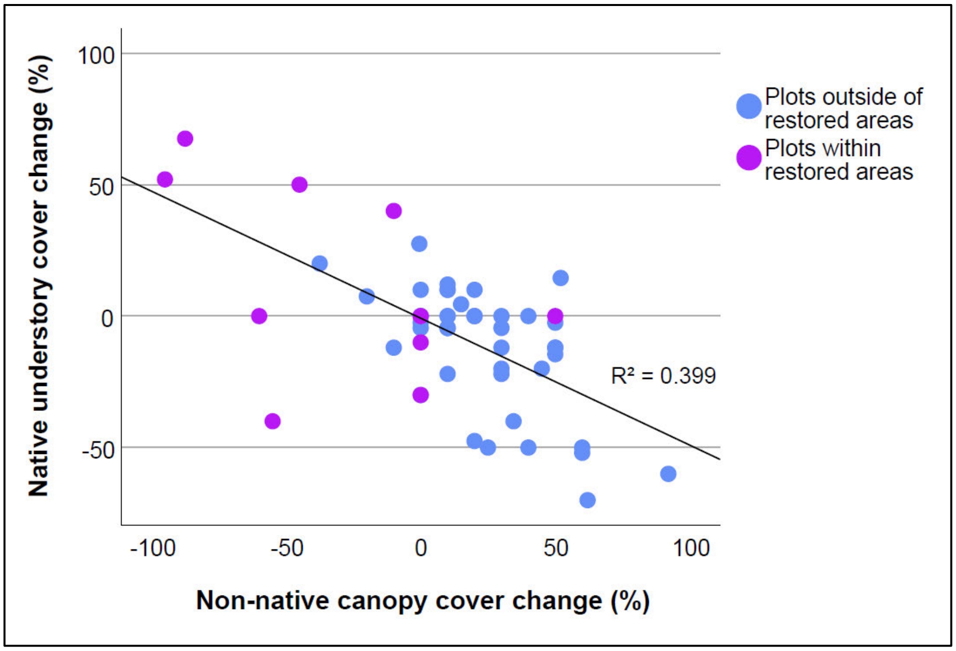

Figure 14: Scatterplot of native understory and non-native canopy cover change between 2009 and 2021 in plots inside vs. outside of restoration areas. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change.

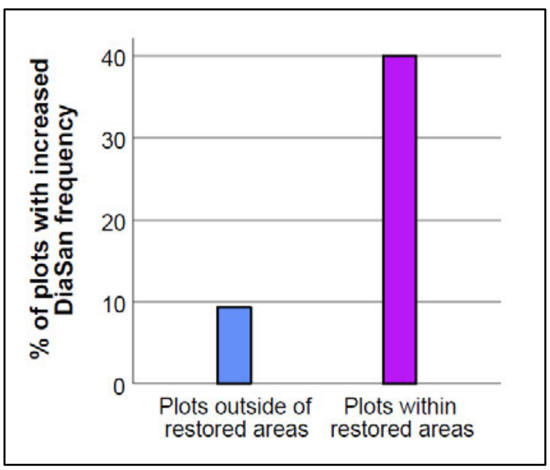

Figure 15: Bar graph showing the proportion of plots with increased frequency of understory *D. sandwicensis* between 2009 and 2021 in plots inside vs outside of restored areas.

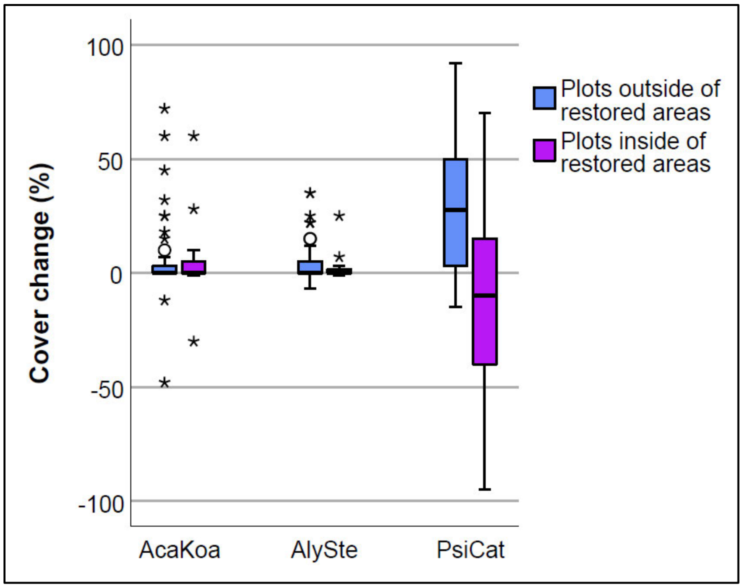

Figure 16: Boxplot of canopy cover change for select species between 2009 and 2021 in plots inside vs. outside of restoration areas. Values > 0 represent increased cover in plots, while those < 0 represent decreased cover. Values equaling 0 represent no change.

Figure 17: An example of a photopoint at the "Schobo Baggins" restoration site, pre-clearing (top, 2019-02-20), post-clearing (middle, 2019-05-29), and two years later (bottom, 2021-05-18), showing rapid and dramatic change from nearly monotypic *Psidium cattleianum* to substantial infilling of diverse native understory resulting from restoration actions of clearing and outplanting.

SUMMARY AND DISCUSSION

Management goals continue to be met only for percent cover of non-native understory at Kahanahaiki MU. Goals remain unmet for native understory, native canopy, and non-native canopy cover. There were a number of significant differences in vegetation data over the years, many of which were relatively small. The most noteworthy changes included:

- **Categorical cover**
  - Increased
    - Non-native understory shrubs
    - Non-native canopy
  - Decreased
    - Native understory shrubs
    - Native understory
- **Richness**
  - Increased
    - Non-native understory
- **Frequency**
  - Increased
    - Native understory
      - *D. sandwicensis*
    - Non-native understory
      - *C. hirta*
      - *P. suberosa*
    - Non-native canopy
      - *P. suberosa*
  - Decreased
    - Native understory
      - *A. platyphyllum*
    - Non-native understory
      - *G. robusta*
    - Native canopy
      - *K. affinis*
    - Non-native canopy
      - *G. robusta*
- **Species cover**
  - Increased:
    - Non-native understory
      - *B. appendiculatum*
    - Native canopy
      - *A. koa*
      - *A. stellata*
    - Non-native canopy
      - *P. cattleianum*
  - Decreased:
    - Native understory
      - *N. exaltata* subsp. *hawaiiensis*
- **Vegetation management**
  - From targeted control, canopy *G. robusta* no longer present in plots; reduced understory presence likely resulting from decreased seed rain.

- Targeted control appears effective in preventing spread of *M. hibiscifolia*
- Beneficial influence from restoration actions on native understory and non-native canopy; worsened conditions in unrestored areas for native understory and non-native canopy.

Overall, many of these changes reflect worsening conditions at Kahanahaiki Subunit I. Despite substantial efforts, vegetation management has not been able to get ahead of the natural progression of weedy tree invasion, which has been to the detriment of the native understory. For individual taxa, increased frequency and/or cover of weed taxa *B. appendiculatum*, *C. hirta*, *P. suberosa*, and *P. cattleianum* is not surprising as it has occurred similarly in several other MUs. The presence of *T. ciliata* in plots is concerning, as successful approaches to prevent its explosive spread remain unknown. Seed will continue to rain into Subunit I from the surrounding areas, including Subunit II as well as Pahole MU, where its frequency is 3% in the canopy (Appendix 3-13). It is interesting that *P. aureum*, though not necessarily as problematic as other weed taxa, has spread here as well as at Ekahanui MU, Kaluaa and Waieli MU, and Palikea MU (ANRPO 2019, 2021c, and 2021d). Reduced *A. platyphyllum*, *K. affinis*, and *N. exaltata* subsp. *hawaiiensis* at Kahanahaiki is unfortunate. *Nephrolepis exaltata* subsp. *hawaiiensis* has also declined nearby at Kapuna MU (ANRPO 2018b). Though *N. exaltata* subsp. *hawaiiensis* declined for the MU, it has fared well at chipper site, with an increased frequency from 5% to 75% in the 10 years following clearing (ANRPO 2021b). The decline in *C. orbiculatus*, though perhaps not the biggest player in native ecosystems, is nonetheless also unfortunate, particularly as it has also declined at Ekahanui MU and at Kaluaa and Waieli MU (ANRPO 2019 and 2021c).

However, notable positive change has occurred as well from restoration efforts including beneficial changes for some native and non-native taxa. The increased native understory and decreased non-native canopy in response to restoration efforts holds promise for eventual progress towards management goals as restoration efforts expand in area, and as native understory vegetation grows into the canopy layer over time. Positive results also occurred for individual native taxa, as *D. sandwicensis* frequency, and canopy cover for *A. koa* and *A. stellata* improved. *Dianella sandwicensis* is known to be good at naturally recruiting and expanding cover in open/restored areas, as documented at the chipper site (where active restoration has been largely limited to *Bidens torta* seeds sows), with frequency increased from 0 to 60% in 10 years (ANRPO 2021b). Indeed, increased MU frequency for *D. sandwicensis* was influenced by restoration, but it also increased outside of restoration area, too, and occurred both in the Maile Flats and gulch regions between 2009 and 2021. This could be due to rat control, as the first MU-wide gridded trapout was concurrent with the initial MU vegetation monitoring in 2009. *Dianella sandwicensis* was the most abundant animal-handled native seed to show up in seed rain traps at the chipper site (Hruska 2019), and frugivory of this taxon has been documented by several non-native birds, including Red-billed leiothrix (*Leiothrix lutea*), Red-vented bulbuls (*Pycnonotus cafer*), Red-whiskered Bulbuls (*Pycnonotus jocosus*), and Spotted Doves (*Spilopelia chinensis*) (Vizentin-Bugoni *et al*. 2019 and S. Case unpublished data). *Alyxia stellata* is also known to be good at expanding cover in open/restored areas, as also documented at the chipper site, where, following a reduction in frequency from 86% in both the understory and canopy as a result of clearing, in 10 years frequency increased from 40 to 75% in the understory, and from 0 to 45% in the canopy (ANRPO 2021b). Increased *A. stellata* cover in the MU between 2009 and 2021 occurred mostly in Maile Flats, and interestingly, mostly outside of restoration areas, as the increased cover was not influenced by restoration. *Acacia koa* is also known to be good at naturally recruiting and expanding cover in open/restored areas; at the chipper site, frequency increased from 0% to 70% in the understory, and from 15% to 95% in the canopy (due solely to natural recruitment, as outplanting of that taxon did not occur there). Canopy cover increase for *A. koa* only occurred in the southern half of the MU between 2009 and 2021, interestingly both inside and outside of restoration, as cover change was not influenced by restoration. Targeted control of *G. robusta* has been very successful at Kahanahaiki Subunit I, as evidenced not only by its reduced canopy frequency from 19% to 0%, but also by its reduced understory frequency from 23% to 2%, which is most remarkable as only mature trees were targeted during sweeps, suggesting reduced recruitment occurred in association with the canopy control. Though propagules will likely continue to blow in from neighboring areas, reduced propagule production within the MU appears to limit recruitment. During monitoring in 2021, evidence of the biocontrol agent (*Tectococcus ovatus*) for *P. cattleianum* was observed to have spread to several locations in the MU, which holds promise for reduced *P. cattleianum* growth and seed production in the coming years.

This is first time that an assessment of the influence of restoration efforts on MU vegetation change has been possible, as the scale of restoration has previously been on too small of a scale for analysis (too few plots occurring within restored areas for comparison with those outside restoration areas) for any of the ANRPO MUs. Analyses of MU weed control efforts typically has not demonstrated general ecosystem weeding to have an influence on vegetation change. In large part this is because analyses of plots that fall within vs. outside of weeded areas to discern the impacts of weeding efforts is complicated by the fact that not all weeding efforts are equivalent. Weeding may be patchy over large areas, have varying levels of intensity, have varying degrees of ongoing weed control maintenance, may target single species, may occur just in the understory or just in the canopy, and may have inaccurate GIS data. Only some targeted species control has had demonstrable evidence of those efforts having a significant influence on vegetation change at ANRPO MUs. Restoration impacts, however, are much more definitive in comparison with general ecosystem weeding. At Kahanahaiki, the significant influence of restoration on the non-native canopy and native understory was not surprising, given that during restoration, typically all the alien canopy is removed, and common native species are outplanted, sown, and/or transplanted. The lack of influence of restoration on native canopy was expected, as most of the restoration was fairly recent, such that plants have not had time to grow into the canopy. The lack of influence on understory weed cover was also not surprising, as understory weeds are challenging to control in restoration areas, as the initial open nature of the sites typically results in flushes of weedy pioneer species. In time, as the native vegetation grows, and with ongoing weeding, understory weed cover should theoretically decline, and native canopy should increase. Though vegetation management has not gotten ahead of the weedy invasion on an MU scale, vegetation management within restoration areas clearly is having a hugely beneficial impact.

RECOMMENDATIONS

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

- Continued planned general ecosystem weeding at rare taxa and restoration sites, grass control, and ICA control
- Discuss priorities and strategies for general ecosystem weeding outside of rare taxa and restoration sites
- Discuss utility of general ecosystem weeding sweeps through Maile Flats in native-dominated areas on a regular rotation
- Continued targeting of *G. robusta* whenever seen during the course of other weed control efforts. Evaluate the utility and frequency of follow-up IPA sweeps targeting *G. robusta* in the canopy. It would be informative to conduct a buried seed trial to determine seed bank persistence.
- Considerations should be made for how to manage the inevitable invasion of *T. ciliata*, and how to effectively keep it out of canopy in Kahanahaiki Subunit I. IPA control has not slowed its spread at Makaha, Manuwai, or Kaluaa and Waieli MUs, though it was already well established in those MU (all with canopy frequencies above 30%) when sweeps were conducted.
- Consider strategies for concurrent targeted sweeps for limited distribution target taxa, to include *M. hibiscifolia*, *N, brownii*¸ *P. guajava*, *S. campanulata*, *S. cumini*, *T. ciliata*, and *T. semitriloba*
- Continued focused efforts on controlling *P. suberosa* during general ecosystem weeding

- Scope *S. terebinthifolius* areas in Maile Flats and consider management options, perhaps via experimental removal that is monitored to assess outcomes
- Consider strategies and timeline for continued and expanded native ecosystem restoration efforts where appropriate, which may include:
    - Continue to connect existing sites, by targeting the areas between Shire and Ethan's, and eventually between Shire and SchObo Baggins
    - Expand existing restoration sites in WCAs Kahanahaiki-07 and -09
    - Consider restoration at smaller stands of *P. cattleianum* in Maile Flats
    - Use chipper where appropriate, such as *P. cattleianum* stands in Maile Flats
    - Sites with existing remnant native canopy, potentially requiring minimal outplanting, in WCAs such as Kahanahaiki-05, -10, -11, and -12
    - Near Generals, perhaps in the more distant future
    - Explore the feasibility of *N. exaltata* subsp. *hawaiiensis* as a restoration taxon (including propagation and outplanting survival)
- Release *T. ovatus* for biocontrol of *P. cattleianum* in areas where it has not yet dispersed naturally, to get biocontrol more widely established in the MU, especially in areas that are not planned for management in the next five to ten years, such as Subunit II
- Explore the potential for biocontrol of *T. ciliata* and *P. suberosa*

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ARMY NATURAL RESOURCES PROGRAM ON OAHU
MONITORING PROGRAM

KAMAILI MANAGEMENT UNIT VEGETATION MONITORING, 2021

INTRODUCTION

The Army Natural Resources Program on Oahu (ANRPO) conducted vegetation monitoring at Kamaili Management Unit (MU) in 2021 in association with Implementation Plan (IP) requirements for long term monitoring of vegetation composition and change over time (ANRPO 2008) (Figure 1). The primary objective of MU monitoring is to assess if the percent cover of non-native plant species is less than 50% across the MU, or is decreasing towards that threshold requirement. The secondary objective is to assess if native cover is greater than 50% across the MU, or is increasing towards that threshold recommendation. Kamaili MU vegetation monitoring took place once previously in 2015 (ANRPO 2016a and 2016b). Previous monitoring indicated that cover goals were met for non-native understory at Kamaili Mauka, and for native canopy at Kamaili Makai. The MU fence for both subunits was completed in 2014.

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Figure 1: Locations of the Mauka and Makai Subunits of Kamaili MU.

METHODS

Point intercept monitoring was used 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 pole was used to determine “hits” in the understory (live vegetation that touched the pole, including leaves, branches and trunks) along an outstretched 50 m long measuring tape at regular intervals. Vegetation “hits” in the understory were recorded from 0 - 2 m above ground level (AGL). A laser pointer held against the pole was used as needed to determine “hits” in the canopy (above 2 m AGL) at those same intercept points, where the point fell within the perimeter of a tree's canopy. The uppermost taxa among overlapping canopy was denoted as such. Locations where no vegetation was intercepted was recorded as non-vegetated. Point intercepts were located every 2.5 m in Kamaili Mauka, and every 1 m in Kamaili Makai, along transects spaced approximately 25 m apart (Kamaili Mauka: n = 505 in 2015 and n = 467 in 2021; Kamaili Makai: n = 516 in 2015 and n = 399 in 2021). Locations of the sampled points were not permanent. Approximations of percent cover were obtained from the proportion of "hits" among all point intercepts. Analysis included Fisher's exact tests for cover change. 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. All analyses were performed using the software R, Version 4.1.2 (R Core Team 2020). Monitoring will continue on a five-year interval.

RESULTS

Management goals were met for native vegetation in the canopy in both subunits, but were not met for the native understory or non-native canopy and understory for either subunit (Table 1). Vegetation cover at both subunits continued to include mixed native and non-native understory and canopy, with the uppermost canopy layer heavily dominated by non-native cover (Tables 2 and 3). Changes in estimated vegetation cover in Kamaili Mauka included increased non-native understory (driven in part by increased understory *Passiflora suberosa*), decreased non-vegetated area in the understory, and increased native canopy (largely driven by increased *Diospyros sandwicensis*). Changes in estimated vegetation cover in Kamaili Makai included decreased understory *Rivina humilis*; increased understory *Oplismenus hirtellus*, *Adiantum hispidulum*, and *P. suberosa*; and decreased upper canopy *Grevillea robusta*. No incipient control area (ICA) taxa were intercepted or anecdotally observed at either subunit. Among the nine limited distribution target (LDT) taxa for Kamaili MU (ANRPO 2022), seven were encountered during monitoring. Of these, four were intercepted (*Abutilon grandifolium*, *Megathyrsus maximus*, *Spathodea campanulata*, and *Toona ciliata*) and two anecdotally observed (*Fraxinus uhdei* and *Montanoa hibiscifolia*) at Kamaili Mauka; and at Kamaili Makai, two were intercepted (*M. maximus* and *T. ciliata*) and three anecdotally observed (*A. grandifolium*, *Coffea arabica*, and *S. campanulata*). All LDTs had low cover (< 4%).

Table 1: Vegetation cover by stratum between 2015 and 2021 at Kamaili MU Mauka and Makai subunits. Fisher's exact tests were used for absolute cover changes > 10%. Arrows indicate increase (↑) or decrease (↓) in cover. Cover goals that are met are highlighted in blue; unmet goals are highlighted in orange.

	Mauka			Makai		
	2015	2021	P	2015	2021	P
Understory						
Native	6.7	14.6	--	6.8	12.5	--
Non-native	28.5	57.8	0.000↑	71.3	78.7	--
Non-vegetated	66.9	36.4	0.000↓	26.2	18.0	--
Canopy						
Native	42.8	55.0	0.000↑	60.9	68.9	--
Non-native	85.7	85.7	--	78.1	70.4	--
Non-vegetated	2.2	2.6	--	5.2	5.3	--
Uppermost Canopy						
Native	21.0	21.8	--	21.3	28.3	--
Non-native	76.6	74.7	--	73.4	65.4	--

Table 2: Species percent cover by stratum between 2015 and 2021 at Kamaili MU Mauka and Makai subunits. Fisher's exact tests were used for absolute cover changes > 10%. Native taxa are in boldface. Arrows indicate increase (↑) or decrease (↓) in cover. [1]Limited distribution target taxon.

Taxa	Mauka 2015	2021	P	Makai 2015	2021	P
Understory						
Abutilon sandwicense	0.0	0.0	--	0.0	1.8	--
Adiantum hispidulum	8.1	15.2	--	10.5	20.6	0.000↑
Ageratina adenophora	0.2	0.0	--	0.0	0.0	--
Ageratina riparia	0.0	0.6	--	0.2	0.3	--
Aleurites moluccana	0.0	0.0	--	0.0	0.3	--
Alyxia stellata	0.0	0.9	--	0.0	0.0	--
Asplenium nidus	0.0	0.2	--	0.0	0.0	--
Blechnum appendiculatum	0.4	1.7	--	0.2	0.0	--
Buddleja asiatica	0.0	0.2	--	0.0	0.0	--
Cheilanthes viridis	0.0	0.0	--	0.0	0.3	--
Chrisella parasitica	0.0	0.2	--	0.0	0.0	--
Conyza bonariensis	0.0	0.4	--	0.0	0.0	--
Crassocephalum crepidioides	0.0	0.2	--	0.0	0.0	--
Cuphea carthagenesis	0.0	0.2	--	0.0	0.0	--
Cyperus hypochlorus* var. *hypochlorus	0.0	0.4	--	0.0	0.0	--
Dicliptera chinensis	0.0	0.0	--	0.0	2.0	--
Digitaria insularis	0.0	0.0	--	0.2	1.3	--
Diospyros hillebrandii	0.6	1.1	--	0.0	0.0	--
Diospyros sandwicensis	5.0	9.2	--	4.1	6.0	--
Dodonaea viscosa	0.4	0.4	--	0.0	0.5	--
Doryopteris decipiens	0.0	0.0	--	0.2	0.3	--
Grevillea robusta	0.0	0.2	--	0.2	1.5	--
Hibiscus arnottianus subsp. arnottianus	0.0	0.4	--	0.0	0.0	--
Kalanchoe pinnata	0.2	0.0	--	0.0	0.3	--
Lantana camara	0.2	0.4	--	1.2	0.8	--
Lepisorus thunbergianus	0.0	0.2	--	0.0	0.0	--
Leucaena leucocephala	0.2	0.4	--	0.2	0.3	--
Malvastrum coromandelianum	0.0	0.0	--	0.0	0.5	--
Megathyrsus maximus[1]	0.0	0.4	--	0.0	0.8	--
Melia azedarach	0.2	0.2	--	0.0	0.0	--
Melinis minutiflora	0.4	0.6	--	0.0	0.0	--
Melinis repens	0.0	0.2	--	0.0	0.0	--
Mesosphaerum pectinatum	0.0	0.4	--	0.6	0.8	--
Microlepia strigosa	0.2	0.0	--	0.0	0.0	--
Nephrolepis brownii	0.0	0.4	--	0.0	0.0	--
Nestegis sandwicensis	0.0	0.2	--	0.0	0.8	--
Oplismenus hirtellus	12.1	20.8	--	15.7	28.1	0.000↑
Paspalum conjugatum	0.0	0.4	--	0.0	0.0	--
Passiflora edulis	0.2	0.9	--	0.0	0.0	--
Passiflora suberosa	1.0	11.8	0.000↑	7.0	17.8	0.000↑
Peperomia blanda	0.0	0.0	--	0.2	0.0	--
Peperomia tetraphylla	0.0	0.0	--	0.2	0.0	--
Planchonella sandwicensis	0.0	0.2	--	0.0	0.3	--
Pluchea carolinensis	0.0	0.0	--	0.0	0.3	--
Plumbago zeylanica	0.0	0.9	--	0.4	1.5	--
Psidium cattleianum	0.0	0.4	--	0.0	0.0	--
Psidium guajava	0.4	0.2	--	0.0	0.5	--
Psydrax odorata	0.4	0.6	--	0.8	0.8	--
Rauvolfia sandwicensis	0.0	0.0	--	0.4	1.0	--
Rivina humilis	4.4	5.6	--	53.1	41.6	0.001↓

Table 2 (continued).

Taxa	Mauka 2015	2021	P	Makai 2015	2021	P
Understory (continued)						
Rockia sandwicensis	0.2	0.0	--	0.0	0.0	--
Salvia coccinea	0.4	1.3	--	0.0	0.0	--
Sapindus oahuensis	0.2	0.2	--	0.6	0.0	--
Schinus terebinthifolius	2.6	6.9	--	1.9	5.8	--
Spathodea campanulata[1]	0.0	0.2	--	0.0	0.0	--
Streblus pendulinus	0.0	0.0	--	0.0	0.3	--
Syzygium cumini	0.2	0.4	--	0.0	0.0	--
Toona ciliata[1]	1.8	3.6	--	0.4	0.0	--
Triumfetta semitriloba	0.4	0.2	--	0.2	1.5	--
Youngia japonica	0.0	0.2	--	0.0	0.0	--
Canopy						
Abutilon grandifolium[1]	0.0	0.2	--	0.0	0.0	--
Abutilon sandwicense	1.0	0.6	--	0.0	2.8	--
Aleurites moluccana	9.7	7.5	--	0.0	2.3	--
Antidesma pulvinatum	0.0	0.0	--	3.7	0.8	--
Buddleja asiatica	0.2	0.4	--	0.0	0.0	--
Canavalia galeata	0.4	0.4	--	0.0	0.8	--
Diospyros hillebrandii	0.4	1.7	--	0.0	0.0	--
Diospyros sandwicensis	30.9	44.5	0.000↑	50.0	47.9	--
Dodonaea viscosa	0.6	0.9	--	0.0	1.0	--
Dracaena forbesii	0.0	0.2	--	0.0	0.0	--
Fraxinus uhdei[1]	0.2	0.0	--	0.0	0.0	--
Grevillea robusta	9.7	8.6	--	48.1	38.6	--
Hibiscus arnottianus* subsp. *arnottianus	2.4	2.8	--	0.0	0.0	--
Ipomoea cairica	0.0	0.0	--	0.0	0.5	--
Korthalsella complanata	0.0	0.2	--	0.0	0.0	--
Korthalsella degeneri	0.0	1.3	--	0.8	2.0	--
Lantana camara	0.0	0.0	--	0.8	0.0	--
Lepisorus thunbergianus	0.0	0.2	--	0.0	0.0	--
Leucaena leucocephala	0.4	0.4	--	1.4	4.0	--
Melia azedarach	1.0	1.3	--	9.7	10.5	--
Metrosideros polymorpha	1.2	0.0	--	0.0	0.0	--
Nestegis sandwicensis	2.4	1.7	--	0.2	3.5	--
Passiflora edulis	0.2	0.9	--	1.2	0.0	--
Passiflora suberosa	0.4	5.1	--	5.8	3.3	--
Planchonella sandwicensis	0.0	0.2	--	0.0	4.0	--
Pluchea carolinensis	0.0	0.2	--	0.0	0.3	--
Polyscias oahuensis	0.0	0.2	--	0.0	0.0	--
Psidium cattleianum	0.2	0.4	--	0.0	0.0	--
Psidium guajava	3.2	1.9	--	1.7	1.8	--
Psydrax odorata	2.8	4.3	--	3.7	7.5	--
Rauvolfia sandwicensis	0.0	0.0	--	0.6	1.3	--
Rockia sandwicensis	1.2	1.3	--	0.0	0.3	--
Santalum ellipticum	0.0	0.4	--	0.0	0.0	--
Sapindus oahuensis	6.9	7.7	--	8.7	13.8	--
Schinus terebinthifolius	66.7	65.1	--	27.7	27.8	--
Spathodea campanulata[1]	0.4	0.0	--	0.2	0.0	--
Syzygium cumini	4.4	7.9	--	2.7	4.3	--
Toona ciliata[1]	13.1	9.6	--	6.2	9.8	--
Uppermost Canopy						
Aleurites moluccana	6.7	5.1	--	0.0	2.0	--
Antidesma pulvinatum	0.0	0.0	--	2.9	0.0	--

Table 2 (continued).

Taxa	Mauka 2015	2021	P	Makai 2015	2021	P
Uppermost Canopy (continued)						
Buddleja asiatica	0.2	0.2	--	0.0	0.0	--
Canavalia galeata	0.2	0.0	--	0.0	0.8	--
Diospyros sandwicensis	13.1	14.1	--	14.1	18.8	--
Dodonaea viscosa	0.0	0.4	--	0.0	0.3	--
Grevillea robusta	8.9	8.1	--	46.3	30.1	0.000↓
Hibiscus arnottianus* subsp. *arnottianus	0.6	0.2	--	0.0	0.0	--
Korthalsella degeneri	0.0	0.4	--	0.0	0.0	--
Leucaena leucocephala	0.2	0.4	--	0.6	1.5	--
Melia azedarach	0.2	0.6	--	7.4	7.8	--
Metrosideros polymorpha	1.2	0.0	--	0.0	0.0	--
Nestegis sandwicensis	0.8	0.4	--	0.0	1.3	--
Passiflora edulis	0.2	0.2	--	0.2	0.0	--
Planchonella sandwicensis	0.0	0.0	--	0.0	0.3	--
Polyscias oahuensis	0.0	0.2	--	0.0	0.0	--
Psidium cattleianum	0.2	0.4	--	0.0	0.0	--
Psidium guajava	1.2	0.0	--	0.0	0.3	--
Psydrax odorata	0.4	0.9	--	1.0	3.0	--
Rauvolfia sandwicensis	0.0	0.0	--	0.2	0.3	--
Rockia sandwicensis	0.0	0.2	--	0.0	0.0	--
Santalum ellipticum	0.0	0.4	--	0.0	0.0	--
Sapindus oahuensis	4.8	4.5	--	3.1	3.8	--
Schinus terebinthifolius	44.4	45.6	--	13.2	10.3	--
Spathodea campanulata[1]	0.2	0.0	--	0.0	0.0	--
Syzygium cumini	3.8	6.2	--	1.0	3.8	--
Toona ciliata[1]	10.5	7.7	--	4.8	9.8	--

Table 3: All taxa intercepted (I) or anecdotally (A) observed in any strata (either 0-2 m AGL or >2 m AGL) between 2015 and 2021 at Kamaili MU Mauka and Makai subunits. [1]Limited distribution target taxon.

Taxa	Mauka 2015	2021	Makai 2015	2021
Abutilon grandifolium[1]	A	I	A	A
Abutilon sandwicense	I	I	A	I
Adiantum hispidulum	I	I	I	I
Ageratina adenophora	I	A	A	A
Ageratina riparia	A	I	I	I
Ageratum conyzoides		A	A	A
Aleurites moluccana	I	I	A	I
Alyxia stellata	A	I		
Antidesma pulvinatum			I	I
Asplenium nidus		I		
Bidens torta		A		
Blechnum appendiculatum	I	I	I	A
Buddleja asiatica	I	I		
Canavalia galeata	I	I		I
Carex meyenii	A	A		
Cheilanthes viridis	A	A	A	I
Christella parasitica		I		
Clidemia hirta		A		
Cocculus orbiculatus	A	A		
Coffea arabica[1]			A	A

Table 3 (continued).

Taxa	Mauka 2015	Mauka 2021	Makai 2015	Makai 2021
Conyza bonariensis	A	I	A	A
Cordyline fruticosa	A	A	A	A
Crassocephalum crepidioides	A	I		
Cuphea carthagenesis		I		
Cyperus hypochlorus* var. *hypochlorus	A	I		
Dicliptera chinensis		A		I
Digitaria insularis			I	I
Diospyros hillebrandii	I	I		
Diospyros sandwicensis	I	I	I	I
Dodonaea viscosa	I	I	A	I
Doodia kunthiana	A	A		
Doryopteris decipiens	A	A	I	I
Dracaena forbesii		I		
Fraxinus uhdei[1]	I	A		
Grevillea robusta	I	I	I	I
Hibiscus arnottianus* subsp. *arnottianus	I	I	A	A
Indigofera suffruticosa	A			
Ipomoea cairica				I
Kalanchoe pinnata	I	A	A	I
Korthalsella complanata		I		
Korthalsella degeneri		I	I	I
Lantana camara	I	I	I	I
Lepisorus thunbergianus	A	I	A	A
Leucaena leucocephala	I	I	I	I
Malvastrum coromandelianum				I
Megathyrsus maximus[1]	A	I	A	I
Melia azedarach	I	I	I	I
Melinis minutiflora	I	I		
Melinis repens		I		
Mesosphaerum pectinatum	A	I	I	I
Metrosideros polymorpha	I			
Microlepia strigosa	I	A		
Montanoa hibiscifolia[1]		A		
Myrsine lanaiensis		A	A	A
Nephrolepis brownii		I		
Neraudia angulata			A	A
Nestegis sandwicensis	I	I	I	I
Oplismenus hirtellus	I	I	I	I
Oxalis corniculata	A	A		
Paspalum conjugatum	A	I		
Passiflora edulis	I	I	I	A
Passiflora suberosa	I	I	I	I
Peperomia blanda			I	
Peperomia tetraphylla	A	A	I	A
Phlebodium aureum	A	A		
Planchonella sandwicensis	A	I	A	I
Plectranthus parviflorus	A		A	A
Pluchea carolinensis	A	I		I
Plumbago zeylanica		I	I	I
Polyscias oahuensis		I		
Psidium cattleianum	I	I		
Psidium guajava	I	I	I	I
Psilotum nudum	A	A		

Table 3 (continued).

Taxa	Mauka 2015	Mauka 2021	Makai 2015	Makai 2021
Psydrax odorata	I	I	I	I
Rauvolfia sandwicensis	A	A	I	I
Rivina humilis	I	I	I	I
Rockia sandwicensis	I	I		I
Salvia coccinea	I	I	A	A
Santalum ellipticum		I		
Santalum freycinetianum	A			
Sapindus oahuensis	I	I	I	I
Schinus terebinthifolius	I	I	I	I
Setaria parviflora		A		
Sida fallax			A	A
Sida rhombifolia	A	A	A	
Sida spinosa			A	
Spathodea campanulata[1]	I	I	I	A
Streblus pendulinus				I
Strongylodon ruber	A	A		
Syzygium cumini	I	I	I	I
Toona ciliata[1]	I	I	I	I
Trema orientalis		A		
Triumfetta semitriloba	I	I	I	I
Verbena litoralis	A			
Youngia japonica	A	I		

DISCUSSION AND RECOMMENDATIONS

Prior to monitoring in 2015, weeding efforts were limited to small areas around rare plant populations of *Abutilon sandwicense* and *Neraudia angulata* (Figure 2). Since then, extensive weed control has occurred in both subunits, covering over half of the MU, including targeted control of both understory and canopy weeds. The reduced cover in the uppermost *G. robusta* canopy at Kamaili Makai was not surprising as substantial canopy control was done at that unit including *G. robusta* as well as other taxa. Reduced *R. humilis* cover at Kamaili Makai was also not surprising, as the reintroduction site for *N. angulata* expanded in area between 2015 and 2021, and *R. humilis* (prevalent in that area) was cleared and maintained in association with that expansion. Increased understory weediness is not uncommon in the initial years following fencing/ungulate removal (Weller *et al*. 2011, Cole and Litton 2014), as such, increased understory non-native cover at Kamaili Mauka and increased understory *P. suberosa*, *O. hirtellus*, and *A. hispidulum* at Kamaili Makai was not surprising. The understory was largely non-vegetated in 2015, allowing room for weed expansion. During monitoring in 2021, staff observed localized areas heavily invaded by *P. suberosa* at both subunits, with curtains of it covering vegetation, including stands of *Diospyros* and some rare plants. Following this, staff worked to clear those areas, and should continue to do so as needed. Only two small ICAs (both for *Chromolaena odorata*) occur within or near to Kamaili MU, and staff were relieved that no additional plants were found during vegetation monitoring of the MU. It was not surprising that a number of LDT taxa were found, given their known occurrence in the MU, and fortunately cover was low for those taxa.

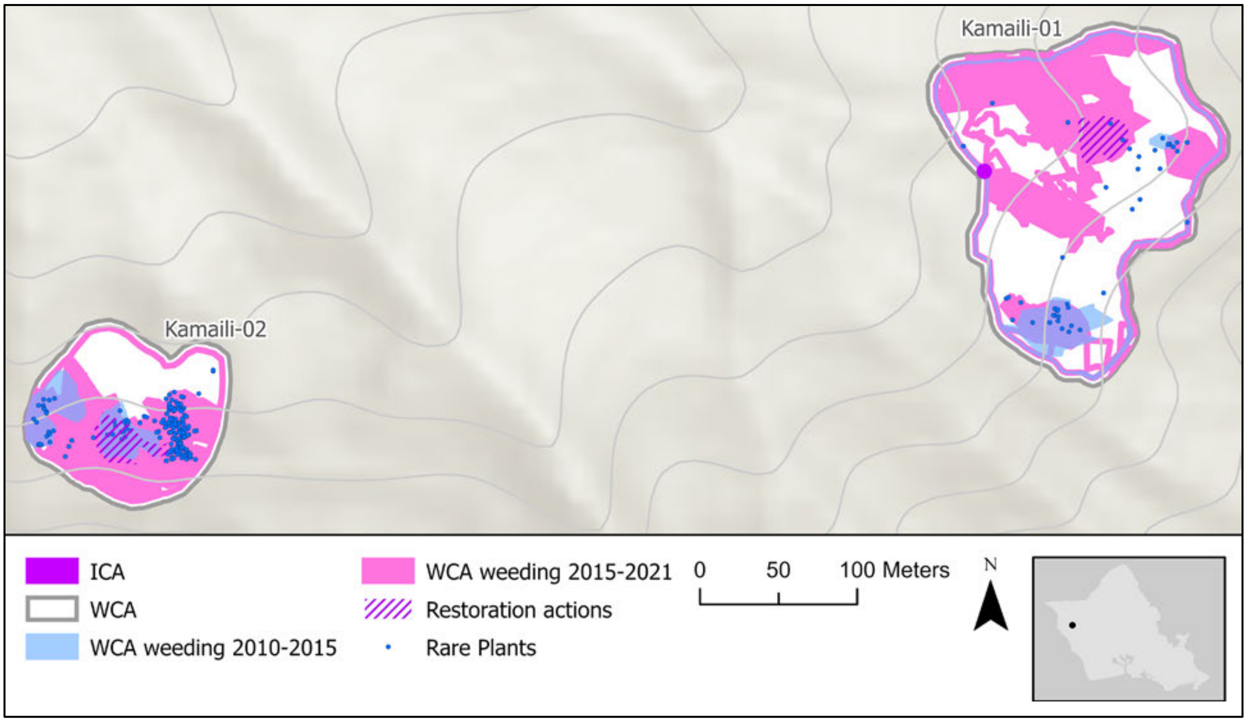

Figure 2: Vegetation management at WCAs Kamaili-01 (Mauka unit) and Kamaili-02 (Makai unit), showing areas of weed control and restoration efforts in relation to rare plants, prior to and following initiation of vegetation monitoring in 2015.

Restoration efforts only recently began in 2019 in prioritized areas in both subunits, and were not expected to have had an MU-scale impact yet given the limited area and time since outplanting. The increased estimated cover of canopy *D. sandwicensis* and overall native canopy was relatively small (< 15%) at Kamaili Mauka, possibly resulting in part from a sampling issue relating to differing transect locations between years (Type I error, statistical results suggest a difference though none exists), as this taxon is very slow growing, occurs in bands, and could conceivably be hit or missed in accordance with transect alignment (Figure 3). ANRPO staff have, however, anecdotally observed that *D. sandwicensis* trees are doing “really well” there. To mitigate potential future sampling errors, the transect layout should not differ between years. The points will still not be permanent, but will sample the same general areas over time. Because GPS reception there is poor, transect starting and ending locations should be permanently marked, and transects flagged periodically along the way. This option is preferred as a time saving measure as opposed to the alternative of having more transects, and increasing the total number of points, which would also provide more reliable results, but would take considerably longer to accomplish.

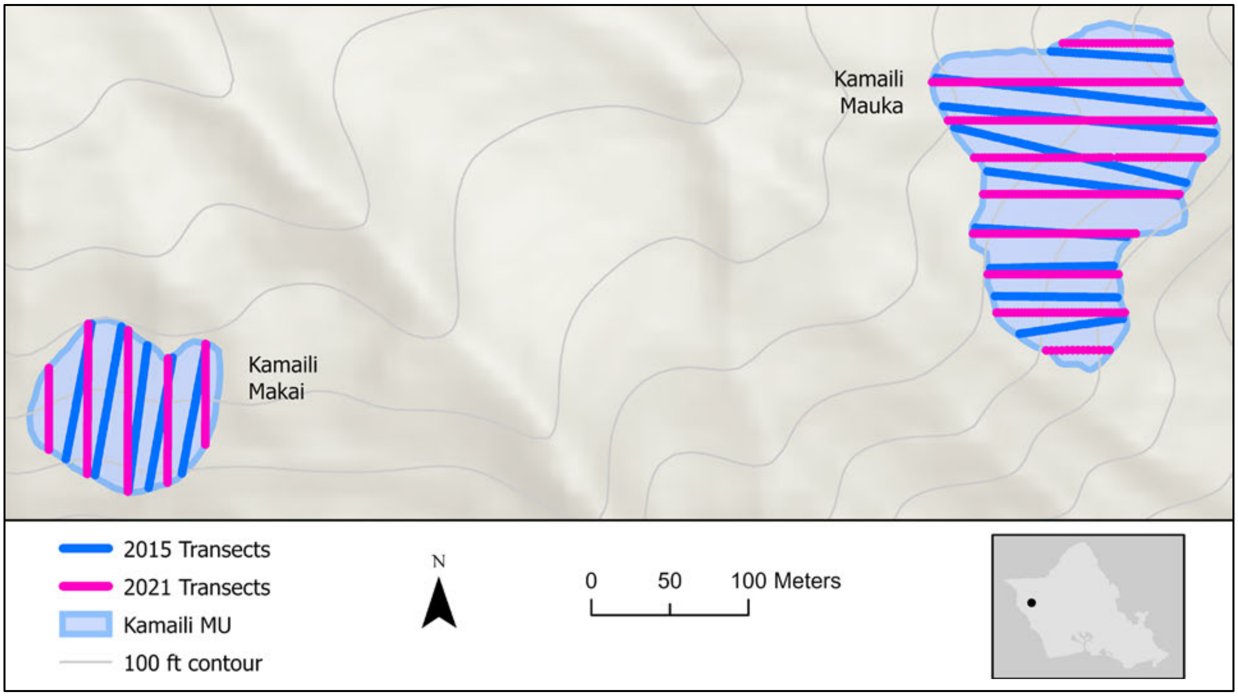

Figure 3: Transect alignments used in 2015 and 2021 for point intercept vegetation monitoring at Kamaili MU.

Achieving IP goals for native understory and non-native understory and canopy at Kamaili Makai MU may be challenging, though progress towards them may be made. Vegetation management strategies recently detailed in the Ecosystem Restoration MU Plan for Kamaili (ANRPO 2021) include targeted weed control in prioritized areas that will occur in a phased approach in combination with restoration of common native species:

Kamaili Mauka

"The WCA consists of four management zones: Lama Zone, Talus Gulch Zone, Rare Plant Zone, and Fence Corridor. Removing fuel-forming alien grasses, particularly *M. maximus* and *M. minutiflora* will be a priority across the WCA.

Since the rare plant zones are primarily in weed-dominated habitat, canopy control and understory weed control ideally should be undertaken in conjunction with common native reintroduction efforts. Maintaining a managed buffer around the rare taxa is a high priority to promote regeneration of *A. sandwicense* and *N. humile*. Removal of alien canopy trees needs to be balanced against light level changes, and staff availability to conduct follow-up weed control maintenance. The area likely had a fairly open understory in the past, as with other more intact dry-mesic forest areas, and currently maintains a fairly open understory, with 67% non-vegetated cover.

The Lama Zone is predominantly native and will be a high priority for weed control. Although there are few rare taxa directly in the Lama Zone, it abuts the Rare Plant Zones and contributes towards vegetation cover goals. Removing targets, such as, *G. robusta*, *Schinus terebinthifolius*, and *T. ciliata*, will be key in maintaining canopy goals for this MU. However, selective efforts are needed given the potential for aggressive colonization by other non-natives and very slow growth of *Diospyros sandwicensis*. *Toona ciliata* removal is a higher priority than other canopy weeds in this zone, as this taxon has great potential to completely overrun the WCA. Other, less common tree weeds, such as *S. cumini* and *M. azedarach* will also be targeted for gradual removal.

Intense restoration is needed in the Talus Gulch Zone of the WCA, but is a low priority except for weed control around rare taxa. Native taxa in the Talus Gulch Zone have been repeatedly struck with rocks. The weed species have outcompeted the natives due to their resilience to the constant rock fall. This zone was selected as the first restoration site, where reintroductions of *D. viscosa*, *H. arnottianus*, and *P. zeylanica* began in 2019. Some outplants, particularly patches of *P. zeylanica* are relatively successful at this site, however the constant re-sprouting of *T. ciliata* and other weeds has severely inhibited the *D. viscosa*, *H. arnottianus.* Incursion of invasive species continues to be a challenge in this area, so the focus for localized restoration plans in the immediate future will move to Kamaili Makai around the *N. angulata* reintroduction to create suitable habitat for recruitment as well as *N. angulata* site augmentations.

The rare plant zones (north gulch and south gulch) require phased control of weeds and selective control of canopy weeds. Areas near the main *A. sandwicense* clusters need to be defined and starting points selected. Initial areas should be no larger than can be adequately maintained. Ground cover species like weedy ferns, vines, and grasses should be treated first, then larger understory species, then selective removal of canopy trees. Treated trees will likely need to be cut down, bucked, and debris piled into slash piles. Initial control trips are needed about one to two times per quarter (see action table at the end of this document) with supplemental planting with fast growing species like *D. viscosa*, *P. sandwicensis*, and *P. albidus*. Aggressive follow up is needed for understory weeds like *B. appendiculatum* and grasses once light levels increase.

The Fence Corridor will be maintained (inside and outside) anytime grass or weeds prohibit staff from checking the fences thoroughly. A catchment is now on site to facilitate weed control. Caution is needed when spraying along portions of the fenceline given recruitment of *A. sandwicense* along the line. Removal of *S. terebinthifolius* is needed in some areas to prevent damage to the fence by uprooting or tree fall."

Kamaili Makai

"Like Kamaili Mauka, this area consists of four zones: Lama Zone, Talus Gulch Zone, Rare Plant Zone, and Fence Corridor… Canopy control and weeding in rare plant zones is ideally undertaken in conjunction with common native reintroduction efforts. Removal of canopy trees needs to be balanced against light level changes. The unit has a fairly dense understory as only 26% of the unit is non-vegetated.

Grevillea robusta and *S. terebinthifolius* will be selectively killed throughout the Lama Zones (primarily on the ridges) and around *A. sandwicense* to slowly increase light levels. This is mostly on the *N. angulata* reintroduction ridge. Sweeps across the whole area should gradually thin the alien canopy, and all understory weeds need treatment except *R. humilis*. Careful weeding is needed to keep back weeds and to not desiccate seedlings. Native fern outplants could be trialed as a replacement for *R. humilis* in spots.

Aggressive restoration efforts (2023-2024) will continue around existing outplanting areas; consideration for large scale restoration will most likely take place within the Mauka section. Common natives selected for this area, such as *D. viscosa,* needs be hardy enough to withstand rockfalls. *Neraudia angulata* was reintroducted in to the fence in 2015 and is the main focus of this WCA. ANRPO staff will mainly control *P. suberosa*, *D. chinensis*, and other herbaceous weeds in this fence.

The main rare plant zones (*N. angulata* reintroduction and *A. sandwicense* patch along western edge) require similar thinning of the canopy. *Grevillea robusta* removal efforts along the western edge have already benefitted the *A. sandwicense* plants in the area. Keeping some bare soil areas open near the rare plants is important for recruitment. Grasses and weedy fern species will need to be kept in check. Outplanting natives (e.g. *M. strigosa*, *P. zeylanica*) to compete with *R. humilis* should be trialed particularly along the western edge.

The Fence Corridor will be maintained (inside and outside) anytime grasses or weeds prohibit us from checking the fences thoroughly. Removal of *S. terebinthifolius* is needed in some areas to prevent damage to the fence by uprooting or downfall."

These practical strategies provide a reasonable pathway for making progress towards IP goals. Added considerations in light of the current monitoring are that while weed control efforts to date have made progress for some weed taxa (*R. humilis* and *G. robusta* at Kamaili Makai), understory weed cover has become much worse at Kamaili Mauka (especially *P. suberosa*), and *P. suberosa*, *O. hirtellus*, and *A. hispidulum* are growing problems at Kamaili Makai. As such, understory weed management will likely prove challenging, and further discussion of pairing weed control with restoration efforts is warranted. A number of problematic taxa remain at low densities, and as such warrant discussion as candidates for targeted removal, including *M. maximus, Dicliptera chinensis, C. arabica*, *Leucaena leucocephala, Melia azedarach, M. hibiscifolia*, and *S. campanulata* which may be targeted at regular intervals, and *T. ciliata*, which may be targeted for gradual removal.

Multilayered and overlapping native and non-native canopy occur at Kamaili (43% overlap at Kamaili Mauka; 45% overlap at Kamaili Makai). Documenting the uppermost canopy layer (a proxy for cover estimates when viewed from above) provided a useful opportunity to examine relative differences in native and non-native cover for >2 m AGL vs. the uppermost canopy layer, with implications for interpretations of vegetation monitoring using satellite or aerial imagery. Given that documentation of the uppermost layer does not account for underlying canopy taxa, both native and non-native cover are expected to be underestimated using this method compared to cover estimates for all taxa >2 m AGL. At Kamaili, underestimation of native cover was much greater than that of non-native cover at both subunits (Figure 4). Such differences between taxon groupings are expected to occur if one group tends to have taller canopy than the other, as is the case at Kamaili, where a number of the dominant non-native canopy taxa (*G. robusta*, *M. azedarach*, *Schinus terebinthifolius*, *Syzygium cumini*, and *T. ciliata*,) tend to grow taller than the dominant native canopy taxon (*D. sandwicensis*) does in that area. It has been understood that one of the limitations of using satellite or aerial imagery is that it does not account for understory vegetation. The monitoring at Kamaili suggests that an additional limitation includes the potential for disproportional underrepresentation for cover of smaller stature trees. Vegetation monitoring using satellite or aerial imagery remains a viable tool for tracking canopy change over time, with the caveat that cover underestimations may vary depending on growth habits of the resident tree taxa.

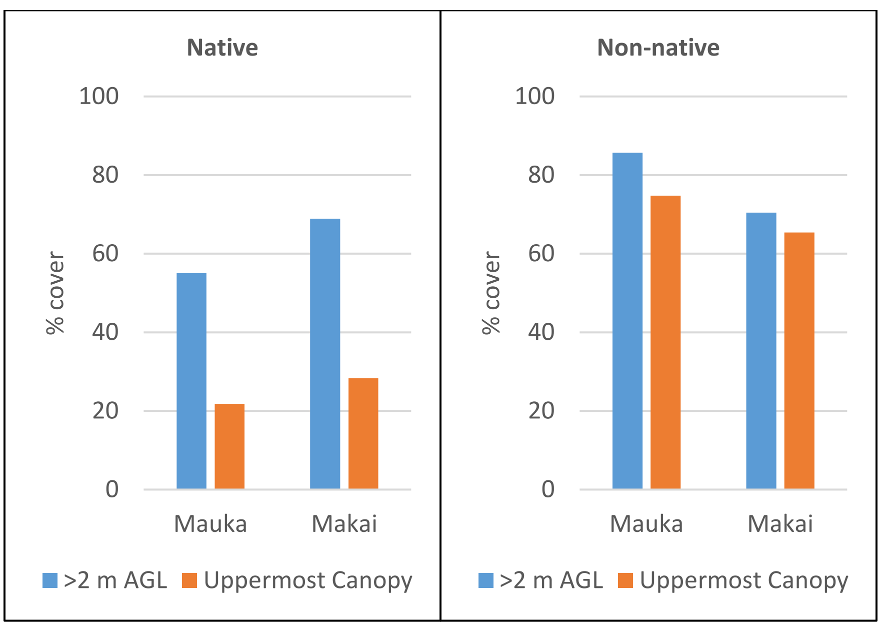

Figure 4: Native and non-native cover estimates for >2 m AGL and the uppermost canopy layer at Kamaili MU Mauka and Makai subunits in 2021. At both subunits, percent cover of non-native canopy is slightly lower for the uppermost layer compared to canopy >2 m AGL, while percent cover of native canopy is considerably lower for the uppermost layer compared to canopy >2 m AGL.

The terrain at Kamaili is very steep and rocky, especially in Kamaili Mauka, and the method of pulling out a 50 m measuring tape required a fair amount of doubling back to wind up and unhook the starting point of the line (which needed to be affixed to avoid accidental movement of the line, particularly when working in a downslope direction, as the line may slide downhill) that was tiresome and posed an added risk of dislodging rocks that could fall on crewmembers. An alternative method for laying out the points should be considered, that will not require backtracking. The workflow may run better (less tiring, safer, and more time efficient) with a shorter line (e.g., 10 m), and with a crew of three staff: one recording data and holding the line, one making observations, and one pulling the line after each segment is completed. With the use of a shorter line, the recorder will always remain within earshot of the observer, and the line may simply be pulled forward without being wound up.

Kamaili MU is the largest and steepest area in which ANRPO conducts point intercept monitoring (2.8 acres at Kamaili Makai, and 6.9 acres at Kamaili Mauka). All other ANRPO point intercept projects cover considerably smaller areas (0.6 acres or less), such as at vegetation restoration sites (snail enclosures, etc.) and subsampled weeded areas. Monitoring at Kamaili has provided a learning opportunity for the program in assessing and refining field methods for point intercept monitoring of larger areas, which may be taken into consideration in planning future point intercept monitoring of larger scale areas, such as the fenced portion of Makaleha West MU (11.3 acres), which is planned to begin in the coming years, and also contains steep and challenging terrain.

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ARMY NATURAL RESOURCE PROGRAM ON OAHU
MONITORING PROGRAM

PAHOLE MANAGEMENT UNIT VEGETATION MONITORING, 2021

INTRODUCTION

The Army Natural Resources Program on Oahu (ANRPO) conducted baseline vegetation monitoring at Pahole Management Unit (MU) in 2021 in association with Implementation Plan (IP) requirements for long term monitoring of vegetation composition and change over time (ANRPO 2008) (Figure 1). The primary objective of MU monitoring is to assess if the percent cover of non-native plant species is less than 50% across the MU, or is decreasing towards that threshold requirement. The secondary objective is to assess if native cover is greater than 50% across the MU, or is increasing towards that threshold recommendation. Pahole MU vegetation monitoring will occur on a on a five-year interval. The MU fence was completed in 1998.

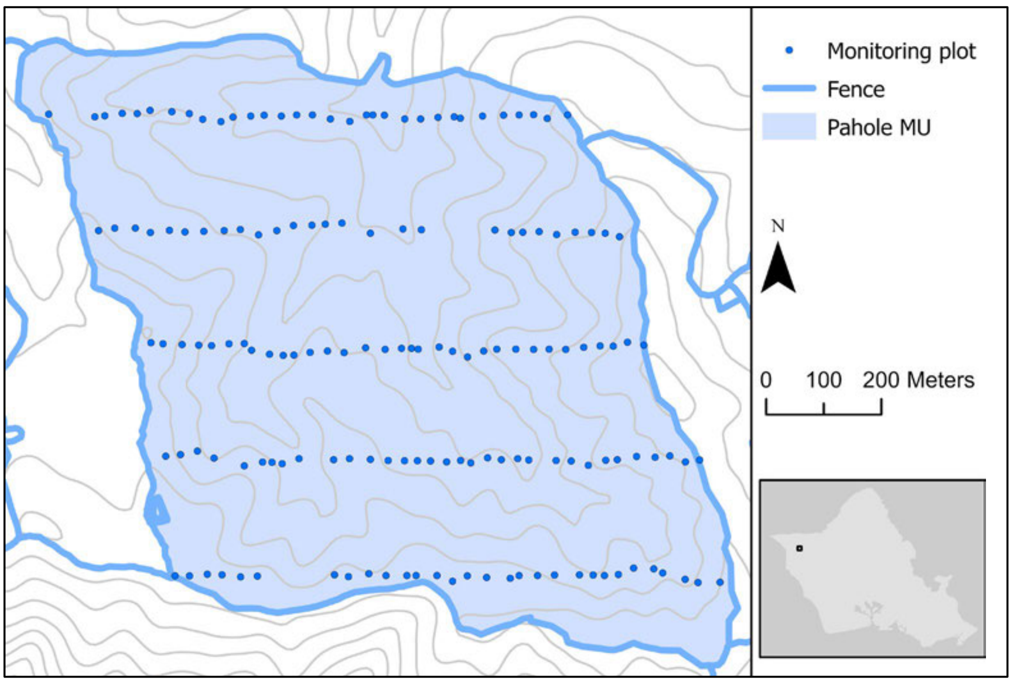

Figure 1: Pahole MU vegetation monitoring plot locations.

METHODS

In October and November of 2021, 155 permanent plots along nine transects were established and monitored in Pahole MU (Figure 2). Plots measuring 5 x 10 m were generally located every 30 m along transects. Areas too steep to monitor safely were skipped. Transects were spaced approximately 200 m apart. Stations were established every 10 m along the transects, marked with engraved metal tags and flagged with a combination of pink and yellow flagging tape. 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, and overall summary percent cover of non-native and native vegetation in the understory and canopy, 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) frequency for tree species was also recorded. Monitoring results will be compared over time. Based on IP recommendations, p-values < 0.05 will be considered significant, and only absolute cover changes ≥ 10% will be recognized. Additional methodology information is detailed in Monitoring Protocol 1.2.1 (ANRPO 2008).

Figure 2: Sample photographs of vegetation in plots monitored in native dominated (left) and non-native dominated (right) habitat at Pahole MU. Webbing visible in the images marks the centerline of the plots.

RESULTS

Understory and canopy cover categories

Management goals of having < 50% non-native understory and canopy and > 50% native understory and canopy cover were only met for the non-native understory (45% median cover) (Table 1 and Figure 3). Non-native canopy was very high (95% median cover). Native understory and canopy cover were low (both at 7.5% median cover). Locations of low to high native and non-native understory and native canopy percent cover were patchily distributed across the MU, though native understory was more consistently higher near the Makua rim. High non-native canopy cover occurred consistently across the MU, with the exception of the southwest corner, where cover was low (Figure 4).

Table 1: Median percent cover of native and non-native vegetation categories in the canopy and understory at Pahole MU in 2021. Categories specifically addressed in management goals are shaded in blue.

	2021	Management goal currently met?
Understory		
Native shrubs	0.5	
Native ferns	3.0	
Native grass/sedges	0.0	
Total native understory	7.5	No
Non-native shrubs	15.0	
Non-native ferns	3.0	
Non-native grass/sedges	0.5	
Total non-native understory	45.0	Yes
Canopy		
Native canopy	7.5	No
Non-native canopy	95.0	No
Total canopy	95.0	

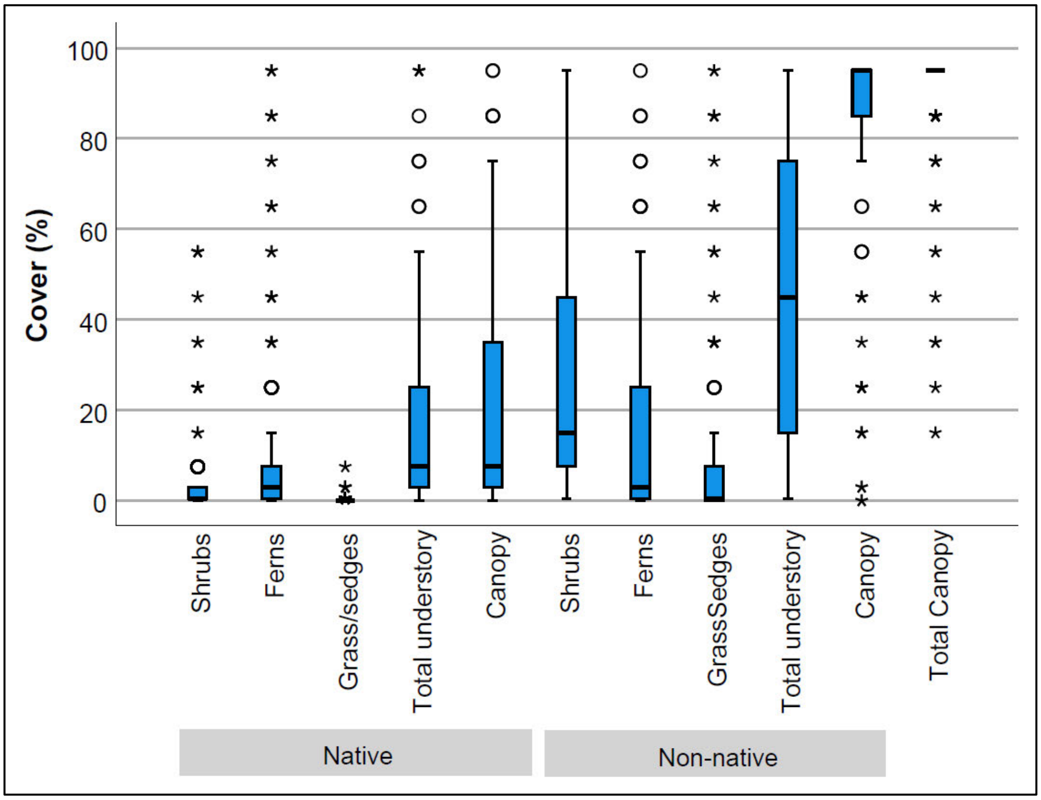

Figure 3: Boxplots for cover of native and non-native taxon categories in 2021 in Pahole MU. *Note: Boxplots depict the range of values of variables. The boxes depict 50% of the data values, and the horizontal line inside the box represents the median value. Very high or low values relative to the shaded box are indicated by circles (1.5 to 3 times the length of the shaded box) and asterisks (> 3 times the length of the shaded box), while the lines extending above and below the shaded box depict the range in values for all remaining data. Circles and asterisks that appear to be in boldface indicate multiple data points for the same values.*

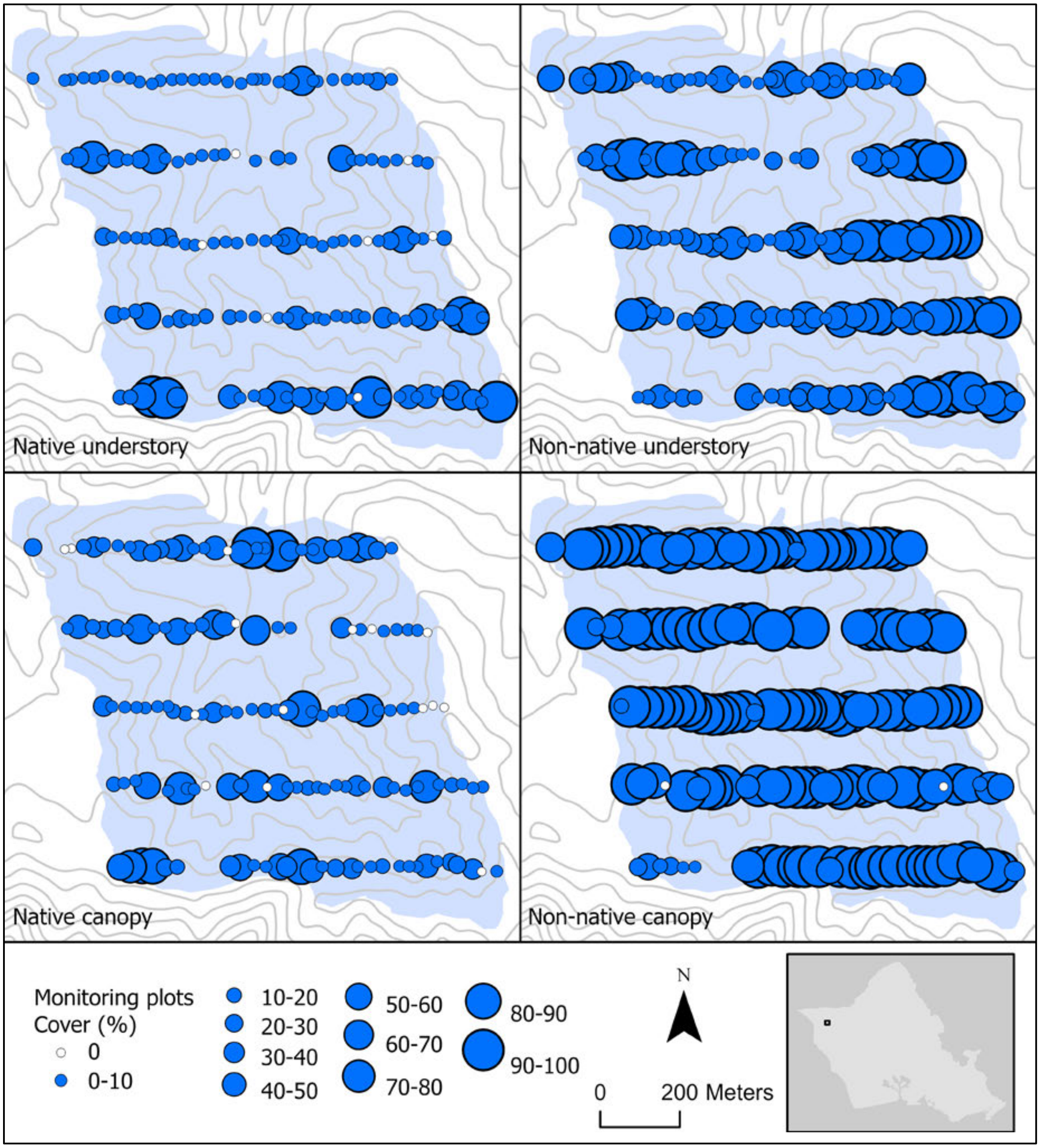

Figure 4: Locations of low to high percent cover of native and non-native understory and canopy vegetation among monitored plots at Pahole in 2021. Larger circles denote higher percent cover, while smaller circles represent lower cover.

Species richness

During monitoring in 2021, 131 species were recorded in the understory (64% native taxa), and 63 were identified in the canopy (70% native). Median richness was typically low for both native and non-native canopy. Native and non-native understory had somewhat greater richness than the canopy (Table 2 and Figure 5). Locations of high and low species richness for the native and non-native understory and canopy were patchily distributed across the MU (Figure 6).

Table 2: Pahole MU understory and canopy species richness in 2021. Median species richness per plot during vegetation monitoring is shown by year, with the total number of species recorded among all plots in parentheses.

	2021
Native understory	5 (84)
Non-native understory	5 (47)
Native canopy	2 (44)
Non-native canopy	3 (19)

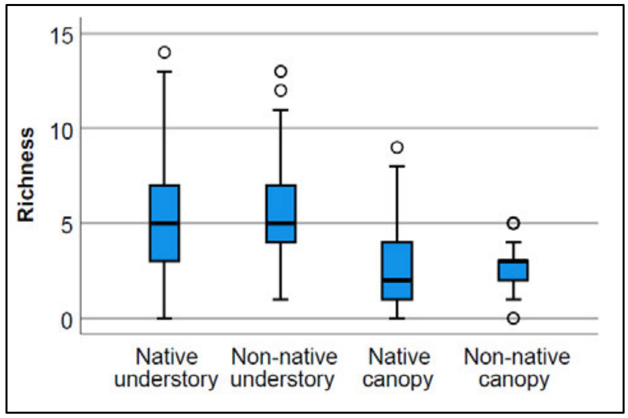

Figure 5: Boxplots for native and non-native richness within plots in the understory and canopy in 2021 in Pahole MU.

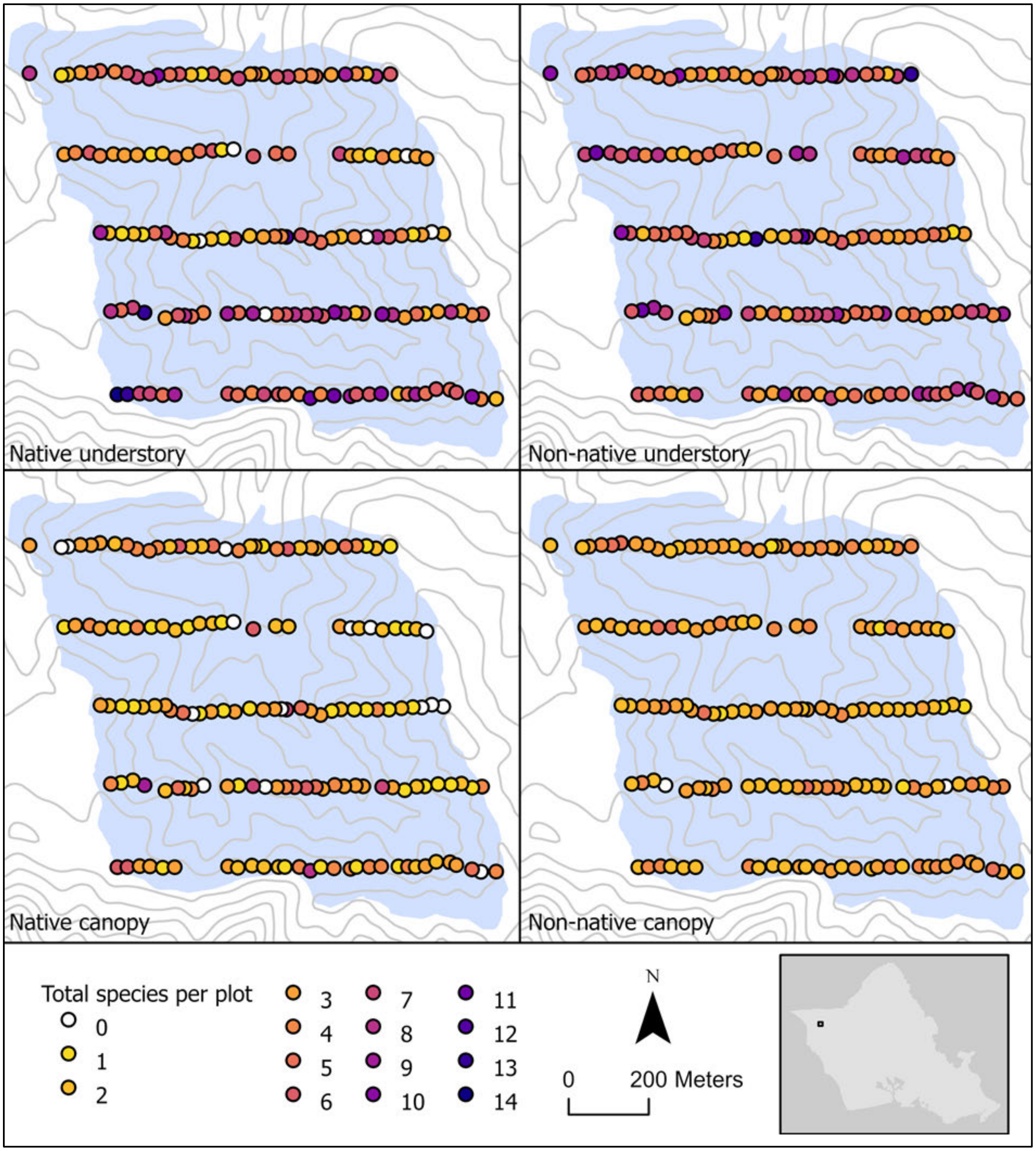

Figure 6: Locations of low to high species richness among plots in the native and non-native understory and canopy in Pahole in 2021. Color gradients of yellow to purple indicate low to high values, respectively, of the number of species occurring in plots (i.e., yellow indicates low diversity, while purple indicates relatively higher diversity).

Species frequency

Non-native species that occurred most frequently in plots (present in more than half the plots) in the understory in 2021 included *Psidium cattleianum*, *Clidemia hirta*, *Blechnum appendiculatum*, and *Schinus terebinthifolius*, while *P. cattleianum* and *S. terebinthifolius* also occurred most commonly in the canopy (Table 3). The most frequent native understory species (present in at least a quarter of the plots) included *Microlepia strigosa*, *Alyxia stellata*, *Psydrax odorata*, and *Nephrolepis exaltata*, while

Metrosideros polymorpha and *Acacia koa* occurred most commonly in the canopy. Six rare taxa were recorded in plots during monitoring in 2021, including wild *Cyrtandra dentata* and *Microlepia strigosa* var. *mauiensis*, and reintroduced *Cyanea superba* subsp. *superba*, *Euphorbia herbstii*, *Schiedea pentandra* (planted by DLNR), and *Urera kaalae* (planted by DLNR). Numerous target weed taxa (taxa of special concern for weed management, ranging from incipient species to those with widespread distributions) (ANRPO 2021) for Pahole MU were present in monitored plots in 2021 in either the understory or canopy, though most taxa were those with widespread distributions (Figure 7). One Incipient Control Area (ICA) target, *Angiopteris evecta*, was present in a single plot (new ICA). Five limited distribution target (LDT) taxa were recorded in plots, including *Fraxinus uhdei*, *Nephrolepis brownii*¸ *Passiflora suberosa*, *Spathodea campanulata*, and *Zingiber zerumbet*, all of which were in frequencies (< 10%). Among these, *N. brownii*¸ *P. suberosa*, and *S. campanulata* were most widespread. *Toona ciliata* and *Triumfetta semitriloba*, which are both listed as widespread targets, actually had limited distributions, and may be considered for addition to the LDT list. *Syzygium cumini*, also listed as widespread, had a relatively limited distribution, but is more challenging to control, and not prioritized for control at this time. A few other observed species that are not on the target list, but may also be considered for addition to the LDT list, include *Araucaria columnaris* and *Cyrtomium falcatum* (both present in plots in low frequencies), and *Phoenix* sp. (anecdotally observed). *Grevillea robusta* is a major target at neighboring Kahanahaiki MU (Appendix 3-11), but is fairly widespread throughout much of Pahole MU (Figure 8).

Table 3: Species frequencies in the understory and canopy in 2021, with taxa ordered by highest to lowest frequency. Native species are in boldface. ‡Rare taxa. Target weed taxa: *ICA, **LDT.

Taxon	Freq.	Taxon	Freq.
Understory		Understory	
Psidium cattleianum	92.9	***Ceodes brunoniana***	3.9
Clidemia hirta	80.6	***Dianella sandwicensis***	3.9
Blechnum appendiculatum	58.1	***Pteridium aquilinum***	3.9
Microlepia strigosa	53.5	***Sapindus oahuensis***	3.9
Schinus terebinthifolius	51.6	*Spathodea campanulata***	3.9
Alyxia stellata	42.6	***Tectaria gaudichaudii***	3.9
Psydrax odorata	42.6	*Ageratina riparia*	3.2
Oplismenus hirtellus	40.6	***Ceodes umbellifera***	3.2
Nephrolepis exaltata	36.8	***Diplazium sandwichianum***	3.2
Christella parasitica	27.7	***Leptecophylla tameiameiae***	3.2
Doodia kunthiana	27.7	***Rockia sandwicensis***	3.2
Metrosideros polymorpha	19.4	*Stachytarpheta australis*	3.2
Lepisorus thunbergianus	18.1	***Asplenium nidus***	2.6
Lantana camara	16.8	***Cyrtandra dentata*‡**	2.6
Rubus rosifolius	16.8	***Dodonaea viscosa***	2.6
Phlebodium aureum	16.1	***Euphorbia multiformis***	2.6
Nestegis sandwicensis	14.2	***Odontosoria chinensis***	2.6
Kadua affinis	13.5	***Pipturus albidus***	2.6
Adiantum hispidulum	12.3	***Psychotria hathewayi***	2.6
Diospyros hillebrandii	12.3	***Asplenium kaulfussii***	1.9
Melinis minutiflora	12.3	***Canavalia galeata***	1.9
Paspalum conjugatum	11.6	*Oxalis debilis*	1.9
Cocculus orbiculatus	10.3	***Peperomia tetraphylla***	1.9
Cibotium chamissoi	9.7	*Polystachya concreta*	1.9
Psidium guajava	9.7	***Psilotum nudum***	1.9
Acacia koa	9.0	*Syzygium cumini*	1.9
Carex meyenii	9.0	***Xylosma hawaiiense***	1.9
Coprosma foliosa	9.0	*Ageratum conyzoides*	1.3
Dicranopteris linearis	9.0	*Andropogon virginicus*	1.3
Grevillea robusta	9.0	*Araucaria columnaris*	1.3
Cordyline fruticosa	8.4	***Asplenium excisum***	1.3
*Passiflora suberosa***	8.4	***Asplenium macraei***	1.3
Diospyros sandwicensis	7.7	***Asplenium polyodon***	1.3
Carex wahuensis	7.1	*Conyza bonariensis*	1.3
Freycinetia arborea	6.5	***Dryopteris fusco-atra***	1.3
Psychotria mariniana	6.5	***Elaeocarpus bifidus***	1.3
Toona ciliata	6.5	***Kadua acuminata***	1.3
Aleurites moluccana	5.8	***Peperomia blanda***	1.3
Antidesma platyphyllum	5.8	***Phyllostegia grandiflora***	1.3
Christella dentata	5.8	*Angiopteris evecta**	0.6
Deparia petersenii	5.8	***Asplenium aethiopicum***	0.6
Ageratina adenophora	5.2	***Asplenium contiguum***	0.6
Asplenium caudatum	5.2	*Buddleja asiatica*	0.6
Cyperus hillebrandii* subsp. *decipiens	5.2	*Chamaecrista nictitans*	0.6
*Nephrolepis brownii***	5.2	***Charpentiera obovata***	0.6
Vandenboschia davallioides	5.2	***Charpentiera tomentosa***	0.6
Wikstroemia oahuensis* var. *oahuensis	5.2	***Cyanea superba* subsp. *superba*‡**	0.6
Adiantum raddianum	4.5	*Cyrtomium falcatum*	0.6
Bidens torta	4.5	***Deparia fenzliana***	0.6
Dryopteris sandwicensis	4.5	***Dryopteris glabra***	0.6
Hibiscus arnottianus* subsp. *arnottianus	4.5	***Euphorbia herbstii*‡**	0.6
Planchonella sandwicensis	4.5	*Fraxinus uhdei***	0.6

Table 3 (continued).

Taxon	Freq.	Taxon	Freq.
Understory (continued)		Understory	
Gahnia beecheyi	0.6	*Pityrogramma austroamericana*	0.6
Ipomoea ochracea	0.6	***Psilotum complanatum***	0.6
Korthalsella complanata	0.6	***Santalum freycinetianum* var. *freycinetianum***	0.6
Lysimachia hillebrandii	0.6	***Scaevola gaudichaudiana***	0.6
Melicope sandwicensis	0.6	***Schiedea pentandra*‡**	0.6
Melinis repens	0.6	***Selaginella arbuscula***	0.6
Menisciopsis cyatheoides	0.6	*Setaria parviflora*	0.6
***Microlepia strigosa* var. *mauiensis*‡**	0.6	***Streblus pendulinus***	0.6
Myrsine lessertiana	0.6	*Triumfetta semitriloba*	0.6
Oxalis corniculata	0.6	***Urera kaalae*‡**	0.6
Passiflora edulis	0.6	***Vandenboschia cyrtotheca***	0.6
Peperomia membranacea	0.6	*Youngia japonica*	0.6
***Peperomia* sp.**	0.6	*Zingiber zerumbet***	0.6
Pittosporum glabrum	0.6		
Canopy		Canopy	
Psidium cattleianum	94.8	*Cordyline fruticosa*	2.6
Schinus terebinthifolius	82.6	***Dicranopteris linearis***	2.6
Psydrax odorata	38.1	***Psychotria hathewayi***	2.6
Metrosideros polymorpha	35.5	***Cyrtandra dentata*‡**	1.9
Grevillea robusta	29.7	*Phlebodium aureum*	1.9
Acacia koa	26.5	***Santalum freycinetianum* var. *freycinetianum***	1.9
Alyxia stellata	24.5	***Cocculus orbiculatus***	1.3
Psidium guajava	20.0	***Elaeocarpus bifidus***	1.3
Nestegis sandwicensis	19.4	*Fraxinus uhdei***	1.3
Clidemia hirta	11.6	***Nephrolepis exaltata***	1.3
Lepisorus thunbergianus	11.6	***Phyllostegia grandiflora***	1.3
Aleurites moluccana	11.0	***Pipturus albidus***	1.3
Diospyros hillebrandii	11.0	***Xylosma hawaiiense***	1.3
Planchonella sandwicensis	8.4	*Araucaria columnaris*	0.6
Kadua affinis	6.5	***Canavalia galeata***	0.6
Lantana camara	6.5	***Charpentiera obovata***	0.6
Psychotria mariniana	6.5	***Charpentiera tomentosa***	0.6
Sapindus oahuensis	5.8	***Cyanea superba* subsp. *superba*‡**	0.6
Cibotium chamissoi	5.2	***Euphorbia multiformis***	0.6
Diospyros sandwicensis	5.2	*Ipomoea ochracea*	0.6
Hibiscus arnottianus* subsp. *arnottianus	5.2	***Kadua acuminata***	0.6
Syzygium cumini	5.2	***Korthalsella complanata***	0.6
Antidesma platyphyllum	4.5	***Korthalsella platycaula***	0.6
Freycinetia arborea	4.5	***Leptecophylla tameiameiae***	0.6
Coprosma foliosa	3.9	*Melinis minutiflora*	0.6
Ceodes brunoniana	3.2	***Myrsine lanaiensis***	0.6
Dodonaea viscosa	3.2	***Pittosporum glabrum***	0.6
*Passiflora suberosa***	3.2	*Polystachya concreta*	0.6
Rockia sandwicensis	3.2	*Stachytarpheta australis*	0.6
*Spathodea campanulata***	3.2	***Streblus pendulinus***	0.6
Toona ciliata	3.2	***Wikstroemia oahuensis* var. *oahuensis***	0.6
Ceodes umbellifera	2.6		

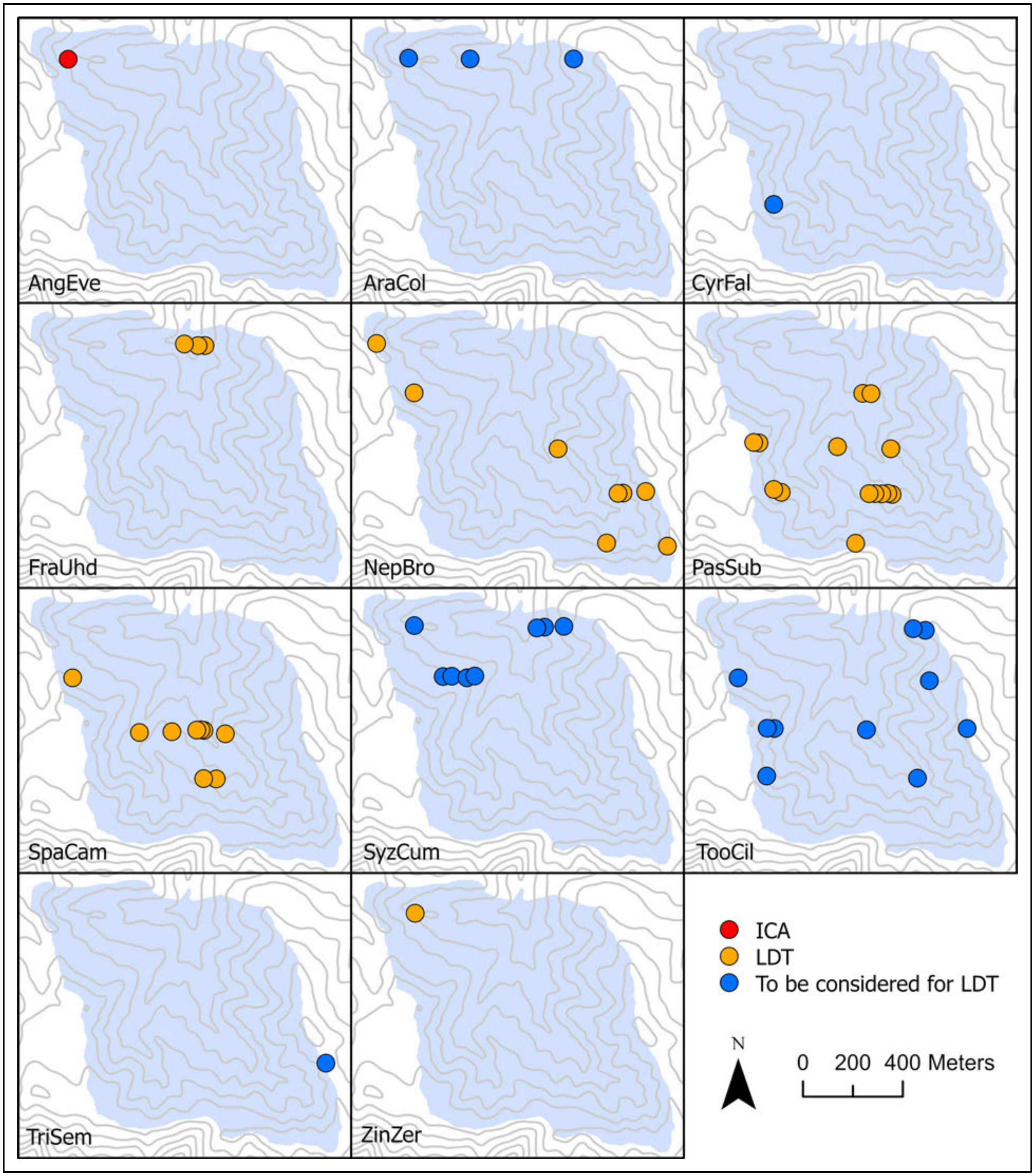

Figure 7: Locations of ICA and LDT target taxa, and species to be considered for addition to the LDT taxa list, found in the understory and/or canopy in monitoring plots at Pahole MU in 2021.

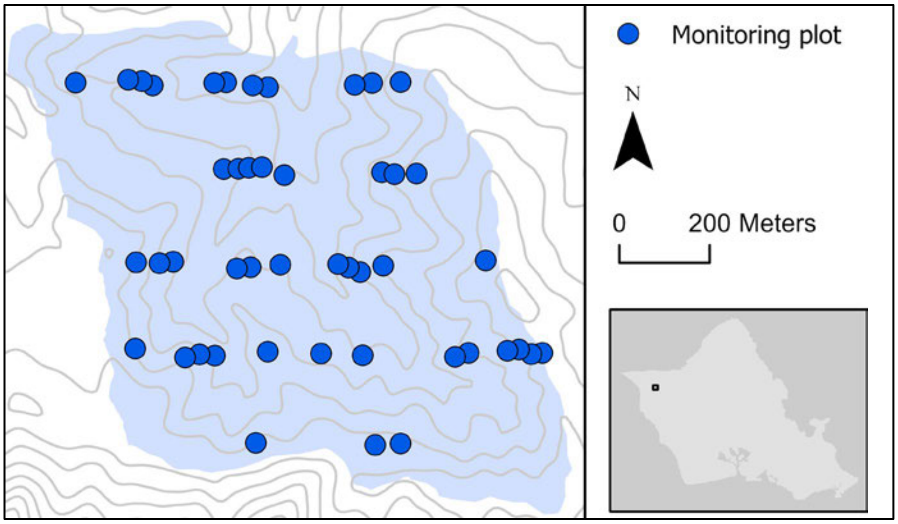

Figure 8: Locations of *Grevillea robusta* found in the canopy in monitoring plots at Pahole MU in 2021.

Species cover

Species cover was examined for taxa present in at least three-quarter of the plots. Native taxa cover was typically lower than non-native taxa cover (Figure 9). *Psidium cattleianum* and *B. appendiculatum* in the understory, and *P. cattleianum* and *S. terebinthifolius* in the canopy, had notably high cover.

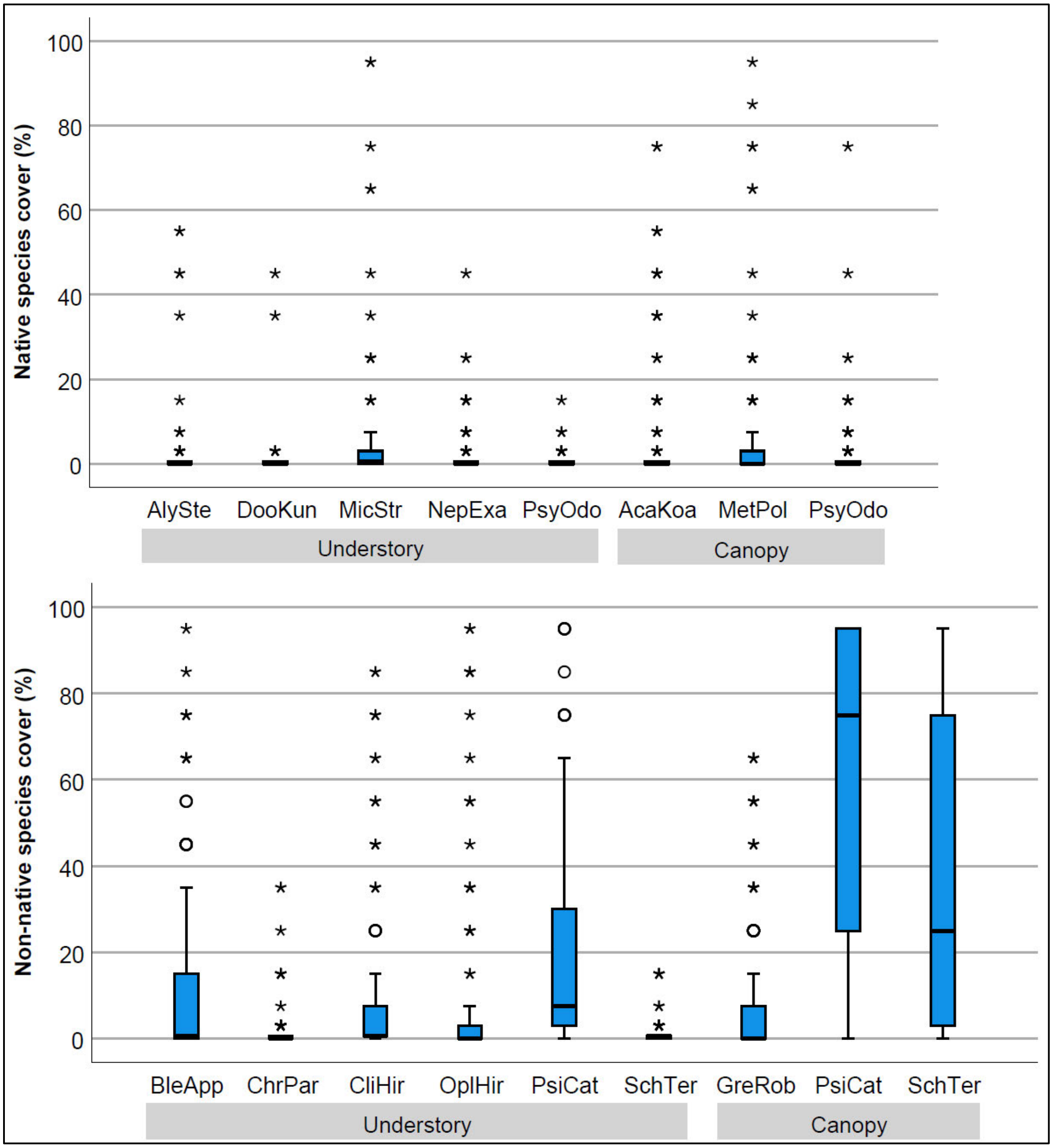

Figure 9: Boxplots for understory and canopy cover ranges of native and non-native taxa that are present in at least three-quarters of plots at Pahole MU in 2021.

Canopy replacement

In 2021, 31 tree taxa (74% native) were found recruiting in the understory (Table 4). *Psidium cattleianum* was the most commonly recruiting tree species, occurring in three-quarters of the plots. One rare taxon (*U. kaalae*, an outplant) was found recruiting in a single plot. Native tree taxa with no recruitment in the understory were relatively infrequent in the canopy (with frequencies < 2%). Two LDT weed taxa (*S. campanulata* and *F. uhdei*) were found recruiting in plots. Recruitment frequencies within plots for these taxa were < 4%. 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 4: Tree species recruitment frequencies in 2021, ordered by highest to lowest recruitment frequency. Native species are in boldface. ‡Rare taxa. Target taxa: *ICA, **LDT.

Taxon	Freq.	Taxon	Freq.
Psidium cattleianum	75.5	***Psychotria mariniana***	1.9
Psydrax odorata	21.9	***Ceodes umbellifera***	1.3
Schinus terebinthifolius	18.1	***Dodonaea viscosa***	1.3
Acacia koa	7.7	***Metrosideros polymorpha***	1.3
Grevillea robusta	7.1	***Rockia sandwicensis***	1.3
Diospyros hillebrandii	5.8	***Xylosma hawaiiense***	1.3
Toona ciliata	5.8	***Melicope sandwicensis***	0.6
Aleurites moluccana	5.2	***Planchonella sandwicensis***	0.6
Psidium guajava	5.2	***Psychotria hathewayi***	0.6
Diospyros sandwicensis	4.5	***Santalum freycinetianum* var. *freycinetianum***	0.6
Kadua affinis	4.5	***Streblus pendulinus***	0.6
Sapindus oahuensis	3.9	***Urera kaalae*‡**	0.6
*Spathodea campanulata***	3.9	*Araucaria columnaris*	0.6
Ceodes brunoniana	2.6	***Elaeocarpus bifidus***	0.0
Nestegis sandwicensis	2.6	***Myrsine lessertiana***	0.0
Pipturus albidus	2.6	***Pittosporum glabrum***	0.0
Antidesma platyphyllum	1.9	*Fraxinus uhdei***	0.0
Hibiscus arnottianus* subsp. *arnottianus	1.9	*Syzygium cumini*	0.0

Vegetation management

Pahole MU has not been highly prioritized for vegetation management by ANRPO, as program efforts there are more focused on rare plant stabilization. ANRPO weed control efforts began at Pahole MU in 2004, and consisted of Weed Control Area (WCA) and ICA weeding (Figure 10). WCA efforts included general ecosystem weeding and grass sprays. Relative to other MUs, limited ANRPO weed control occurs at Pahole, with efforts mainly focused around rare plant sites and ICAs. ANRPO native plant restoration efforts began in 2017, and have been limited to two very small areas along the west edge of the MU. The DLNR DOFAW Native Ecosystems Protection and Management Program (NEPM) also conducts additional weed control and native plant restoration in designated zones along the west and south edges of the MU. Monitoring plots overlap areas of both ANRPO and NEPM vegetation management. While the vast majority of rare plants fall within areas of both ANRPO and NEPM management, some, but not all, plots with high native cover also fall within managed areas at Pahole (Figure 11). However, few of these plots with high native cover outside of managed areas have low non-native cover. These findings generally align with indications from NEPM staff that areas of NEPM and ANRPO vegetation management encompass the highest quality remnant native habitat.

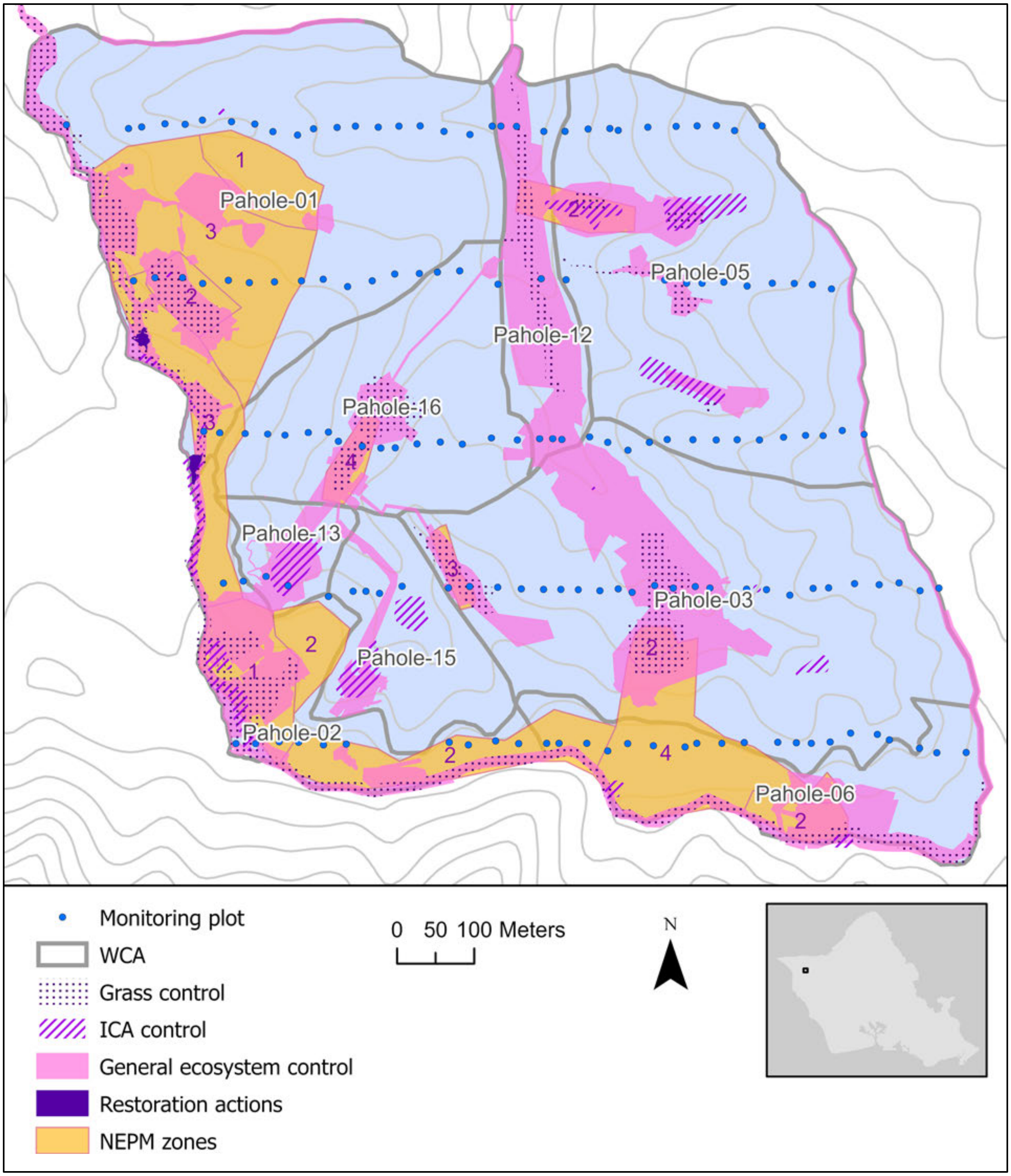

Figure 10: Locations of ANRPO weed control and restoration efforts prior to 2021 monitoring in relation to monitored plots in Pahole MU. Weeded areas include general ecosystem, grass, and ICA control efforts. DLNR DOFAW NEPM management zones are also shown, labeled according to class rankings of 1 (highest priority, most intact remaining native habitat) to 4.

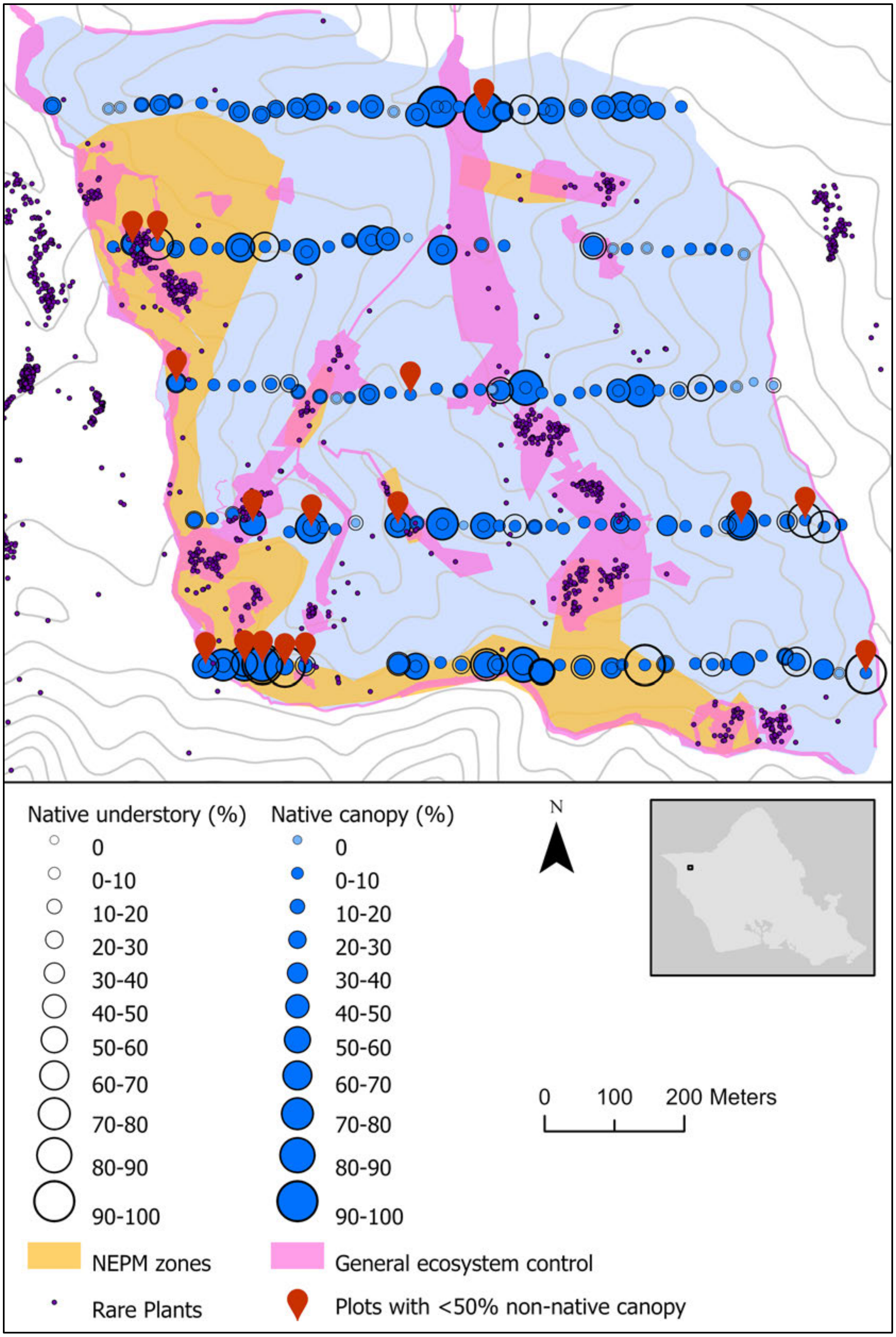

Figure 11: Locations of low to high native understory and canopy cover in plots in relation to rare plants, NEPM management zones, and ANRPO general ecosystem weed control in recent years (within the five year period prior to monitoring), with markers for plots with low non-native canopy cover (< 50%).

SUMMARY AND DISCUSSION

Management goals were only met, and barely so, for percent cover of non-native understory at Pahole MU. Goals were unmet for native understory, native canopy, and non-native canopy cover. Native cover was typically very low both in the understory and canopy. Non-native canopy cover was typically very high throughout most of the MU. Overall vegetation conditions at Pahole were worse than that of the neighboring MUs of Kahanahaiki (Appendix 3-11) and Upper Kapuna (ANRPO 2018). The extent to which management goals are applicable to this MU are debatable, as the habitat is heavily degraded, and weed control and restoration efforts are limited.

Weedy expansion of *P. cattleianum*, *G. robusta*, *T. ciliata*, *S. terebinthifolius*, *C. hirta*, *P. suberosa*, and *B. appendiculatum* have been challenging to control, even in ANRPO MUs with relatively high levels of vegetation management. These taxa, with the exception of *T. ciliata* and *P. suberosa*, are already widespread; all are expected to get worse at Pahole. Of particular concern is *T. ciliata*, which had low frequencies in the understory and canopy, but is likely to become a serious invader in the coming years if it is not controlled. As weed cover increases, native cover is expected to decline. Because limited vegetation management occurs at the MU, overall conditions are likely to deteriorate.

Some smaller scale positive aspects for the MU are that remnant high value native-dominated areas still remain in some areas (albeit these areas are patchy and not connected, which presents further management challenges), and areas with intensive vegetation management are having positive impacts (pers. obs.). During monitoring, evidence of the biocontrol agent (*Tectococcus ovatus*, released by NEPM) for *P. cattleianum* was observed to have spread to several locations in the MU, which holds promise for reduced *P. cattleianum* growth and seed production in the coming years.

RECOMMENDATIONS

Progress towards meeting management goals is challenging, even in smaller MUs with better habitat and intensive vegetation management such as the adjacent Kahanahaiki MU. Given the highly degraded condition of the habitat and limited vegetation management at Pahole, progress towards meeting management goals is unlikely to occur without massive effort, landscape level actions, and extensive collaboration with NEPM. Based on the results of vegetation monitoring, a number of recommendations were made with the aim of making progress towards improving habitat and mitigating the spread of problematic weeds in prioritized areas, particularly those with rare plants, to be discussed and coordinated with the NARS program:

- Continued general ecosystem weeding and grass control around rare plants and in prioritized areas
- Continued ICA control
- Considerations should be made for how to manage the inevitable invasion of *T. ciliata*. IPA control has not slowed its spread at Makaha, Manuwai, or Kaluaa and Waieli MUs, though it was already well established in those MU (all with canopy frequencies above 30%) when sweeps were conducted. Based on its current limited distribution, control efforts may be effective in preventing its spread. Aerial imagery may be one effective means of locating areas for control.
- Add *A. columnaris*, *C. falcatum*, *Phoenix* sp., *T. ciliata*, and *T. semitriloba* to the limited distribution target taxa weed list for Pahole MU, and consider adding *S. cumini* if more effective control measures are developed

- Consider sweeps for limited distribution target weeds, consider which WCAs or portions of WCAs are a priority for such sweeps, with a focus on taxa with low frequencies, perhaps aided by imagery and/or aerial surveys
- Consider management options and strategies for *G. robusta*. Targeted IPA sweeps have been very effective at controlling this taxon where it occurred in lower frequencies in other MUs. Given how widespread it is at Pahole, and prevalence of other non-native canopy taxa, determine to what extent and where it is a priority, and partner with NEPM to control if it is a priority for them, also.
- Release *T. ovatus* for biocontrol of *P. cattleianum* in areas where it has not yet been released or dispersed naturally, to get biocontrol more widely established in the MU
- Focus restoration actions to create more suitable habitat for rare plants and complement NEPM restoration efforts, to possibly include expanded efforts in the Gulch 2 area, areas adjacent to Kahanahaiki (possibly including the area between Puu 2210 and the Bill Garnett site), and along the Makua rim. This will realistically be limited to 1 or 2 areas given limited time, funding, and priorities being greater in other MUs.
- Meet with NEPM to discuss monitoring results and determine how to address these results together, particularly management strategies for *T. ciliata* and *G. robusta*, discuss their management plans for the coming years, and discuss their priority management areas if there have been or will be any changes to them. Also discuss the monitoring interval, and the extent to which this will be a useful tool for tracking MU-scale change/decline over time. Discuss the possibility of efforts to manage low cover invasive species via grants from the Readiness and Environmental Protection Integration program, which funds management work in areas abutting military lands to improve environmental conditions on military land.

REFERENCES CITED

ANRPO. 2008. Appendix 2.0 MIP/OIP Belt Plot Sampling Monitoring Protocol *in* 2008 Status Report for the Makua Implementation Plan.

ANRPO. 2018. Appendix 3-9 Kapuna Upper Management Unit Vegetation Monitoring, 2011 - 2017 *in* 2018 Status Report for the Makua and Oahu Implementation Plans.

ANRPO. 2021. Target Weed Taxa. Available upon request.

ARMY NATURAL RESOURCES PROGRAM ON OAHU
MONITORING PROGRAM

VEGETATION MONITORING RESULTS FOR THE GIANT OHIA RESTORATION SITE AT MAKAHA, 2022

INTRODUCTION

The Army Natural Resources Program on Oahu (ANRPO) documents vegetation cover change at the "Giant Ohia" restoration site at Makaha I Management Unit (MU) (Figure 1). The site encompasses approximately 0.4 acres of mesic forest within 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 quarterly maintenance understory weeding. The majority of initial clearing was for *Psidium cattleianum* trees. Weeding efforts were accomplished using cut-stump, girdle, and "clip and drip" methods 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. A number of common native taxa were sown, transplanted, or outplanted at the site between 2016 and 2022 (Table 1). Point intercept 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. This report documents vegetation cover at the restoration site through 5.5 years post-clearing.

**Image Redacted
Sensitive Information
Available Upon Request**

Figure 1: Location of Giant Ohia restoration site at Makaha I MU.

Table 1: Species outplanted, sown, and/or transplanted over time in association with native vegetation restoration at the Giant Ohia restoration site.

	2016-09	2016-10	2017-05	2017-10	2018-09	2018-12	2022-04*	**Total**
Outplants								
Dodonaea viscosa						10		**10**
Eragrostis grandis						6		**6**
Hibiscus arnottianus subsp. *arnottianus*				42		11		**53**
Kadua affinis				14				**14**
Microlepia strigosa				8				**8**
Plumbago zeylanica						1		**1**
Sapindus oahuensis				1				**1**
Total outplants				**65**		**28**		**93**
Seed/fruit sows								
Alyxia stellata (fruit)							273	**273**
Bidens torta (seed)					125			**125**
Pipturus albidus (fruit)	1250	200						**1450**
Total seeds/fruit sown	**1250**	**200**			**125**			**1848**
Transplants								
Acacia koa			10					**10**
Microlepia strigosa			25					**25**
Total transplants			**35**					**35**

*Occurred on the same day as the April 2022 monitoring as an opportunistic sow from nearby plants that were fruiting prolifically.

METHODS

Canopy and understory cover: Point intercept monitoring was conducted prior to weeding in August 2016, and post-weeding after six months (March 2017), one year (September 2017), two years (September 2018), and five and a half years (April 2022) (hereafter referred to as baseline, Year 0.5, Year 1, Year 2, and Year 5.5 monitoring) 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 mm diameter pole was used to determine "hits" in the understory, to include live vegetation less than 2 m 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 m AGL) at these same intercept points, where the point fell within the perimeter of a tree's canopy containing live vegetation. Locations where no live vegetation was intercepted were recorded as non-vegetated. Bare branches of treated canopy trees were considered non-living. Locations of transects and sampled points were not permanent. Point intercepts were located every 0.5 m along 11 transects spaced 5 m apart during baseline monitoring (n = 630 total point intercepts), and along 9 transects spaced 6 m apart in all other years (Year 0.5: n = 547; Year 1: n = 548; Year 2 n = 540; Year 5.5: n = 545). Approximations of percent cover were obtained from the proportion of "hits" among all intercepts.

Supplemental data: Permanent photopoints were established for visual documentation of change in each cardinal direction for each of four points. During the course of vegetation monitoring, supplemental species diversity lists were created documenting all species that happened to be observed, but not intercepted, to help document change in the presence or absence of species that have low cover, or are uncommon, and therefore less likely to be documented during point intercept monitoring.

Analysis: Analysis included Fisher's exact tests for the point intercept data. Taxa with < 10% absolute cover change were excluded from analyses to mitigate the probability of detecting a change when none exists (Type I error). Significance determinations were based on $\alpha = 0.05$. These analyses were performed using the software R, Version 4.1.2 (R Core Team 2021). Prediction maps of taxa occurrence were created in Geostatistical Analyst, ArcGIS Pro. Prediction maps were generated using ordinary kriging (statistical method used 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.

RESULTS

During baseline monitoring (prior to non-native vegetation clearing) the restoration area contained a nearly continuous (99.5%) canopy cover of mixed non-native (88%) and native (67%) vegetation (ANRPO 2017) (Table 2). The understory included scattered non-native (30%) and native (21%) cover. Non-native vegetation primarily consisted of *P. cattleianum* both in the canopy (86%) and understory (29%) (Table 3). Native vegetation was mainly *Psydrax odorata* (35%), *Acacia koa* (30%), and *Metrosideros polymorpha* (13%) in the canopy, and *Alyxia stellata* (11%) and *P. odorata* (8%) in the understory. Additional taxa were anecdotally observed but not intercepted during monitoring, most of which were native (Table 4). Though native cover was lower than non-native cover, there was more than twice as much overall native diversity.

In Year 0.5 (following weed clearing), there was a significant reduction in non-native vegetation, resulting in 7% canopy and < 1% understory cover, largely influenced by the significant reduction in *P. cattleianum* to 3% in the canopy and < 1% in the understory (ANRPO 2017). This was paired with a significant increase in non-vegetated area to 30% in the canopy and 79% in the understory. A number of new taxa were documented, most of which were anecdotally observed non-native species. Non-native diversity doubled following clearing, while native diversity remained relatively stable. Similar monitoring results were obtained in Year 1 (ANRPO 2017).

By Year 2, there was a significant increase in native canopy cover to 84% (meeting the cover goal), mainly attributable to significant canopy increases for *P. odorata* (54%) and *M. polymorpha* (25%) resulting from flushing/expansion of in situ trees (ANRPO 2019a). Weed cover goals were maintained, and few new weed taxa were observed from Year 1. Native and non-native diversity remained similar to that observed in Year 0.5.

By Year 5.5, there was a significant increase from baseline results in native canopy cover to 85.5%, mainly attributable to significant canopy increases for *P. odorata* (64.6%) and *M. polymorpha* (28.6%). There was also a significant increase in native understory cover to 43.7%, mainly attributable to a significant understory increase for *P. odorata* (19.3%). Weed cover goals continued to be maintained, and only two new weed taxa were observed (anecdotally). Non-native diversity remained similar to that observed during previous post-clearing monitoring, while there was a slight increase in native diversity.

The dramatic changes in native understory and canopy cover from baseline to Year 5.5 are quite apparent as seen in geostatistical prediction maps (Figure 2) as well as in the visual representation of sub-canopy vegetation in photopoint images (Figures 3-6). Changes generally occurred throughout most the restoration area, rather than being limited to isolated regions.

Table 2. Vegetation cover by stratum over time at the Giant Ohia restoration site. Fisher's exact tests were used for cover change between baseline and Year 5.5 data. Cover values meeting management goals are highlighted in blue.

	Baseline	Year 0.5	Year 1	Year 2	Year 5.5	p
Understory						
Native	20.8	20.3	26.1	26.9	43.7	0.000
Non-native	29.8	0.7	5.7	3.3	7.0	0.000
Non-vegetated	52.9	79.0	69.5	70.4	51.9	0.770
Canopy						
Native	67.1	74.4	75.9	84.3	85.5	0.000
Non-native	88.3	7.1	6.9	1.1	1.5	0.000
Non-vegetated	0.5	22.9	20.6	15.7	14.3	0.000

Table 3: Species percent cover by stratum and year. Native taxa are in boldface. Listed in order of highest to lowest cover in Year 5.5. Fisher's exact tests were used for > 10% absolute cover change between baseline and Year 5.5. Native taxa are in boldface. *Taxon represented in restoration efforts prior to 2022 monitoring.

Species	Baseline	Year 0.5	Year 1	Year 2	Year 5.5	p
Understory						
Psydrax odorata	7.6	6.6	8.0	8.1	19.3	0.000
Alyxia stellata	11.3	7.9	10.8	12.2	16.7	
Microlepia strigosa**	0.8	0.9	1.5	2.0	4.4	
Cordyline fruticosa	0.3	0.4	0.7	1.7	2.4	
Psidium cattleianum	28.7	0.2	3.8	1.5	2.2	0.000
Metrosideros polymorpha	0.0	0.9	0.0	1.5	1.5	
Diospyros sandwicensis	0.3	0.4	0.4	1.1	1.5	
Carex wahuensis	0.5	0.5	0.2	1.1	1.5	
Acacia koa**	0.2	3.3	5.8	0.9	1.3	
Clidemia hirta	0.2	0.0	0.5	0.0	1.1	
Kadua affinis**	0.3	0.0	0.4	0.6	0.9	
Doodia kunthiana	0.3	0.4	0.4	0.4	0.9	
Euphorbia multiformis	0.0	0.2	0.2	0.4	0.6	
Ageratum conyzoides	0.0	0.0	0.0	0.0	0.6	
Hibiscus arnottianus* subsp. *arnottianus**	0.0	0.0	0.0	0.0	0.6	
Mesosphaerum pectinatum	0.0	0.0	0.0	0.0	0.4	
Dodonaea viscosa**	0.0	0.2	0.0	0.4	0.2	
Psychotria mariniana	0.2	0.0	0.0	0.2	0.2	
Bidens torta**	0.0	0.0	0.0	0.2	0.2	
Nestegis sandwicensis	0.0	0.0	0.0	0.2	0.2	
Bobea elatior	0.2	0.0	0.0	0.0	0.2	
Christella parasitica	0.0	0.0	0.0	0.0	0.2	
Conyza bonariensis	0.0	0.0	0.0	0.0	0.2	
Emilia sonchifolia	0.0	0.0	0.0	0.0	0.2	
Passiflora suberosa	0.0	0.0	0.0	0.0	0.2	
Schinus terebinthifolius	0.2	0.0	0.0	0.2	0.0	
Syzygium cumini	0.3	0.0	0.4	0.0	0.0	
Passiflora edulis	0.0	0.0	0.4	0.0	0.0	
Asplenium caudatum	0.0	0.0	0.2	0.0	0.0	
Nephrolepis exaltata* subsp. *hawaiiensis	0.0	0.0	0.2	0.0	0.0	
Crassocephalum crepidoides	0.0	0.2	0.0	0.0	0.0	
Lepisorus thunbergianus	0.0	0.2	0.0	0.0	0.0	
Coprosma foliosa	0.8	0.0	0.0	0.0	0.0	

Table 3 (continued).

Species	Baseline	Year 0.5	Year 1	Year 2	Year 5.5	p
Understory (continued)						
Coffea arabica	0.2	0.0	0.0	0.0	0.0	
***Melicope* sp.**	0.2	0.0	0.0	0.0	0.0	
Canopy						
Psydrax odorata	34.6	44.4	41.2	54.4	64.6	0.000
Acacia koa*	30.3	31.8	34.9	35.9	37.4	
Metrosideros polymorpha	13.3	21.2	22.8	24.6	28.6	0.000
Alyxia stellata	9.0	5.3	6.6	4.6	6.1	
Diospyros sandwicensis	6.3	4.8	4.9	4.8	5.9	
Dodonaea viscosa*	0.6	1.5	2.7	3.1	5.5	
Psychotria mariniana	1.9	1.6	2.0	1.9	2.9	
Nestegis sandwicensis	2.9	1.1	2.0	3.9	2.4	
Bobea elatior	2.1	1.5	1.3	0.7	1.5	
Psidium cattleianum	86.0	3.1	5.1	0.7	1.1	0.000
Kadua affinis*	0.5	0.0	0.0	0.6	0.6	
Cordyline fruticosa	0.2	0.0	0.0	0.0	0.4	
Schinus terebinthifolius	1.3	2.0	0.4	0.4	0.0	
Syzygium cumini	2.7	2.0	1.5	0.0	0.0	
Grevillea robusta	1.3	0.0	0.0	0.0	0.0	
Aleurites moluccana	0.5	0.0	0.0	0.0	0.0	
Cocculus orbiculatus	0.2	0.0	0.0	0.0	0.0	

Table 4: All taxa intercepted (I) or anecdotally (A) observed over time during monitoring in the understory and/or canopy. *Taxon represented in restoration efforts prior to 2022 monitoring. **Taxon represented in rare plant reintroduction.

Native	Baseline	Year 0.5	Year 1	Year 2	Year 5.5	Non-native	Baseline	Year 0.5	Year 1	Year 2	Year 5.5
_Acacia koa_*	I	I	I	I	I	_Adiantum hispidulum_					A
Alyxia stellata	I	I	I	I	I	_Ageratina riparia_			A	A	
Asplenium caudatum		A	I		A	_Ageratum conyzoides_			A	A	I
Asplenium nidus	A			A	A	_Aleurites moluccana_	I	A	A		
_Bidens torta_*			A	I	I	_Andropogon virginicus_				A	
Bobea elatior	I	I	I	I	I	_Blechnum appendiculatum_		A	A		A
Carex wahuensis	I	I	I	I	I	_Cheilanthes viridis_					A
Cocculus orbiculatus	I		A		A	_Christella parasitica_			A	A	I
Coprosma foliosa	I		A	A	A	_Clidemia hirta_	I	A	I	A	I
Dianella sandwicensis					A	_Coffea arabica_	I	A	A	A	
Diospyros sandwicensis	I	I	I	I	I	_Conyza bonariensis_		A	A	A	I
_Dodonaea viscosa_*	I	I	I	I	I	_Cordyline fruticosa_	I	I	I	I	I
Doodia kunthiana	I	I	I	I	I	_Crassocephalum crepidoides_		I	A	A	A
Euphorbia multiformis	A	I	I	I	I	_Erectities valerianifolia_				A	
Hibiscus arnottianus subsp. _arnottianus_*					I	_Emilia sonchifolia_		A			I
_Kadua affinis_*	I	A	I	I	I	_Grevillea robusta_	I		A	A	A
Korthalsella complanata		A				_Lantana camera_			A		
Lepisorus thunbergianus	A	I	A	A	A	_Mesosphaerum pectinatum_			A		I
Melicope sp.	I	A		A	A	_Paspalum conjugatum_		A			
Metrosideros polymorpha	I	I	I	I	I	_Passiflora edulis_		A	I	A	
_Microlepia strigosa_*	I	I	I	I	I	_Passiflora suberosa_			A	A	I
Nephrolepis exaltata subsp. _hawaiiensis_	A		I		A	_Phlebodium aureum_	A	A	A	A	A
Nestegis sandwicensis	I	I	I	I	I	_Psidium cattleianum_	I	I	I	I	I
_Pipturis albidus_*		A	A	A	A	_Rivina humilis_			A		
Planchonella sandwicensis	A				A	_Rubus rosifolius_		A	A	A	
Psilotum nudum		A				_Schinus terebinthifolius_	I	I	I	I	A
Psychotria mariniana	I	I	I	I	I	_Sonchus oleraceus_			A		A
Psydrax odorata	I	I	I	I	I	_Spathodea campanulata_		A	A		
Scaevola gaudichaudiana			A	A	A	_Syzygium cumini_	I	I	I		
Schiedea obovata**					A	_Toona ciliata_		A	A	A	A
Sphenomeris chinensis			A	A		_Trema orientalis_		A		A	
Viola chamissoniana subsp. _tracheliifolia_			A								
Total native diversity	21	20	24	22	28	Total non-native diversity	9	18	24	19	18

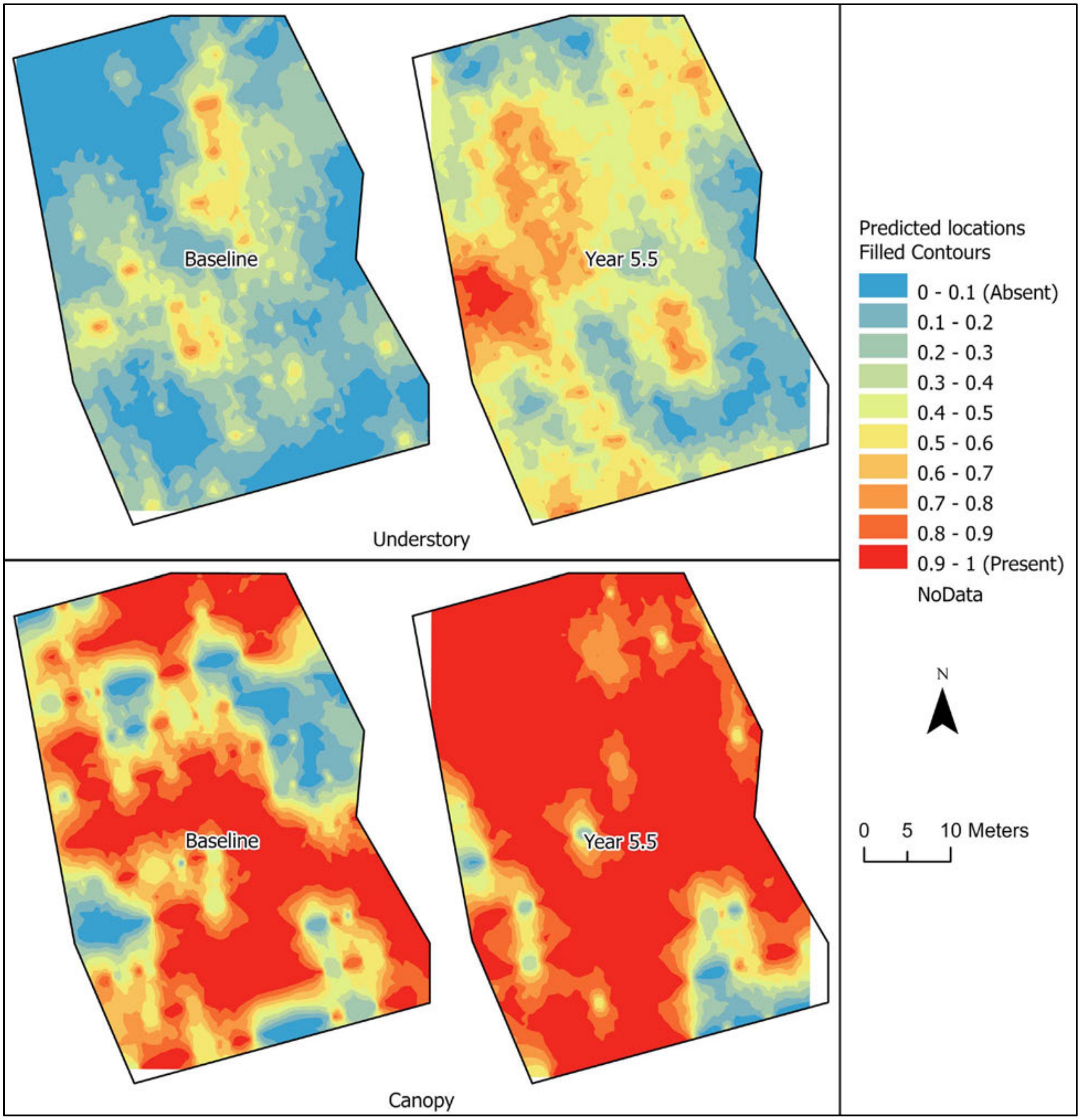

Figure 2: Ordinary kriging predicted locations of native understory and canopy cover during baseline and Year 5.5 monitoring. Probability of occurrence is scaled from zero (contours shown in blue, indicating absence) to one (contours shown in red, indicating presence).

Figure 3: Photopoint 1 images over time with views in each cardinal direction.

Figure 4: Photopoint 2 images over time with views in each cardinal direction.

Figure 5: Photopoint 3 images over time with views in each cardinal direction.

Figure 6: Photopoint 4 images over time with views in each cardinal direction.

DISCUSSION

Restoration efforts successfully altered vegetation at the Giant Ohia restoration site at Makaha by Year 5.5 such that the management goals of obtaining < 10% non-native and > 80% native canopy cover, and < 25% non-native and > 50% native understory cover, were all met with the exception of the native understory goal. Non-native canopy and understory goals were met and maintained following clearing efforts, and the native canopy goal was met by two years post-clearing. Though the goal was not met for the native understory by Year 5.5, considerable progress was made with the goal nearly met in association with expansion of existing vegetation and natural recruitment as well as growth and recruitment from outplants, seed sows and transplants.

As discussed previously (ANRPO 2017), while the significant reduction in non-native cover in the canopy and understory was anticipated, 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, as occurred at the Chipper Site at Kahanahaiki and at the Palikea North snail enclosure (ANRPO 2016, ANRPO 2019b). However, this was not the case. 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. However, the strategy of leaving dead trees standing may result in damage to native vegetation in the future, as limbs and trunks fall down over time, and could additionally pose a safety risk to staff. No substantial damage from fallen limbs was observed by Year 5.5. The low initial cover values for *A. stellata* in the canopy and understory at this site also likely minimized the impact to that species. Expansion of the native canopy cover was much faster than anticipated, particularly for typically slow growing trees *P. odorata* and *M. polymorpha*, and is testament to the potential for recovery of existing native forest canopy following removal of alien canopy. The doubling of native understory cover by Year 5.5 was informative for the potential for understory restoration under relatively low light conditions beneath existing native canopy. This bodes well for other restoration sites with existing native tree cover, such as the 3 Points snail enclosure, where expansion of understory cover was slow over the first two years (ANRPO 2021).

As many of the outplanted, sown or transplanted species were already naturally occurring on-site, are known to naturally recruit, and propagules were not individually tracked, the extent their presence was a direct result of active restoration efforts was not quantified. While most of the cover change in the understory was likely a result of recovery of in situ vegetation, largely attributable to the flushing out of *P. odorata*, there were anecdotal observation of some intercepted outplants, including *Hibiscus arnottianus* subsp. *arnottianus*. Any additional restoration inputs should be targeted to fill in remaining open, uncanopied areas, which are more prone to being weedy.

Weed ingress was expected to occur rapidly in response to increased light levels following alien canopy removal, and while there was higher weed diversity post-clearing, the ingress was slower than expected, and understory weed cover has been maintained well below the goal. The relatively high native canopy cover may have mitigated the change in light levels from non-native canopy removal, and helped facilitate maintenance of weeds in the understory at low levels, precluding weedy incursions in expansive light gaps which could otherwise occur following the removal of dense *P. cattleianum* canopy. The clearing was also timed to precede the *P. cattleianum* fruiting season and at a time when the *P. cattleianum* seed bank was depleted, as most seeds are not viable after six months (Uowolo and Denslow 2008), mitigating the potential for a flush of *P. cattleianum* seedlings post-clearing. It was anticipated that quarterly weeding would be necessary to maintain understory weeds, however weeding in alternating quarters has been sufficient.

Following the early positive results from restoration efforts, a new rare plant reintroduction population for *Schiedea obovata* (>200 outplants) was established at the site in 2019-2020 (ANRPO 2018). However, this population did not fare well, with only 13% of plants surviving in early 2022 (ANRPO 2022). Possible reasons for this could have been that the site was at the lower elevational extent of appropriate habitat for that taxon, and outplanting (typically timed to occur during the wet season) occurred late in season (March 2019 and May 2020).

The monitoring to date has been useful to track short term change in association with progress towards vegetation restoration goals. As all goals were either met, or nearly met, in Year 5.5, subsequent monitoring may be extended to occur on a five year (or greater) interval, to track longer term change in association with restoration. Monitoring is planned for Year 10, after which the interval will be re-evaluated.

The Giant Ohia restoration site has been an excellent example of how aggressive restoration of native vegetation in non-native dominated forests, in the form of non-native canopy elimination, weed maintenance, and inputs of common native plants (through outplanting, seed sows and transplants), has the potential to result in marked recovery of native forest. Results from efforts at this site compared with others having lower levels of native canopy cover (including the new Kahanahaiki snail enclosure, see Appendix 5-2, and the Palikea North snail enclosure, see Appendix 5-5) at the outset of restoration suggest that the amount of remnant native forest cover likely has a large influence on restoration outcomes, with respect to the timing and speed of understory and canopy recovery, as well as the degree of understory weed incursions and required maintenance.

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ARMY NATURAL RESOURCES PROGRAM ON OAHU
MONITORING PROGRAM

NATIVE WOODY VEGETATION MONITORING IN WEED CONTROL AREAS AT OHIKILOLO LOWER MANAGEMENT UNIT, 2022

INTRODUCTION

The Army Natural Resources Program on Oahu (ANRPO) conducts monitoring at Ohikilolo Lower Management Unit (MU) within the Makua Military Reservation (MMR) to assess cover change in native woody plant vegetation over time at the weed control areas (WCAs) surrounding the rare plant populations *Euphorbia celastroides* var. *kaenana* MMR-D (WCA Lower Ohikilolo-01 and-02) and *Hibiscus brackenridgei* subsp. *mokuleianus* MMR-A and MMR-F (WCA Lower Ohikilolo-03) using gigapixel panoramic imagery (www.gigapan.com) (Figure 1). These WCAs primarily consist of non-native grasses with scattered common and rare native shrubs. The surrounding habitat, dominated by invasive species *Leucaena leucocephala* and *Megathyrsus maximus*, is highly degraded and fire-prone. General ecosystem weeding within the WCAs has been ongoing since 2001, with intensive efforts to minimize fire fuel load from non-native grasses. Active restoration (outplanting) of common native plants within Lower Ohikilolo-02 and Lower Ohikilolo-03 began in 2016, and is ongoing (over 4200 total outplants) (Table 1). The majority of outplanted taxa consist of shrubs and trees. Active restoration has not begun at Lower Ohikilolo-01. The intent of active restoration efforts is to improve and protect the habitat at these rare plant populations and to minimize the labor required for weed control. Replacing non-native grasses with native shrubs improves habitat, reduces potential fire fuel around the rare plant populations, and potentially buffers the rare plant populations from fire. Weed control efforts controlling grass to mitigate potential fire fuel are extensive, and have required between 150 to 380 hours per year at the site over the last ten years. Expansive grass cutting/spraying is not conducive to native plant recruitment. While most ANRPO WCAs only have a small portion weeded within them annually, these Ohikilolo Lower WCAs are weeded in their entirety every year, and usually several times during the year. Most of the efforts at Ohikilolo Lower MU consist of controlling grasses and herbs. Woody invasives have relatively less recruitment here, and are controlled when seen. The objective of monitoring native woody vegetation cover at these locations is to document change in association with active restoration efforts along with natural recovery of *in situ* vegetation. Non-woody plants (grasses and herbs) were not monitored as cover of these plant types is much more variable than shrubs in association with rainfall levels, due to difficulties distinguishing native vs. non-native taxa in the imagery, and because the majority of outplants are woody taxa. Non-native cover was not monitored, as non-native shrub cover is presumed to be minimal as a result of weeding efforts, and weedy non-woody cover may vary greatly in association the amount of time since the last weeding effort as well as rainfall levels, and may be difficult to distinguish from native non-woody cover.

In June 2022 a fire burned through a large portion of Ohikilolo Lower MU, including WCA Lower Ohikilolo-03 in its entirety (Appendix ES-09). The majority of the vegetation at this WCA burned, though a patchy distribution of woody plants remained unburned or partially burned.

Figure 1: Locations of weed control areas Lower Ohikilolo-01, -02, and -03, showing GigaPan vantage points and areas with restoration actions prior to monitoring in 2022.

Table 1: Common native species outplanted over time in association with native vegetation restoration at Ohikilolo Lower MU. No common native species were outplanted at Lower Ohikilolo-01 prior to monitoring in 2022.

WCA	2016-01	2017-01	2017-10	2019-03	2019-04	2019-12	2020-11	2022-01	**Total**
Lower Ohikilolo-02									
Bidens cervicata						70	9		**79**
Chenopodium oahuense						84	250	98	**432**
Dodonaea viscosa	406	408				29	300	98	**1241**
Erythrina sandwicensis	64	102				80		80	**326**
Myoporum sandwicense	76	44							**120**
Santalum ellipticum						3			**3**
Scaevola taccada		129							**129**
Sida fallax							6		**6**
Total outplants	**546**	**683**				**266**	**565**	**276**	**2336**
Lower Ohikilolo-03									
Bidens cervicata				40		55			**95**
Chenopodium oahuense						100		69	**169**
Dodonaea viscosa			305	267				98	**670**
Eragrostis variabilis								22	**22**
Erythrina sandwicensis	32		220	110	15	120		55	**552**
Myoporum sandwicense			330	60	21				**411**
Sida fallax								3	**3**
Total outplants	**32**		**855**	**477**	**36**	**275**		**247**	**1922**

METHODS

Panoramic imagery was obtained in January 2016, March 2019, April 2022, and June 2022 (post-fire, for Lower Ohikilolo-03) from two vantage points (ANRPO 2016 and 2020) using a GigaPan Epic 100 robotic mount fitted with a Canon PowerShot SX30 IS digital camera in 2016 and 2022, and a GigaPan Epic Pro with a Canon PowerShot SX60 in 2019. Imagery was taken from the same vantage points in all years. Because of the higher focal length of the camera used in 2019, a greater number of images was obtained that year. Panoramas were stitched using GigaPan Stitch Version 2.1.0161. Imagery was taken following WCA weeding and grass spraying as possible, such that WCA boundaries would be distinguishable, and any shrubs (woody plants) identified within the WCAs were presumed native, though in 2019 weeding was less complete, and live grasses were still present. Differences in light levels as well as the presence of live grass in the 2019 imagery resulted in less contrast as compared to the 2016 and 2022 imagery. Imagery was taken during the same time of year (wet season), to mitigate seasonality influences, with the exception of the post-fire imagery in June 2022. In that panorama, vegetation cover may have been partially influenced by the dry summer conditions, though it is presumed that the fire was the predominant influence on cover change, given the magnitude of the burn which encompassed the entirety of the WCA.

Cover measurements were obtained from an arbitrary grid of sampled images within the panoramas, encompassing approximately 56% of each WCA. Using Adobe Photoshop, a line drawing tool was used to estimate the proportion of shrub cover in each sampled image. For Lower Ohikilolo-03 post-fire images, measurements were made of the proportion of live foliated shrub cover. Because some images partially included areas outside of WCA boundaries, only the portion of the image representing WCA area was used to obtain cover data. Cover measurements are from an oblique angle, and do not represent horizontal ground cover. While cover data derived from an angled perspective likely differs from horizontal measurements, trends in cover change over time may be effectively tracked with imagery taken from the same vantage point.

Cover change was assessed using logistic regression. Data were weighted by the proportion of the image that fell within the WCA area. Cover and standard error estimates for each WCA were derived from logistic regression model predictions. Statistical analyses were performed using the software R, Version 4.1.2 (R Core Team 2021).

Re-monitoring using GigaPan imagery occurs on a three-year interval. Re-monitoring should occur following weeding efforts as possible to ensure that shrubs in the imagery are native, and at the same time of year (wet season) to minimize seasonality influences. To better document native woody shrub survival post-fire at WCA Lower Ohikilolo-03, monitoring will additionally occur at the end of the next rainy season in 2023, as some plants impacted by the fire in 2022 may recover, while others may not survive.

RESULTS

Native woody cover increased significantly at all three WCAs between 2016 and 2022 (prior to the fire) (Table 2 and Figure 2). By 2022, native woody plants covered nearly a quarter of Lower Ohikilolo-01, over half of Lower Ohikilolo-02, and nearly half of Lower Ohikilolo-03 (pre-fire). Cover increases were gradual for Lower Ohikilolo-01 (where no common outplanting occurred) and Lower Ohikilolo-03 (where common outplanting mostly occurred later and in relatively fewer numbers), but fairly rapid for Lower Ohikilolo-02 (where common native outplanting occurred earlier in greater numbers). Following the fire, unburned native woody vegetation covered only one-sixteenth of Lower Ohikilolo-03. Expanded cover between 2016 and 2022 (pre-fire) is visible in the imagery for all three WCAs, particularly so in Lower Ohikilolo-02 imagery, while the devastating impacts from the fire are strikingly visible in the Lower Ohikilolo-03 post-fire imagery (Figures 3-5) and in one example of a photopoint (Figure 6) from that WCA.

Table 2: Native shrub cover over time at WCA Lower Ohikilolo-01, -02, and -03. Cover represented as proportional data. Cover and standard error estimates derived from logistic regression model predictions. Analysis of cover change does not include post-fire data.

WCA Lower-Ohikilolo-	2016			2019			2022 (pre-fire)			2022 (post-fire)			p*
	Cover	SE	n	Cover	SE	n	Cover	SE	n	Cover	SE	n	
01	0.133	0.012	11	0.188	0.010	24	0.239	0.016	12	NA			0.0000
02	0.218	0.014	12	0.405	0.011	25	0.546	0.021	12	NA			0.0000
03	0.375	0.011	24	0.411	0.007	49	0.456	0.014	19	0.063	0.007	17	0.0000

*Logistic regression for 2016, 2019, and 2022 (pre-fire).

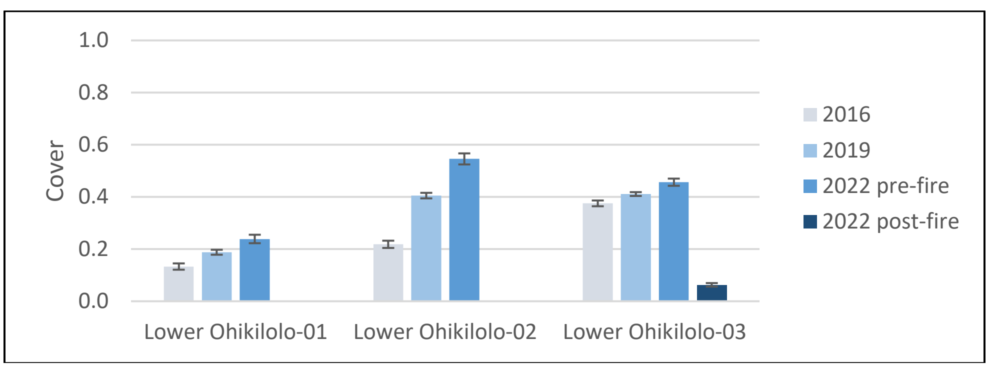

Figure 2: Native shrub cover over time at WCA Lower Ohikilolo-01, -02, and -03. Cover represented as proportional data. Error bars represent standard error. Cover and standard error estimates derived from logistic regression model predictions.

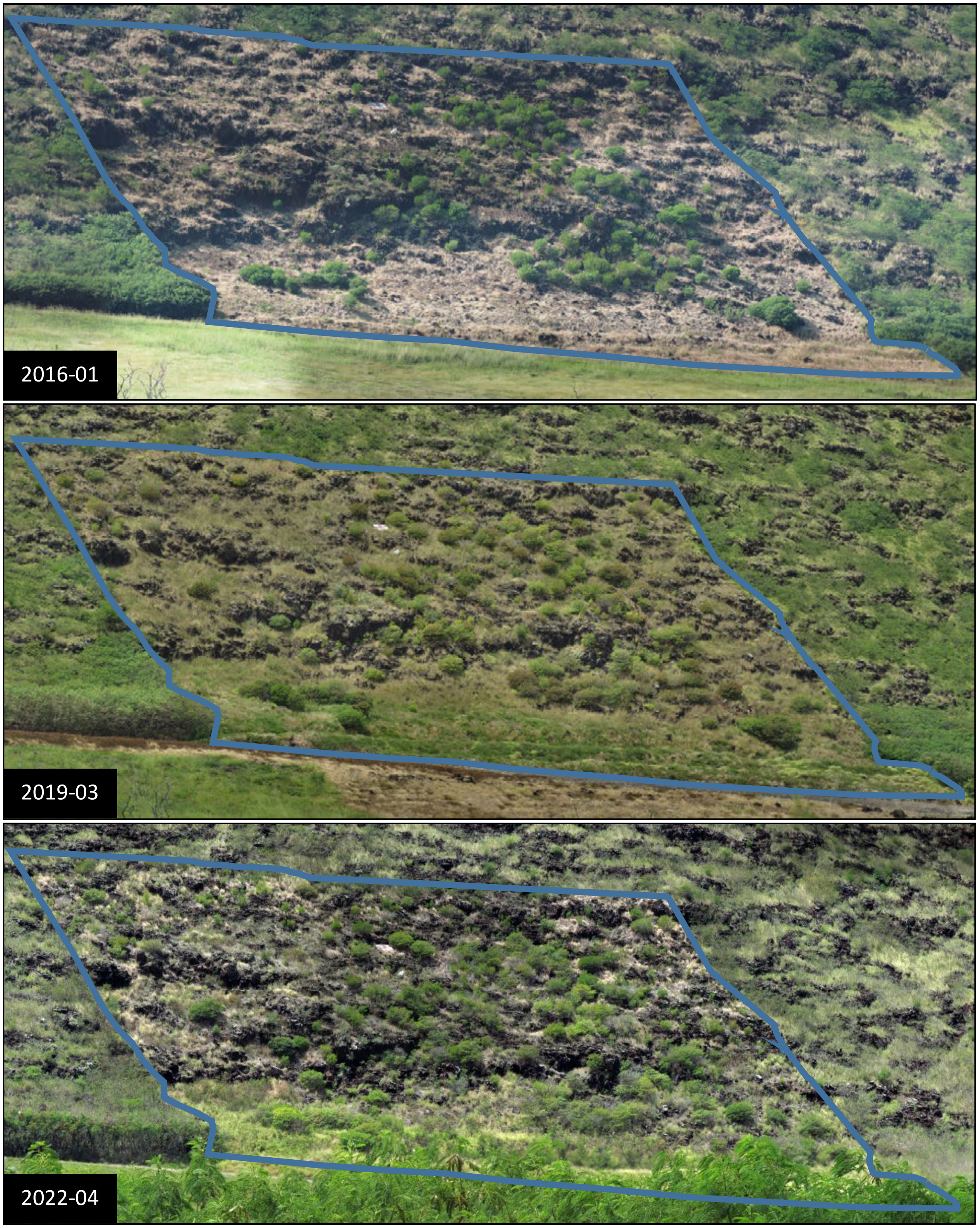

Figure 3: GigaPan imagery of WCA Lower Ohikilolo-01 over time.

Figure 4: GigaPan imagery of WCA Lower Ohikilolo-02 over time.

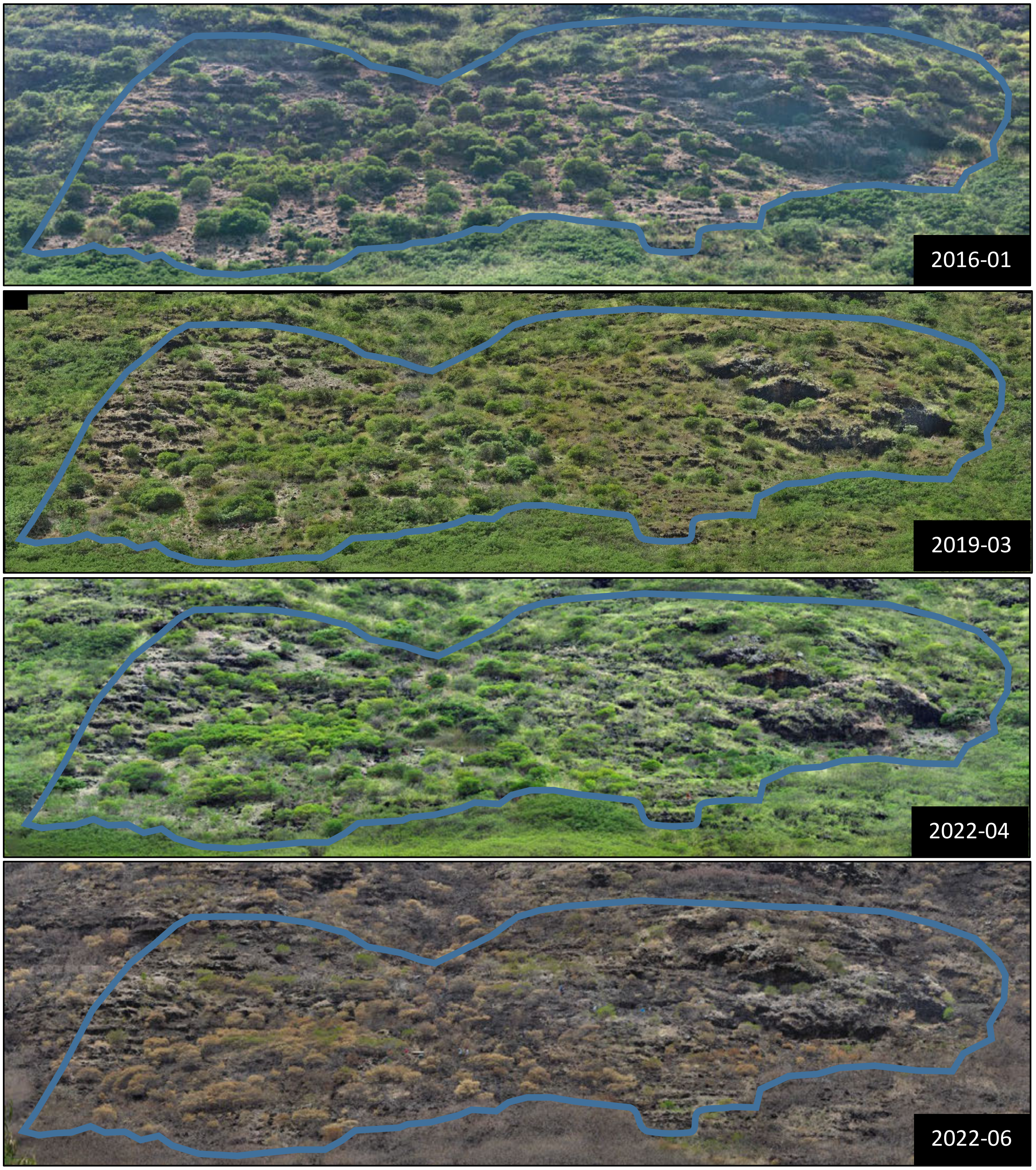

Figure 5: GigaPan imagery of WCA Lower Ohikilolo-03 over time.

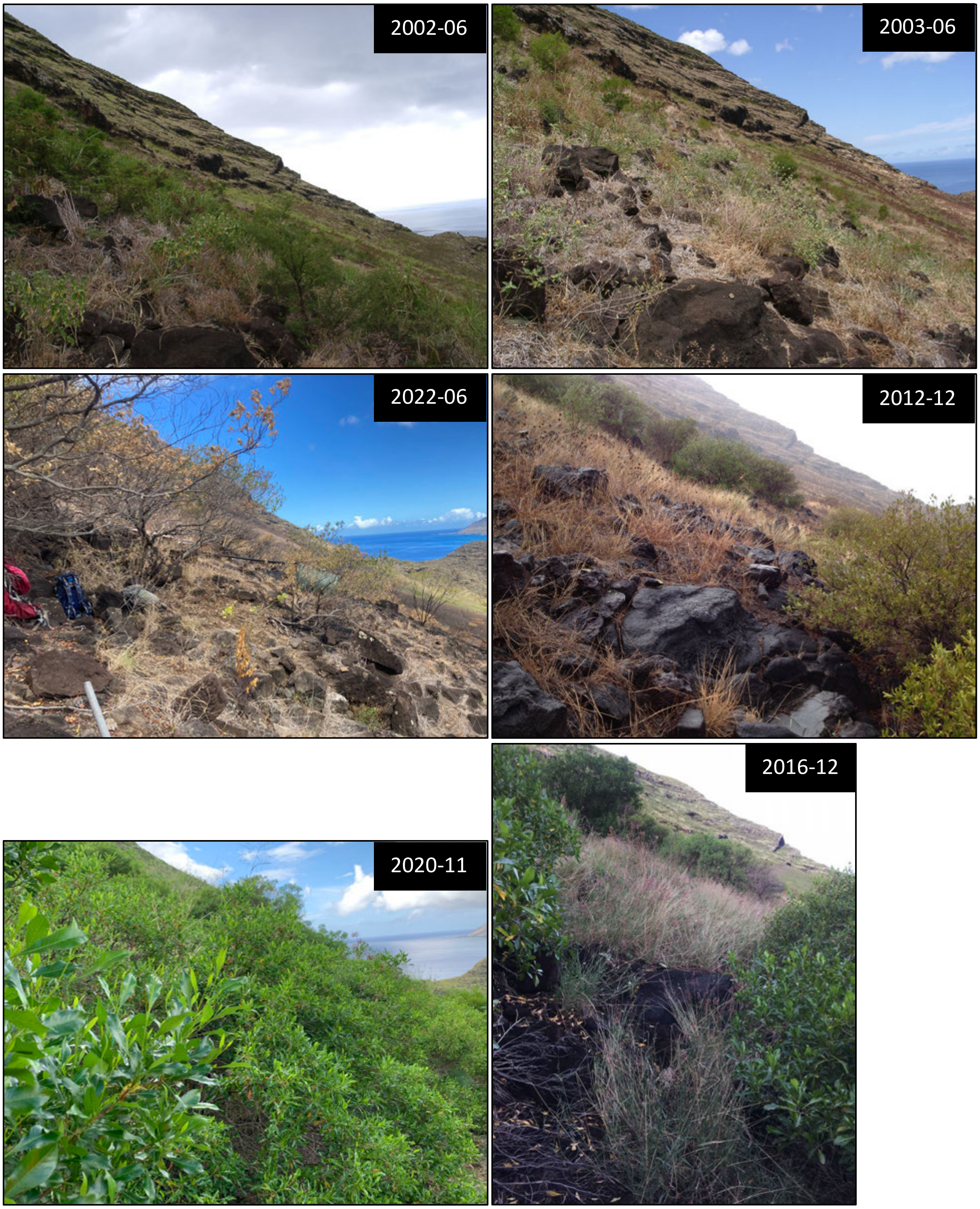

Figure 6. Example of a photopoint (Pole 8, at 270°) at Lower Ohikilolo-03 showing change in vegetation over time, clockwise from top left: in 2002, during the initial stages of vegetation management, with some woody invasives still present; in 2003, after removal of woody invasives, and showing remnant native plants; in 2012, showing natural recovery of native woody plants, in 2016, showing continued expansion of native vegetation (and when GigaPan monitoring was initiated); in 2020, showing substantial native vegetation infilling; and in June of 2022, following the fire, with most of the plants burned. Note that there are seasonality differences among the images.

DISCUSSION

The dramatic increase in native woody cover at Lower Ohikilolo-02 documented from GigaPan monitoring is a testament to the value and efficacy of intensive active restoration efforts (outplanting in large numbers) in dryland habitat. However, substantial natural recovery of native woody vegetation can also occur in conjunction with intensive weed management (removal of all woody weeds, regular grass control), as occurred at Lower Ohikilolo-01, where common native outplanting has not occurred. GigaPan monitoring has only tracked change over the last six years, following the initiation of common native outplanting, but intensive weed control efforts have been going on for over 20 years. During that time, a considerable amount of natural recovery has occurred, as exemplified by sample photopoint images for Lower Ohikilolo-03 (Figure 6). Unfortunately, this photopoint series also exemplifies the devastating impact from the most recent fire.

Makua has a considerable history of fires, including at least 325 fires between 1970 and 1998 (Beavers *et al.* 1999), and several more after live fire training ceased in 1998, including ones in 2003, 2005, 2006, 2007, 2009, 2010, 2018, 2020 and 2022 (two fires). The largest fires occurred in 1970 (one-third of the valley burned), in 1995 (two-thirds of the valley burned), and in 2003 (two-thirds of the valley burned). Among the fires since 1995, those directly impacting Ohikilolo Lower WCAs were limited to the ones in 1998 (burned the entirety of Lower Ohikilolo-01, and most of Lower Ohikilolo-02), 2003 (burned the edges of Lower Ohikilolo-01, but did not burn rare plants), and 2022 (burned the entirety of Lower Ohikilolo-03) (Figure 7). A few additional fires occurred directly adjacent to Lower Ohikilolo-01, -02 and -03, including ones in 1995 and 2005. Though fire records prior to 1995 were incomplete, the presence of charcoal in Lower Ohikilolo-03 observed in the early years of management for that WCA indicate that it had also burned previously. The lower native shrub cover at Lower Ohikilolo-01 and -02 compared to Lower Ohikilolo-03 at the start of GigaPan monitoring in 2016 could be a reflection of fire history, as fire had occurred more recently at Lower Ohikilolo-01 and -02 than at Lower Ohikilolo-03 at the outset of monitoring.

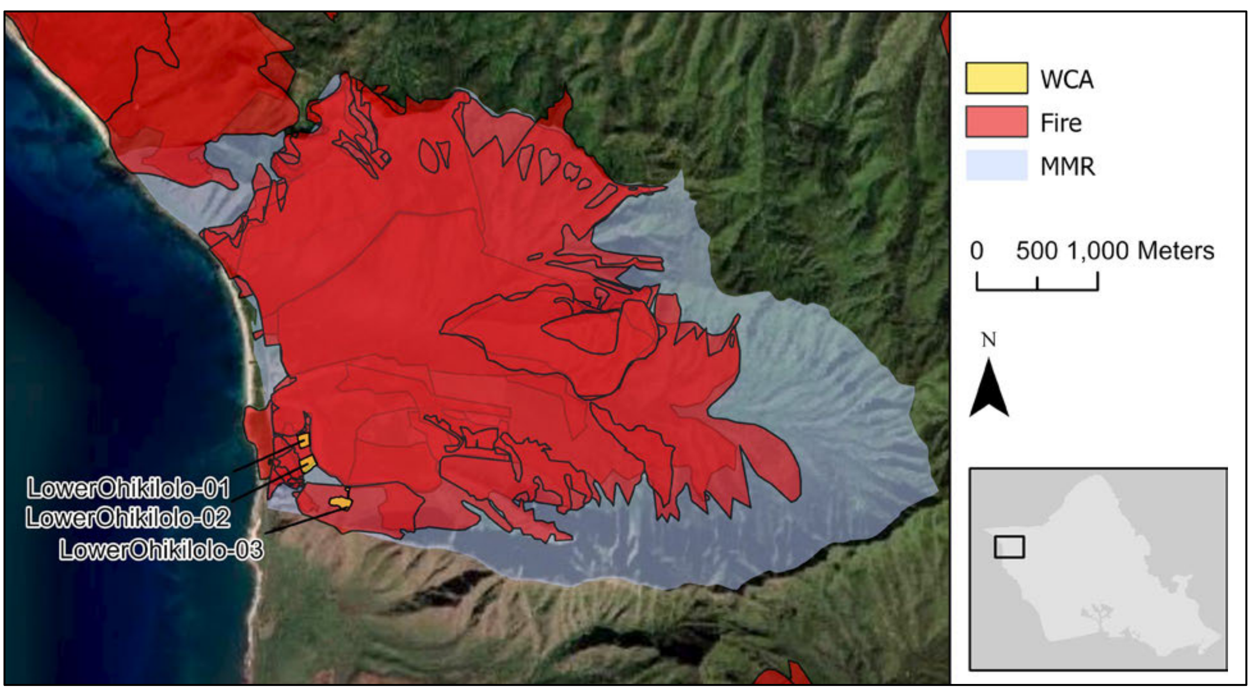

Figure 7. Fires in the vicinity of weed control areas Lower Ohikilolo-01, -02, and -03 since 1995.

The threat level for fire is high at Ohikilolo Lower MU, particularly in the dry season. *Megathyrsus maximus* and *L. leucocephala*, dominant in the areas surrounding the WCAs, both have a high fire index (Pacific Fire Exchange 2022), and contribute to the spread and intensity of fires. While live fire training (particularly tracers) was the primary source of fire between 1970 and 1998 (Beavers *et al.* 1999), subsequent potential sources of fire include the nearby the highway, beach, and heavily used hiking trails, where accidental or deliberate fires may occur and spread to the MU, as well as unexploded ordnance, which is the suspected cause for both of the fires in 2022, and two additional fires in recent decades. A number of Army fire risk reduction measures have been incorporated over the years, including firebreak roads, regular grass control along the inside edge of firebreak roads, the establishment of an Army wildland fire crew, and requirements to have helicopters on standby to fight fires. Within the WCAs, weed fuel control, aspects of topography, rocky substrate, and the presence of restored native taxa, all help mitigate the spread and intensity of fires. With the June 2022 fire, weed control, topography, rocky substrate, helicopter fire response, and the presence of restored native plants, provided a degree of protection to some rare plants and native vegetation within Lower Ohikilolo-03, and helicopter fire response prevented it from spreading to Lower Ohikilolo-01 and -02 (see fire report in Appendix ES-09). However, despite these factors, there is still the potential for substantial impacts from fires to managed areas before fires are completely controlled.

Fire frequency and intensity will likely increase in association with climate change. The frequency of fires should be taken into account with respect to rare plant management needs and strategies. Considerations of how best to move forward with the management of Lower Ohikilolo-03 is underway, summarized below:

- Consider whether or not to continue to manage the WCA in its entirety
    - In the long term, focus management efforts in the more immediate areas around the surviving rare plants?
    - Limit the management in the remainder of the WCA to fuel suppression?
- Consider placement of future rare plant outplants
    - Plant in proximity to surviving plants?
    - Plant under rocky cliffs, which appeared to offer some protection from fire?
- Consider alternative sites for rare plant reintroductions that are less fire prone
    - Kaluakauila experimental outplants are doing well with limited management
    - 50 additional outplants are planned which may serve as a backup population
    - Consider additional locations outside of the typical grassland habitat where *H. brackenridgei* subsp. *mokuleianus* is currently found, for example, shrubland ridges in the back of Makua Valley.
- Consider firebreak strategies
    - Green firebreaks, with native and/or non-native plants? Experimental outplantings of potential taxa to test survivorship are planned. If non-native taxa are used, they should have low weed risk assessment scores. Layout strategies to be explored.
    - Aerial application of herbicide? At what frequency?
    - Aerial application of fire retardant? At what frequency?
- Consider appropriate common native outplant taxa and appropriate placement in relation to rare plants

Similar considerations should be made for Lower Ohikilolo-01 and -02. In the meantime, management actions will continue as planned for these WCAs. At Lower Ohikilolo-03, weed control strategies will mainly focus on grass control, as this will facilitate finding seedlings that emerge post-fire. The full extent of the damage from the fire will be assessed over the next year, with monitoring of *H. brackenridgei* subsp. *mokuleianus* survival and recruitment, and GigaPan monitoring of the WCA to better document native woody shrub survival post-fire at the end of the next rainy season in 2023, as some plants impacted by the fire in 2022 may recover, while others may not survive.

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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 2021	Total Immature 2021	Total Seedling 2021	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	0	1	0	**0**	**0**	**0**	0	0	0	0	0	0	2021-09-07	Last known tree died
Makua	Manage for stability	15	0	0	4	0	0	**4**	**0**	**0**	4	0	0	0	0	0	2017-02-14	No monitoring in the last year
South Mohiakea	Genetic Storage	16	1	0	1	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2022-05-17	Last known tree died
West Makaleha	Genetic Storage	40	4	0	2	0	0	**1**	**0**	**0**	1	0	0	0	0	0	2022-05-11	Thorough monitoring in the last year showed a decline
	In Total:	73	11	0	7	1	0	**5**	**0**	**0**	5	0	0	0	0	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 2021	Total Immature 2021	Total Seedling 2021	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	2	0	0	**2**	**0**	**0**	2	0	0	0	0	0	2018-03-15	No monitoring in the last year
Makaha	Manage for stability	75	0	2	7	0	0	**6**	**0**	**0**	6	0	0	0	0	0	2022-05-04	Small changes were noted during monitoring 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 plants present since 2015
	Out Total:	141	3	2	9	0	0	**8**	**0**	**0**	8	0	0	0	0	0		
	Total for Taxon:	214	14	2	16	1	0	**13**	**0**	**0**	13	0	0	0	0	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 2021	Total Immature 2021	Total Seedling 2021	**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	254	109	0	**275**	**150**	**0**	55	12	0	220	138	0	2022-07-25	More plants were added to the outplanting site
Kuaokala	Genetic Storage				1	3	0	**0**	**0**	**0**	0	0	0	0	0	0	2022-06-15	Thorough monitoring in the last year showed a decline
	In Total:	210	66	0	255	112	0	**275**	**150**	**0**	55	12	0	220	138	0		

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 2021	Total Immature 2021	Total Seedling 2021	**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	171	21	3	**167**	**59**	**0**	65	2	0	102	57	0	2022-03-16	More plants were added to the outplanting site
Makaha and Waianae Kai	Manage for stability	9	3	0	129	17	0	**71**	**3**	**6**	6	0	0	65	3	6	2022-09-22	Thorough monitoring in the last year showed a decline
South Huliwai	Genetic Storage	27	0	0	42	2	0	**32**	**5**	**0**	32	5	0	0	0	0	2021-07-13	Thorough monitoring in the last year showed a decline in mature plants
	Out Total:	56	3	0	342	40	3	**270**	**67**	**6**	103	7	0	167	60	6		
	Total for Taxon:	266	69	0	597	152	3	**545**	**217**	**6**	158	19	0	387	198	6		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Cyanea grimesiana subsp. obatae

Target # of Matures: 100 # MFS PU Met Goal: 1 of 4

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	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	44	96	0	**63**	**62**	**0**	4	0	0	59	62	0	2021-12-20	A thorough census has shown immature plants transition into mature plants
	In Total:	22	24	0	44	96	0	**63**	**62**	**0**	4	0	0	59	62	0		

Action Area: Out

TaxonName: Cyanea grimesiana subsp. obatae

Target # of Matures: 100 # MFS PU Met Goal: 1 of 4

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	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	26	27	0	**20**	**25**	**0**	3	1	0	17	24	0	2022-08-30	Thorough monitoring in the last year showed a decline
Makaha	Genetic Storage				15	229	0	**15**	**229**	**0**	0	0	0	15	229	0	2018-12-17	No monitoring in the last year
North branch of South Ekahanui	Manage reintroduction for stability	5	0	0	60	49	0	**60**	**38**	**0**	0	0	0	60	38	0	2022-01-26	Small changes were noted during monitoring in the last year
Palikea (South Palawai)	Manage for stability	3	60	0	917	2	0	**662**	**23**	**2**	12	0	0	650	23	2	2022-01-06	Thorough monitoring in the last year showed a decline
	Out Total:	8	60	0	1018	307	0	**757**	**315**	**2**	15	1	0	742	314	2		
	Total for Taxon:	30	84	0	1062	403	0	**820**	**377**	**2**	19	1	0	801	376	2		

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 2021	Total Immature 2021	Total Seedling 2021	**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	68	57	0	**56**	**31**	**0**	14	0	0	42	31	0	2022-07-14	Thorough monitoring in the last year showed a decline
Pahole	Manage for stability	114	0	0	57	149	0	**85**	**149**	**10**	79	136	10	6	13	0	2022-07-26	A thorough census led to more plants being discovered
	In Total:	180	0	0	125	206	0	**141**	**180**	**10**	93	136	10	48	44	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 2021	Total Immature 2021	Total Seedling 2021	**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	21	8	0	**19**	**2**	**0**	5	0	0	14	2	0	2022-09-20	Small changes were noted during monitoring in the last year
	Out Total:	4	0	0	21	8	0	**19**	**2**	**0**	5	0	0	14	2	0		
	Total for Taxon:	184	0	0	146	214	0	**160**	**182**	**10**	98	136	10	62	46	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 2021	Total Immature 2021	Total Seedling 2021	**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	20	231	0	**18**	**135**	**0**	0	0	0	18	135	0	2022-04-28	A thorough census has shown a substantial decline in the immature age class
Kaluaa	Manage reintroduction for stability				0	28	0	**0**	**85**	**0**	0	0	0	0	85	0	2022-02-08	More plants were added to the outplanting site
Pahole to Kapuna	Genetic Storage	31	139	0	42	26	2	**33**	**23**	**3**	0	0	0	33	23	3	2021-12-22	Thorough monitoring in the last year showed a decline
Palikea	Manage reintroduction for stability				18	308	0	**19**	**277**	**0**	0	0	0	19	277	0	2021-11-09	Small changes were noted during monitoring in the last year
	In Total:	34	288	0	80	593	2	**70**	**520**	**3**	0	0	0	70	520	3		

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 2021	Total Immature 2021	Total Seedling 2021	**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				39	75	0	**58**	**13**	**0**	0	0	0	58	13	0	2021-10-12	More outplants matured this year; but populations declined slightly overall
	Out Total:				39	75	0	**58**	**13**	**0**	0	0	0	58	13	0		
	Total for Taxon:	34	288	0	119	668	2	**128**	**533**	**3**	0	0	0	128	533	3		

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 2021	Total Immature 2021	Total Seedling 2021	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	13	39	6	**29**	**45**	**12**	29	45	12	0	0	0	2021-10-12	A thorough census led to more plants being discovered
Kawaiiki (Koolaus)	Manage for stability	50	0	0	2	19	1	**2**	**19**	**1**	2	19	1	0	0	0	2016-06-23	No monitoring in the last year
Opaeula (Koolaus)	Manage for stability	21	5	0	29	55	3	**34**	**74**	**11**	34	74	11	0	0	0	2022-04-20	A thorough census led to more plants being discovered
Pahole to West Makaleha	Manage for stability	300	0	0	524	1105	110	**636**	**1786**	**73**	636	1786	73	0	0	0	2022-09-13	
	In Total:	423	50	0	568	1218	120	**701**	**1924**	**97**	701	1924	97	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 2021	Total Immature 2021	Total Seedling 2021	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	571	1218	120	**704**	**1924**	**97**	704	1924	97	0	0	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Delissea waianaeensis

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 2021	Total Immature 2021	Total Seedling 2021	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	72	2	3	**109**	**34**	**0**	5	0	0	104	34	0	2022-05-09	More plants were added to the outplanting site
Kaluakauila	Manage reintroduction for storage				1	0	0	**1**	**0**	**0**	0	0	0	1	0	0	2022-06-20	No changes observed in the last year
Kapuna	Manage reintroduction for storage				83	1	0	**83**	**1**	**0**	0	0	0	83	1	0	2021-06-16	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	11	0	19	**19**	**4**	**0**	19	4	0	0	0	0	2022-05-17	A thorough census has shown immature plants transition into mature plants
	In Total:	37	1	0	168	3	22	**213**	**39**	**0**	25	4	0	188	35	0		

Population Unit Status - Makua Implementation Plan

Action Area: Out

TaxonName: Delissea waianaeensis

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 2021	Total Immature 2021	Total Seedling 2021	**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	49	58	0	**68**	**57**	**0**	0	0	0	68	57	0	2022-04-11	A thorough census has shown immature plants transition into mature plants
Kaluaa	Manage for stability	44	0	0	189	81	0	**165**	**127**	**0**	4	0	0	161	127	0	2022-07-05	More outplants were added to the outplanting site, but mature age class declined
Kealia	Genetic Storage	0	7	0	2	1	0	**2**	**1**	**1**	2	1	1	0	0	0	2022-05-31	Small changes were noted during monitoring in the last year
Manuwai	Manage reintroduction for stability				43	5	0	**36**	**4**	**0**	0	0	0	36	4	0	2022-05-04	Thorough monitoring in the last year showed a decline
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	307	175	0	**295**	**219**	**1**	30	31	1	265	188	0		
	Total for Taxon:	96	52	0	475	178	22	**508**	**258**	**1**	55	35	1	453	223	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Dubautia herbstobatae

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 2021	Total Immature 2021	Total Seedling 2021	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				225	4	0	**225**	**4**	**0**	225	4	0	0	0	0	2021-06-29	No monitoring in the last year
Ohikilolo Makai	Manage for stability	700	0	0	60	0	0	**48**	**0**	**0**	48	0	0	0	0	0	2021-07-01	Thorough monitoring in the last year showed a decline
Ohikilolo Mauka	Manage for stability	1300	0	0	109	14	0	**125**	**14**	**0**	125	14	0	0	0	0	2022-06-16	A thorough census led to more plants being discovered
	In Total:	2070	0	0	464	18	0	**468**	**18**	**0**	468	18	0	0	0	0		

Action Area: Out

TaxonName: Dubautia herbstobatae

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 2021	Total Immature 2021	Total Seedling 2021	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 plants observed at this site since 2001
Makaha	Manage for stability	0	0	0	21	194	0	**21**	**194**	**0**	3	9	0	18	185	0	2021-06-30	No monitoring in the last year
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	31	198	0	**31**	**198**	**0**	13	13	0	18	185	0		
	Total for Taxon:	2076	0	0	495	216	0	**499**	**216**	**0**	481	31	0	18	185	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 2021	Total Immature 2021	Total Seedling 2021	**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	1	0	0	**1**	**0**	**0**	1	0	0	0	0	0	2018-11-28	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	65	2	0	**66**	**0**	**0**	66	0	0	0	0	0	2022-07-28	Small changes were noted during 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	133	15	0	**133**	**0**	**0**	133	0	0	0	0	0	2021-11-18	Small changes were noted during monitoring in the last year
	In Total:	420	15	0	325	56	0	**326**	**39**	**0**	326	39	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 2021	Total Immature 2021	Total Seedling 2021	**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	9	0	0	**1**	**0**	**0**	1	0	0	0	0	0	2022-06-30	Thorough monitoring in the last year showed a decline
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	36	2	3	**36**	**2**	**3**	36	2	3	0	0	0	2022-08-25	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	959	276	3	**951**	**276**	**3**	951	276	3	0	0	0		
	Total for Taxon:	858	26	0	1284	332	3	**1277**	**315**	**3**	1277	315	3	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 2021	Total Immature 2021	Total Seedling 2021	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	69	51	0	**71**	**29**	**2**	4	1	0	67	28	2	2021-12-08	More outplants matured this year; but populations declined slightly overall
Manuwai	Manage reintroduction for stability				0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		This outplanting has not started
	In Total:	170	0	0	69	51	0	**71**	**29**	**2**	4	1	0	67	28	2		

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 2021	Total Immature 2021	Total Seedling 2021	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				12	37	0	**17**	**27**	**0**	0	0	0	17	27	0	2021-10-19	A thorough census has shown immature plants transition into mature plants
Makaha	Manage reintroduction for storage				2	1	0	**2**	**0**	**0**	0	0	0	2	0	0	2021-08-02	Small changes were noted during monitoring in the last year
	Out Total:				14	38	0	**19**	**27**	**0**	0	0	0	19	27	0		
	Total for Taxon:	170	0	0	83	89	0	**90**	**56**	**2**	4	1	0	86	55	2		

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 2021	Total Immature 2021	Total Seedling 2021	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	9	56	0	**9**	**50**	**0**	5	0	0	4	50	0	2022-07-26	Small changes were noted during monitoring in the last year
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	16	56	0	**16**	**50**	**0**	12	0	0	4	50	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 2021	Total Immature 2021	Total Seedling 2021	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	7	22	0	**12**	**11**	**0**	7	0	0	5	11	0	2022-09-13	A thorough census has shown immature plants transition into mature plants
Manuwai	Manage reintroduction for stability	0	0	0	0	1	0	**0**	**1**	**0**	0	0	0	0	1	0	2022-05-04	No changes observed in the last year
Mt. Kaala NAR	Genetic Storage	4	0	0	2	0	0	**2**	**0**	**0**	2	0	0	0	0	0	2018-04-26	No monitoring in the last year
Nanakuli, south branch	Genetic Storage	1	0	0	1	0	0	**1**	**0**	**0**	1	0	0	0	0	0	2010-10-19	No monitoring in the last year
Waianae Kai	Genetic Storage	1	0	0	1	0	0	**1**	**0**	**0**	1	0	0	0	0	0	2022-06-29	No changes observed in the last year
	Out Total:	19	0	0	17	23	0	**22**	**12**	**0**	17	0	0	5	12	0		
	Total for Taxon:	31	26	0	33	79	0	**38**	**62**	**0**	29	0	0	9	62	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Gouania vitifolia

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 1

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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				2	55	0	**5**	**50**	**0**	4	3	0	1	47	0	2022-05-31	A thorough census led to more plants being discovered
	In Total:				2	55	0	**5**	**50**	**0**	4	3	0	1	47	0		

Action Area: Out

TaxonName: Gouania vitifolia

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 1

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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	Genetic Storage				1	1	0	**0**	**0**	**0**	0	0	0	0	0	0	2022-04-06	No plants alive at site
	Out Total:				1	1	0	**0**	**0**	**0**	0	0	0	0	0	0		
	Total for Taxon:				3	56	0	**5**	**50**	**0**	4	3	0	1	47	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 2021	Total Immature 2021	Total Seedling 2021	**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				0	9	0	**0**	**20**	**0**	0	0	0	0	20	0	2022-02-15	More plants were added to the outplanting site
Pahole NAR	Manage reintroduction for stability	8	0	0	2	0	0	**1**	**0**	**0**	0	0	0	1	0	0	2022-05-24	Small changes were noted during monitoring in the last year
	In Total:	8	0	0	2	9	0	**1**	**20**	**0**	0	0	0	1	20	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 2021	Total Immature 2021	Total Seedling 2021	**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	41	0	**14**	**26**	**0**	3	1	0	11	25	0	2022-03-15	More outplants matured this year; but populations declined slightly overall
Pualii	Manage reintroduction for stability				28	14	0	**23**	**9**	**0**	0	0	0	23	9	0	2022-04-13	Thorough monitoring in the last year showed a decline
Waianae Kai	Genetic Storage	9	0	1	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2018-04-16	No plants at this site since 2017
	Out Total:	22	0	1	39	55	0	**37**	**35**	**0**	3	1	0	34	34	0		
	Total for Taxon:	30	0	1	41	64	0	**38**	**55**	**0**	3	1	0	35	54	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Hibiscus brackenridgei subsp. mokuleianus

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 2021	Total Immature 2021	Total Seedling 2021	**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				62	17	0	**59**	**73**	**9**	14	6	0	45	67	9	2022-04-27	A thorough census led to more plants being discovered
Makua	Manage for stability	4	3	0	91	78	0	**30**	**29**	**0**	5	7	0	25	22	0	2022-06-21	Thorough monitoring in the last year showed a decline
	In Total:	4	3	0	153	95	0	**89**	**102**	**9**	19	13	0	70	89	9		

Action Area: Out

TaxonName: Hibiscus brackenridgei subsp. mokuleianus

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 2021	Total Immature 2021	Total Seedling 2021	**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	48	37	1	**57**	**42**	**16**	0	5	4	57	37	12	2022-05-18	More plants were added to the outplanting site
Manuwai	Manage reintroduction for stability				26	50	0	**38**	**100**	**0**	0	0	0	38	100	0	2022-06-21	More plants were added to the outplanting site
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	123	172	10	**144**	**227**	**25**	49	90	13	95	137	12		
	Total for Taxon:	11	13	0	276	267	10	**233**	**329**	**34**	68	103	13	165	226	21		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Kadua degeneri subsp. degeneri

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 2021	Total Immature 2021	Total Seedling 2021	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	58	11	41	**46**	**28**	**0**	46	28	0	0	0	0	2021-08-25	Thorough monitoring in the last year showed a decline
Makaha to Ohikilolo	Manage reintroduction for stability				52	223	0	**93**	**116**	**0**	0	0	0	93	116	0	2022-01-20	More outplants matured this year; but populations declined slightly overall
	In Total:	161	0	0	110	234	41	**139**	**144**	**0**	46	28	0	93	116	0		

Action Area: Out

TaxonName: Kadua degeneri subsp. degeneri

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 2021	Total Immature 2021	Total Seedling 2021	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	73	75	5	**41**	**57**	**4**	16	13	2	25	44	2	2022-03-15	Thorough monitoring in the last year showed a decline
Central Makaleha and West Branch of East Makaleha	Manage for stability	47	0	0	7	9	0	**6**	**3**	**0**	6	3	0	0	0	0	2021-09-22	Thorough monitoring in the last year showed a decline
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 plants at this site
	Out Total:	117	0	0	80	84	5	**47**	**60**	**4**	22	16	2	25	44	2		
	Total for Taxon:	278	0	0	190	318	46	**186**	**204**	**4**	68	44	2	118	160	2		

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 2021	Total Immature 2021	Total Seedling 2021	**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	82	18	3	**79**	**18**	**0**	43	13	0	36	5	0	2022-04-05	Small changes were noted during monitoring in the last year
	In Total:	66	0	0	82	18	3	**79**	**18**	**0**	43	13	0	36	5	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 2021	Total Immature 2021	Total Seedling 2021	**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				135	46	0	**123**	**22**	**3**	0	0	0	123	22	3	2022-05-25	Thorough monitoring in the last year showed a decline
Halona	Manage for stability	64	0	0	38	135	0	**32**	**126**	**0**	15	4	0	17	122	0	2022-09-07	No census taken in the last year
	Out Total:	64	0	0	173	181	0	**155**	**148**	**3**	15	4	0	140	144	3		
	Total for Taxon:	130	0	0	255	199	3	**234**	**166**	**3**	58	17	0	176	149	3		

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 2021	Total Immature 2021	Total Seedling 2021	**Total Mature Current**	**Total Immature Current**	**Total Seedling Current**	Wild Mature Current	Wild Immature Current	Wild Seedling Current	Outplanted Mature Current	Outplanted Immature Current	Outplanted Seedling Current	PU LastObs Date	Population Trend Notes
Kahanahaiki	Genetic Storage	300	0	0	1	0	0	**1**	**0**	**0**	1	0	0	0	0	0	2016-09-20	No monitoring in the last year
Kaluakauila	Genetic Storage	113	0	0	4	80	0	**4**	**80**	**0**	4	80	0	0	0	0	2011-03-07	No monitoring in the last year
Keawaula	Genetic Storage	20	20	0	200	50	0	**200**	**50**	**0**	200	50	0	0	0	0	2016-03-30	No monitoring in the last year
Ohikilolo	Manage for stability	2008	1	0	570	11	0	**570**	**11**	**0**	570	11	0	0	0	0	2018-01-30	No monitoring in the last year
	In Total:	2441	21	0	775	141	0	**775**	**141**	**0**	775	141	0	0	0	0		

Action Area: Out

TaxonName: Melanthera tenuifolia

Target # of Matures: 50 # MFS PU Met Goal: 3 of 3

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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	1721	411	274	**1721**	**411**	**274**	1721	411	274	0	0	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Neraudia angulata

Target # of Matures: 100 # MFS PU Met Goal: 0 of 4

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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				37	0	5	**19**	**19**	**0**	0	0	0	19	19	0	2022-06-07	More plants were added to the outplanting site
Kapuna	Genetic Storage	1	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2016-05-16	No plants observed at this site since 2008
Makua	Manage for stability	29	0	22	45	4	0	**44**	**80**	**0**	20	4	0	24	76	0	2022-03-21	More plants were added to the outplanting site
Punapohaku	Genetic Storage				2	0	0	**2**	**0**	**0**	2	0	0	0	0	0	2016-05-23	No monitoring in the last year
	In Total:	30	0	22	84	4	5	**65**	**99**	**0**	22	4	0	43	95	0		

Action Area: Out

TaxonName: Neraudia angulata

Target # of Matures: 100 # 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 2021	Total Immature 2021	Total Seedling 2021	**Total Mature Current**	**Total Immature Current**	**Total Seedling Current**	Wild Mature Current	Wild Immature Current	Wild Seedling Current	Outplanted Mature Current	Outplanted Immature Current	Outplanted Seedling Current	PU LastObs Date	Population Trend Notes
Halona	Genetic Storage	15	0	0	4	10	1	**4**	**10**	**1**	4	10	1	0	0	0	2016-08-15	No monitoring in the last year
Leeward Puu Kaua	Genetic Storage	3	0	0	9	0	0	**9**	**0**	**0**	9	0	0	0	0	0	2006-11-21	No monitoring in the last year
Makaha	Manage for stability (backup site)	56	14	0	12	9	3	**29**	**25**	**0**	3	8	0	26	17	0	2022-04-21	More plants were added to the outplanting site
Manuwai	Manage for stability	12	0	0	14	78	0	**18**	**68**	**0**	0	4	0	18	64	0	2022-06-21	More plants were added to the outplanting site
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	A new census was initiated but not yet completed
	Out Total:	111	39	0	63	99	4	**84**	**105**	**1**	36	24	1	48	81	0		
	Total for Taxon:	141	39	22	147	103	9	**149**	**204**	**1**	58	28	1	91	176	0		

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 2021	Total Immature 2021	Total Seedling 2021	**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	28	1	0	**28**	**1**	**0**	28	1	0	0	0	0	2017-05-31	No monitoring in the last year
Kaluakauila	Manage for stability	200	0	0	39	71	0	**43**	**64**	**0**	43	64	0	0	0	0	2021-10-14	More outplants matured this year; but populations declined slightly overall
Keaau	Genetic Storage	21	31	0	20	31	0	**20**	**31**	**0**	20	31	0	0	0	0	2016-09-07	No monitoring in the last year
Keawaula	Genetic Storage	200	30	0	109	22	0	**109**	**22**	**0**	109	22	0	0	0	0	2017-08-03	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 census taken 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 census taken in the last year
	In Total:	834	93	0	425	205	0	**429**	**198**	**0**	422	198	0	7	0	0		

Population Unit Status - Makua Implementation Plan

Action Area: Out

TaxonName: Nototrichium humile

Target # of Matures: 25 # MFS PU Met Goal: 4 of 4

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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
Kapuna and Keawapilau	Genetic Storage	9	1	0	4	0	0	**4**	**0**	**0**	4	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				104	0	0	**101**	**1**	**0**	0	0	0	101	1	0	2022-06-21	Small changes were noted during 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 plants at this site
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	53	135	0	**53**	**135**	**0**	53	135	0	0	0	0	2018-09-18	A new census was initiated but not yet completed
	Out Total:	446	7	0	226	141	0	**223**	**142**	**0**	122	141	0	101	1	0		
	Total for Taxon:	1280	100	0	651	346	0	**652**	**340**	**0**	544	339	0	108	1	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 2021	Total Immature 2021	Total Seedling 2021	**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 plants observed at this site since 2009
Pahole	Manage reintroduction for stability	10	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2010-08-10	No plants observed at this site since 2009
Palikea Gulch	Genetic Storage	10	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2004-09-01	No plants at this site
	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 2021	Total Immature 2021	Total Seedling 2021	**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 plants observed at this site since 2014
Manuwai	Manage reintroduction for stability	0	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2015-03-18	No plants observed at this site since 2014
Waianae Kai	Genetic Storage	6	2	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2004-01-01	No plants at this site
	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: 1 of 4

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	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	28	43	0	**63**	**75**	**0**	63	75	0	0	0	0	2021-11-17	A thorough census led to more plants being discovered
Ohikilolo	Manage for stability	14	0	0	1	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2021-07-21	No plants alive at site
Pahole	Genetic Storage	12	0	0	3	10	0	**0**	**3**	**0**	0	3	0	0	0	0	2021-08-25	Thorough monitoring in the last year showed a decline
	In Total:	46	10	0	32	53	0	**63**	**78**	**0**	63	78	0	0	0	0		

Action Area: Out

TaxonName: Plantago princeps var. princeps

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 2021	Total Immature 2021	Total Seedling 2021	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	1	7	0	**1**	**7**	**0**	1	7	0	0	0	0	2021-05-11	No census taken in the last year
Konahuanui	Manage for stability				32	10	1	**36**	**5**	**3**	36	5	3	0	0	0	2021-09-21	A thorough census led to more plants being discovered
North Palawai	Genetic Storage	32	0	0	1	0	0	**1**	**0**	**0**	1	0	0	0	0	0	2018-02-08	No census taken in the last year
Waieli	Manage reintroduction for storage				0	2	0	**0**	**2**	**0**	0	0	0	0	2	0	2022-04-11	No changes observed in the last year
	Out Total:	48	17	0	34	19	1	**38**	**14**	**3**	38	12	3	0	2	0		
	Total for Taxon:	94	27	0	66	72	1	**101**	**92**	**3**	101	90	3	0	2	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Pritchardia kaalae

Target # of Matures: 25 | # 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 2021	Total Immature 2021	Total Seedling 2021	**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	139	1303	74	**161**	**941**	**477**	76	617	477	85	324	0	2022-04-05	A thorough census led to more plants being discovered
Ohikilolo East and West Makaleha	Manage reintroduction for stability	0	75	0	20	256	0	**45**	**222**	**13**	0	0	0	45	222	13	2022-09-14	A thorough census led to more plants being discovered
	In Total:	65	483	0	159	1559	74	**206**	**1163**	**490**	76	617	477	130	546	13		

Action Area: Out

TaxonName: Pritchardia kaalae

Target # of Matures: 25 | # 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 2021	Total Immature 2021	Total Seedling 2021	**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	**122**	**3**	**0**	122	3	0	0	0	0	2022-01-27	Small changes were noted during monitoring 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	**127**	**8**	**0**	127	8	0	0	0	0		
	Total for Taxon:	211	488	0	287	1575	74	**333**	**1171**	**490**	203	625	477	130	546	13		

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 2021	Total Immature 2021	Total Seedling 2021	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	3	0	**14**	**2**	**0**	14	2	0	0	0	0	2022-06-29	A thorough census led to more plants being discovered
Ohikilolo	Manage for stability	34	128	0	12	130	0	**12**	**115**	**0**	12	96	0	0	19	0	2022-04-05	A thorough census has shown a decline in the immature age class
	In Total:	50	253	0	12	133	0	**26**	**117**	**0**	26	98	0	0	19	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 2021	Total Immature 2021	Total Seedling 2021	Total Mature Current	Total Immature Current	Total Seedling Current	Wild Mature Current	Wild Immature Current	Wild Seedling Current	Outplanted Mature Current	Outplanted Immature Current	Outplanted Seedling Current	PU LastObs Date	Population Trend Notes
Kamaileunu	Manage for stability	26	0	0	31	182	1	**31**	**182**	**1**	31	182	1	0	0	0	2017-03-21	No monitoring in the last year
Puu Kawiwi	Genetic Storage	2	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2016-03-15	No monitoring in the last year
	Out Total:	28	0	0	31	182	1	**31**	**182**	**1**	31	182	1	0	0	0		
	Total for Taxon:	78	253	0	43	315	1	**57**	**299**	**1**	57	280	1	0	19	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Schiedea kaalae

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 2021	Total Immature 2021	Total Seedling 2021	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
Kaluanui	Manage for stability				7	129	0	**46**	**64**	**0**	0	0	0	46	64	0	2022-03-14	More outplants matured this year; but populations declined slightly overall
Pahole	Manage for stability	3	0	0	86	60	0	**67**	**44**	**0**	0	0	0	67	44	0	2022-03-01	Thorough monitoring in the last year showed a decline
	In Total:	3	0	0	93	189	0	**113**	**108**	**0**	0	0	0	113	108	0		

Action Area: Out

TaxonName: Schiedea kaalae

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 2021	Total Immature 2021	Total Seedling 2021	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	130	2	0	**123**	**11**	**20**	0	0	0	123	11	20	2022-05-12	A thorough census led to more plants being discovered
Maakua (Koolaus)	Genetic Storage	4	0	0	3	0	0	**3**	**0**	**0**	3	0	0	0	0	0	2019-09-13	No census taken 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 plants observed at this site since 2005
South Ekahanui	Manage for stability	10	75	0	162	61	11	**151**	**32**	**60**	8	0	0	143	32	60	2022-05-10	A thorough census led to more plants being discovered
	Out Total:	19	128	0	388	63	13	**370**	**43**	**82**	17	0	1	353	43	81		
	Total for Taxon:	22	128	0	481	252	13	**483**	**151**	**82**	17	0	1	466	151	81		

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 2021	Total Immature 2021	Total Seedling 2021	**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	142	29	0	**186**	**14**	**0**	4	0	0	182	14	0	2022-05-03	More plants were added to the outplanting site
Kapuna-Keawapilau Ridge	Manage for stability	3	1	0	88	87	0	**67**	**12**	**15**	0	0	0	67	12	15	2022-04-18	Thorough monitoring in the last year showed a decline
	In Total:	51	18	0	230	116	0	**253**	**26**	**15**	4	0	0	249	26	15		

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 2021	Total Immature 2021	Total Seedling 2021	**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	93	9	0	**174**	**0**	**0**	0	0	0	174	0	0	2022-05-03	More plants were added to the outplanting site
	Out Total:	0	0	0	93	9	0	**174**	**0**	**0**	0	0	0	174	0	0		
	Total for Taxon:	51	18	0	323	125	0	**427**	**26**	**15**	4	0	0	423	26	15		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Schiedea obovata

Target # of Matures: 100 | # 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 2021	Total Immature 2021	Total Seedling 2021	**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	353	525	103	**303**	**223**	**8**	0	0	0	303	223	8	2022-09-12	Thorough monitoring in the last year showed a decline
Keawapilau to West Makaleha	Manage for stability	24	12	0	36	62	54	**38**	**50**	**20**	38	50	20	0	0	0	2022-05-24	Thorough monitoring in the last year showed a decline
	In Total:	89	37	0	389	587	157	**341**	**273**	**28**	38	50	20	303	223	8		

Action Area: Out

TaxonName: Schiedea obovata

Target # of Matures: 100 | # 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 2021	Total Immature 2021	Total Seedling 2021	**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	71	192	7	**203**	**122**	**2**	0	0	0	203	122	2	2022-06-27	More plants were added to the outplanting site
	Out Total:	0	0	0	71	192	7	**203**	**122**	**2**	0	0	0	203	122	2		
	Total for Taxon:	89	37	0	460	779	164	**544**	**395**	**30**	38	50	20	506	345	10		

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 2021	Total Immature 2021	Total Seedling 2021	**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				26	16	0	**35**	**27**	**0**	35	27	0	0	0	0	2021-11-17	A thorough census led to more plants being discovered
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	No monitoring in the last year
Ohikilolo	Manage for stability	2500	0	0	1911	1416	20	**2322**	**968**	**20**	2322	968	20	0	0	0	2021-12-16	A thorough census led to more plants being discovered
Puhawai	Manage for stability	6	6	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2021-11-18	No plants observed at this site since 2017
	In Total:	2581	6	0	2357	1673	37	**2777**	**1236**	**37**	2777	1236	37	0	0	0		

Action Area: Out

TaxonName: Tetramolopium filiforme

Target # of Matures: 50 — # MFS PU Met Goal: 1 of 4

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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	21	0	0	**21**	**0**	**0**	21	0	0	0	0	0	2018-09-18	No monitoring in the last year
	Out Total:	20	2	0	21	0	0	**21**	**0**	**0**	21	0	0	0	0	0		
	Total for Taxon:	2601	8	0	2378	1673	37	**2798**	**1236**	**37**	2798	1236	37	0	0	0		

Population Unit Status - Makua Implementation Plan

Action Area: In

TaxonName: Viola chamissoniana subsp. chamissoniana

Target # of Matures: 50 — # MFS PU Met Goal: 3 of 4

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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 plants observed at the site since 2015
Ohikilolo	Manage for stability				182	50	0	**182**	**50**	**0**	182	50	0	0	0	0	2021-06-29	No monitoring in the last year
Puu Kumakalii	Manage for stability	19	1	0	44	0	0	**73**	**4**	**0**	73	4	0	0	0	0	2021-09-23	A thorough census led to more plants being discovered
In Total:		309	11	0	266	60	0	**295**	**64**	**0**	295	64	0	0	0	0		

Action Area: Out

TaxonName: Viola chamissoniana subsp. chamissoniana

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 2021	Total Immature 2021	Total Seedling 2021	**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	11	6	0	**54**	**0**	**0**	16	0	0	38	0	0	2022-09-07	Outplanting initiated 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	25	46	3	**25**	**99**	**3**	25	6	3	0	93	0	2022-01-27	More plants were added to the outplanting site
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	96	62	4	**139**	**109**	**4**	101	16	4	38	93	0		
Total for Taxon:		410	14	0	362	122	4	**434**	**173**	**4**	396	80	4	38	93	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 2021	Total Immature 2021	Total Seedling 2021	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	36	160	0	**39**	**160**	**0**	39	160	0	0	0	0	2021-10-20	A thorough census led to more plants being discovered
Kahanahaiki	Manage reintroduction for stability	0	0	0	69	43	0	**73**	**30**	**1**	0	0	0	73	30	1	2021-09-08	More outplants matured this year; but populations declined slightly overall
Kaluakauila	Manage reintroduction for storage	0	4	0	0	3	0	**0**	**3**	**0**	0	0	0	0	3	0	2016-08-16	No monitoring in the last year
Keaau	Genetic Storage	1	0	10	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2016-09-07	No plants present at site since 2016
	In Total:	37	92	16	105	206	0	**112**	**193**	**1**	39	160	0	73	33	1		

Population Unit Status - Oahu Implementation Plan

Action Area: Out

TaxonName: Abutilon sandwicense

Target # of Matures: 50 # MFS PU Met Goal: 3 of 4

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	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 Plants since 2013
Ekahanui and Huliwai	Manage for stability	14	30	0	88	45	0	**77**	**27**	**3**	1	13	3	76	14	0	2021-08-31	Thorough monitoring in the last year showed a decline
Halona	Genetic Storage	0	0	0	10	5	0	**10**	**5**	**0**	10	5	0	0	0	0	2016-08-15	No monitoring in the last year
Makaha Makai	Manage for stability	73	27	6	81	66	0	**81**	**66**	**0**	81	66	0	0	0	0	2020-10-21	No monitoring in the last year
Makaha Mauka	Genetic Storage	5	58	4	13	0	0	**13**	**0**	**0**	13	0	0	0	0	0	2018-07-16	No monitoring in the last year
Nanakuli	Genetic Storage	0	0	0	3	1	0	**3**	**1**	**0**	3	1	0	0	0	0	2019-06-08	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 data available
Waianae Kai	Genetic Storage	2	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2015-07-09	No plants present at this site since 2013
West Makaleha	Genetic Storage	0	2	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2012-09-17	No plants at this site since 2010
	Out Total:	98	158	50	204	128	0	**193**	**110**	**3**	117	96	3	76	14	0		
	Total for Taxon:	135	250	66	309	334	0	**305**	**303**	**4**	156	256	3	149	47	1		

Population Unit Status - Oahu Implementation Plan

Action Area: In

TaxonName: Cyanea acuminata

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 2021	Total Immature 2021	Total Seedling 2021	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	23	302	0	**23**	**302**	**0**	23	302	0	0	0	0	2019-05-28	No monitoring in the last year
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 data available
Makaleha to Mohiakea	Manage for stability	85	33	0	195	89	0	**210**	**93**	**0**	210	93	0	0	0	0	2021-11-18	A thorough census led to more plants being discovered
	In Total:	147	46	7	220	391	0	**235**	**395**	**0**	235	395	0	0	0	0		

Action Area: Out

TaxonName: Cyanea acuminata

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 2021	Total Immature 2021	Total Seedling 2021	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	126	123	52	**126**	**123**	**52**	126	123	52	0	0	0	2021-04-13	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 data available
Pia	Genetic Storage	0	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		No data available
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 data available
	Out Total:	39	0	0	210	156	52	**210**	**156**	**52**	210	156	52	0	0	0		
	Total for Taxon:	186	46	7	430	547	52	**445**	**551**	**52**	445	551	52	0	0	0		

Population Unit Status - Oahu Implementation Plan

Action Area: In

TaxonName: Cyanea 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 2021	Total Immature 2021	Total Seedling 2021	Total Mature Current	Total Immature Current	Total Seedling Current	Wild Mature Current	Wild Immature Current	Wild Seedling Current	Outplanted Mature Current	Outplanted Immature Current	Outplanted Seedling Current	PU LastObs Date	Population Trend Notes
Kaipapau, Koloa and Kawainui	Manage for stability	51	25	6	113	12	0	**40**	**24**	**0**	40	24	0	0	0	0	2021-11-30	Thorough monitoring in the last year showed a decline
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	7	0	**22**	**7**	**0**	22	7	0	0	0	0	2021-05-15	No monitoring in the last year
Poamoho	Manage for stability	12	0	0	20	19	0	**20**	**19**	**0**	20	19	0	0	0	0	2017-05-02	No monitoring in the last year
	In Total:	96	36	6	174	47	0	**101**	**59**	**0**	101	59	0	0	0	0		

Action Area: Out

TaxonName: Cyanea 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 2021	Total Immature 2021	Total Seedling 2021	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 census taken in the last year
Lulumahu	Genetic Storage	10	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		No data available
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	192	49	0	**119**	**61**	**0**	119	61	0	0	0	0

Population Unit Status - Oahu Implementation Plan

Action Area: In

TaxonName: Eugenia koolauensis

Target # of Matures: 50 | # MFS PU Met Goal: 0 of 3

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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	17	26	1	**17**	**26**	**1**	17	26	1	0	0	0	2016-03-30	No monitoring in the last year
Kaleleiki	Genetic Storage	25	30	250	14	46	80	**8**	**27**	**16**	8	27	16	0	0	0	2022-03-09	Thorough monitoring in the last year showed a decline
Kaunala	Manage for stability	48	93	6	15	39	27	**6**	**21**	**0**	6	21	0	0	0	0	2022-03-30	Thorough monitoring in the last year showed a decline
Malaekahana	Genetic Storage				0	4	0	**0**	**4**	**0**	0	4	0	0	0	0	2017-04-04	No monitoring in the last year
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	**3**	**1**	**1**	3	1	1	0	0	0	2022-06-01	Thorough monitoring in the last year showed a decline
Pahipahialua	Manage for stability	57	234	1	18	6	124	**2**	**1**	**21**	2	1	21	0	0	0	2022-03-29	Thorough monitoring in the last year showed a decline
	In Total:	169	437	282	79	134	232	**45**	**91**	**39**	45	91	39	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 2021	Total Immature 2021	Total Seedling 2021	**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	81	134	232	**47**	**91**	**39**	47	91	39	0	0	0		

Population Unit Status - Oahu Implementation Plan

Action Area: In

TaxonName: Gardenia mannii

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 2021	Total Immature 2021	Total Seedling 2021	**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	40	85	0	**37**	**84**	**0**	1	0	0	36	84	0	2022-01-18	Small changes were noted during monitoring in the last year
Helemano and Poamoho	Manage for stability	18	0	0	23	0	0	**23**	**0**	**0**	23	0	0	0	0	0	2022-03-03	No changes observed 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	9	47	0	**9**	**20**	**0**	9	1	0	0	19	0	2022-04-19	A thorough census has shown a substantial decline in the immature age class
South Kaukonahua	Genetic Storage	2	0	0	2	0	0	**2**	**0**	**0**	2	0	0	0	0	0	2018-09-25	No monitoring in the last year
Upper Opaeula/Helemano	Genetic Storage	1	0	0	1	34	0	**1**	**27**	**0**	1	0	0	0	27	0	2022-09-27	Small changes were noted during monitoring in the last year
	In Total:	88	1	0	88	166	0	**85**	**131**	**0**	49	1	0	36	130	0		

Population Unit Status - Oahu Implementation Plan

Action Area: Out

TaxonName: Gardenia mannii

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 2021	Total Immature 2021	Total Seedling 2021	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	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2016-03-09	No plants at this site
Kahana and Makaua	Genetic Storage	2	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		No data available
Kaipapau to Punaluu	Genetic Storage	4	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		No data available
Kalauao	Genetic Storage	4	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		No data available
Kaluaa and Maunauna	Genetic Storage	1	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2021-06-29	No monitoring 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 data available
Pukele	Genetic Storage	1	0	0	1	0	0	**1**	**0**	**0**	1	0	0	0	0	0	1986-07-29	No data available as of 1986
Waialae Nui	Genetic Storage	1	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		No data available
	Out Total:	36	0	0	6	0	0	**6**	**0**	**0**	6	0	0	0	0	0		
	Total for Taxon:	124	1	0	94	166	0	**91**	**131**	**0**	55	1	0	36	130	0		

Population Unit Status - Oahu Implementation Plan

Action Area: In

TaxonName: Geniostoma 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 2021	Total Immature 2021	Total Seedling 2021	**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	211	17	0	**206**	**10**	**0**	68	0	0	138	10	0	2022-08-03	Small changes were noted during monitoring in the last year
	In Total:	84	16	2	211	17	0	**206**	**10**	**0**	68	0	0	138	10	0		

Action Area: Out

TaxonName: Geniostoma 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 2021	Total Immature 2021	Total Seedling 2021	**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				1	6	0	**2**	**1**	**0**	0	0	0	2	1	0	2022-05-12	Thorough monitoring in the last year showed a decline
	Out Total:				1	6	0	**2**	**1**	**0**	0	0	0	2	1	0		
	Total for Taxon:	84	16	2	212	23	0	**208**	**11**	**0**	68	0	0	140	11	0		

Population Unit Status - Oahu Implementation Plan

Action Area: In

TaxonName: Hesperomannia swezeyi

Target # of Matures: 25 | # MFS PU Met Goal: 2 of 3

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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	2021-05-18	No monitoring in the last year
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	11	15	6	**11**	**15**	**6**	11	15	6	0	0	0	2017-05-03	No monitoring in the last year
Ohiaai ridge	Genetic Storage	5	1	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		No plants at this site
Poamoho	Genetic Storage	38	16	3	13	1	4	**13**	**1**	**4**	13	1	4	0	0	0	2017-05-03	No monitoring in the last year
	In Total:	182	128	139	213	182	57	**213**	**182**	**57**	213	182	57	0	0	0		

Action Area: Out

TaxonName: Hesperomannia swezeyi

Target # of Matures: 25 | # MFS PU Met Goal: 2 of 3

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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 plants at this site
Kapakahi	Genetic Storage	1	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0		No plants at this site
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 plants at this site
	Out Total:	8	0	0	1	4	1	**1**	**4**	**1**	1	4	1	0	0	0		
	Total for Taxon:	190	128	139	214	186	58	**214**	**186**	**58**	214	186	58	0	0	0		

Population Unit Status - Oahu Implementation Plan

Action Area: In

TaxonName: Phyllostegia hirsuta

Target # of Matures: 100 | # MFS PU Met Goal: 0 of 3

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	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	17	2	0	**12**	**4**	**0**	9	4	0	3	0	0	2022-04-04	Thorough monitoring in the last year showed a decline
Helemano and Opaeula	Genetic Storage	14	5	6	1	4	0	**1**	**4**	**0**	1	4	0	0	0	0	2013-11-20	No monitoring in the last year
Helemano and Poamoho	Genetic Storage	1	0	0	2	0	0	**2**	**0**	**0**	2	0	0	0	0	0	2016-06-02	No monitoring in the last year
Kaipapau and Kawainui	Genetic Storage	7	0	0	4	0	0	**4**	**0**	**0**	4	0	0	0	0	0	2013-12-17	No monitoring in the last year
Kaukonahua	Genetic Storage	4	2	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2010-07-28	No plants at this site
Kawaiiki	Genetic Storage	0	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2008-10-09	No plants at this site
Koloa	Manage for stability	0	0	0	15	6	1	**15**	**3**	**1**	9	2	1	6	1	0	2022-05-11	Small changes were noted during monitoring in the last year
	In Total:	32	19	6	39	12	1	**34**	**11**	**1**	25	10	1	9	1	0		

Action Area: Out

TaxonName: Phyllostegia hirsuta

Target # of Matures: 100 | # MFS PU Met Goal: 0 of 3

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	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	2	1	**1**	**3**	**0**	1	3	0	0	0	0	2022-03-14	Small changes were noted during monitoring 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 monitoring in the last year
Palawai	Genetic Storage	0	1	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2009-03-03	No plants at this site
Puu Palikea	Manage reintroduction for stability				8	0	0	**7**	**39**	**0**	0	0	0	7	39	0	2022-06-06	More plants were added to the outplanting site
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	16	5	1	**15**	**45**	**0**	8	6	0	7	39	0		

Population Unit Status - Oahu Implementation Plan

Total for Taxon:	50	29	13	55	17	2	**49**	**56**	**1**	33	16	1	16	40	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 2021	Total Immature 2021	Total Seedling 2021	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	**0**	**0**	**0**	0	0	0	0	0	0	2020-09-21	No plants observed at this site since 2020
	In Total:	0	4	0	0	0	0	**0**	**0**	**0**	0	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 2021	Total Immature 2021	Total Seedling 2021	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	2	**2**	**4**	**0**	0	0	0	2	4	0	2022-05-10	A thorough census led to more plants being discovered
Kaluaa	Manage for stability	38	11	0	21	3	0	**20**	**5**	**0**	0	0	0	20	5	0	2022-04-07	Small changes were noted during monitoring in the last year
Pualii	Manage reintroduction for stability	0	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2017-08-16	No plants observed at this site since 2017
Waieli	Genetic Storage	0	0	0	0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2018-04-12	No plants observed at this site since 2017
	Out Total:	73	11	0	22	3	2	**22**	**9**	**0**	0	0	0	22	9	0		
	Total for Taxon:	73	15	0	22	3	2	**22**	**9**	**0**	0	0	0	22	9	0		

Population Unit Status - Oahu Implementation Plan

Action Area: In

TaxonName: Schiedea trinervis

Target # of Matures: 50 # MFS PU Met Goal: 1 of 1

Population Unit Name	Management Designation	Total Mature Original IP	Total Imm Original IP	Total Seedling Original IP	Total Mature 2021	Total Immature 2021	Total Seedling 2021	**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	416	351	377	**418**	**745**	**377**	296	351	377	122	394	0	2022-08-03	A thorough census led to more plants being discovered
	In Total:	180	196	318	416	351	377	**418**	**745**	**377**	296	351	377	122	394	0		
	Total for Taxon:	180	196	318	416	351	377	**418**	**745**	**377**	296	351	377	122	394	0		

Population Unit Status - Oahu Implementation Plan

Action Area: In

TaxonName: Stenogyne kanehoana

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 2021	Total Immature 2021	Total Seedling 2021	**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	0	18	0	**1**	**15**	**0**	0	0	0	1	15	0	2022-09-21	No changes observed in the last year
	In Total:	1	0	0	0	18	0	**1**	**15**	**0**	0	0	0	1	15	0		

Action Area: Out

TaxonName: Stenogyne kanehoana

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 2021	Total Immature 2021	Total Seedling 2021	**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	5	11	0	**5**	**9**	**0**	0	0	0	5	9	0	2022-04-11	Small changes were noted during monitoring in the last year
Makaha	Manage reintroduction for stability				0	0	0	**0**	**0**	**0**	0	0	0	0	0	0	2019-06-03	No plants observed at this site
	Out Total:	0	79	0	5	11	0	**5**	**9**	**0**	0	0	0	5	9	0		
	Total for Taxon:	1	79	0	5	29	0	**6**	**24**	**0**	0	0	0	6	24	0		

Threat Control Summary Makua Implementation Plan

Action Area: In

TaxonName: Alectryon macrococcus var. macrococcus

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

Action Area: Out

TaxonName: Alectryon macrococcus var. macrococcus

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Central Kaluaa to Central Waieli	Manage for stability	2	Partial 0%	Partial 0%	Partial 0%	Partial 0%	No
Makaha	Manage for stability	6	Partial 100%	Partial 100%	Partial 100%	No	No
Waianae Kai	Genetic Storage	0	Partial	No	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary Makua Implementation Plan

Action Area: In

TaxonName: Cenchrus agrimonioides var. agrimonioides

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Kahanahaiki and Pahole	Manage for stability	275	Yes	Partial 100%	Partial 80%	No	No
Kuaokala	Genetic Storage	0	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	167	Yes	Partial 99%	Yes	No	No
Makaha and Waianae Kai	Manage for stability	71	Partial 92%	Partial 100%	Partial 92%	Partial 85%	No
South Huliwai	Genetic Storage	32	No	Partial 100%	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

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Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary Makua Implementation Plan

Action Area: In

TaxonName: Cyanea grimesiana subsp. obatae

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Pahole to West Makaleha	Manage for stability	63	Partial 95%	Partial 100%	Partial 38%	Partial 33%	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	20	Partial 100%	Partial 100%	Partial 70%	Partial 20%	No
Makaha	Genetic Storage	15	Yes	Partial 100%	Yes	Partial 100%	No
North branch of South Ekahanui	Manage reintroduction for stability	60	Yes	Partial 100%	Partial 100%	Partial 100%	No
Palikea (South Palawai)	Manage for stability	662	Yes	Partial 100%	Yes	Yes	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	56	Partial 96%	Partial 100%	Partial 86%	Partial 96%	No
Pahole	Manage for stability	85	Yes	Partial 100%	No	Partial 100%	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	19	Yes	Partial 100%	Yes	Yes	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	18	Yes	Partial 100%	Partial 100%	Partial 78%	No
Kaluaa	Manage reintroduction for stability	0	Partial	Partial	Partial	Partial	No
Pahole to Kapuna	Genetic Storage	33	Yes	Partial 94%	No	Partial 18%	No
Palikea	Manage reintroduction for stability	19	Partial 100%	Partial 100%	Partial 100%	Yes	Partial 100%

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	58	Partial 100%	Partial 100%	Yes	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 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	29	Yes	Partial 100%	Yes	No	No
Kawaiiki (Koolaus)	Manage for stability	2	No	No	No	No	No
Opaeula (Koolaus)	Manage for stability	34	Partial 97%	Partial 56%	Partial 53%	Partial 53%	No
Pahole to West Makaleha	Manage for stability	636	Yes	Partial 87%	Partial 2%	Partial 34%	No

Action Area: Out

TaxonName: Cyrtandra dentata

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Central Makaleha	Genetic Storage	3	No	No	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

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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	109	Yes	Partial 97%	Partial 29%	Partial 72%	No
Kaluakauila	Manage reintroduction for storage	1	Yes	Partial 100%	No	No	No
Kapuna	Manage reintroduction for storage	83	Yes	Partial 100%	No	No	No
Palikea Gulch	Genetic Storage	1	No	No	No	No	Partial 100%
South Mohiakea	Genetic Storage	19	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	68	Yes	Partial 100%	Partial 100%	Partial 100%	No
Kaluaa	Manage for stability	165	Yes	Partial 100%	Partial 73%	Partial 73%	No
Kealia	Genetic Storage	2	No	No	No	No	No
Manuwai	Manage reintroduction for stability	36	Yes	Partial 100%	Yes	Yes	No
Palawai	Genetic Storage	24	Partial 96%	No	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

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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 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	225	No	No	No	No	No
Ohikilolo Makai	Manage for stability	48	Yes	Partial 56%	No	No	No
Ohikilolo Mauka	Manage for stability	125	Yes	Partial 12%	Partial 9%	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	21	Yes	Partial 100%	Yes	No	No
Waianae Kai	Genetic Storage	10	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 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	1	Yes	No	No	No	No
Kaluakauila	Genetic Storage	11	No	No	No	No	No
Makua	Manage for stability	66	Yes	Partial 100%	No	No	Partial 100%
North Kahanahaiki	Genetic Storage	115	Yes	No	No	No	No
Puaakanoa	Manage for stability	133	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	1	No	Partial 100%	No	No	No
Kaena	Manage for stability	880	No	Partial 100%	No	No	No
Keawaula	Genetic Storage	36	No	No	No	No	No
Waianae Kai	Genetic Storage	34	No	No	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

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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: Euphorbia herbstii

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Kapuna to Pahole	Manage for stability	71	Yes	Partial 97%	No	Partial 94%	No
Manuwai	Manage reintroduction for stability	0	Yes	Partial	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	17	Yes	Partial 100%	No	No	No
Makaha	Manage reintroduction for storage	2	Yes	Partial 100%	Yes	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 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	9	Yes	Partial 78%	Partial 11%	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	12	Partial 83%	Partial 92%	Partial 75%	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

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary Makua Implementation Plan

Action Area: In

TaxonName: Gouania vitifolia

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Keaau	Manage for stability	5	Yes	Partial 20%	No	No	No

Action Area: Out

TaxonName: Gouania vitifolia

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
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

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary   Makua Implementation Plan

Action Area: In

TaxonName: Hesperomannia oahuensis

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Haleauau	Manage for stability	0	Yes	Partial	No	No	No
Pahole NAR	Manage reintroduction for stability	1	Yes	Partial 100%	Yes	No	No

Action Area: Out

TaxonName: Hesperomannia oahuensis

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Makaha	Manage for stability	14	Yes	Partial 100%	Yes	Partial 79%	No
Pualii	Manage reintroduction for stability	23	Yes	Partial 100%	Yes	No	No
Waianae Kai	Genetic Storage	0	No	No	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	59	Yes	Partial 100%	No	No	No
Makua	Manage for stability	30	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	57	No	Partial 100%	No	No	No
Manuwai	Manage reintroduction for stability	38	Yes	Partial 100%	No	No	No
Waialua	Genetic Storage	49	No	No	No	No	Partial 100%

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary Makua Implementation Plan

Action Area: In

TaxonName: Kadua degeneri subsp. degeneri

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Kahanahaiki to Pahole	Manage for stability	46	Yes	Partial 100%	No	Partial 4%	No
Makaha to Ohikilolo	Manage reintroduction for stability	93	Partial 100%	Partial 100%	Yes	Partial 71%	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	41	Partial 95%	Partial 61%	No	No	No
Central Makaleha and West Branch of East Makaleha	Manage for stability	6	No	Partial 100%	No	No	No
East branch of East Makaleha	Genetic Storage	0	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 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	79	Yes	Partial 65%	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	123	Yes	No	Yes	No	No
Halona	Manage for stability	32	Partial 53%	Partial 94%	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 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	Yes	No	No	No	No
Kaluakauila	Genetic Storage	4	Yes	No	No	No	No
Keawaula	Genetic Storage	200	No	No	No	No	No
Ohikilolo	Manage for stability	570	Partial 100%	Partial 2%	No	No	Partial 9%

Action Area: Out

TaxonName: Melanthera tenuifolia

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Kamaileunu and Waianae Kai	Manage for stability	815	Partial 21%	Partial 8%	Partial 10%	No	No
Mt. Kaala NAR	Manage for stability	131	Yes	Partial 100%	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 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	19	Yes	Partial 100%	No	No	No
Kapuna	Genetic Storage	0	No	Partial	No	No	No
Makua	Manage for stability	44	Yes	Partial 55%	No	No	No
Punapohaku	Genetic Storage	2	Yes	Partial 100%	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)	29	Partial 90%	Partial 90%	Partial 90%	No	No
Manuwai	Manage for stability	18	Yes	Partial 100%	No	No	No
Waianae Kai Makai	Genetic Storage	13	Yes	No	No	No	Partial 100%
Waianae Kai Mauka	Manage for stability	11	Partial 100%	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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Threat Control Summary Makua Implementation Plan

Action Area: In

TaxonName: Nototrichium humile

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Kahanahaiki	Genetic Storage	28	Yes	Partial 64%	Partial 39%	No	No
Kaluakauila	Manage for stability	43	Yes	Partial 51%	No	No	No
Keaau	Genetic Storage	20	No	No	No	No	No
Keawaula	Genetic Storage	109	No	No	No	No	No
Makua (East rim)	Genetic Storage	1	Yes	No	No	No	No
Makua (south side)	Manage for stability	50	Yes	No	No	No	No
Punapohaku	Genetic Storage	178	Yes	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%
Kapuna and Keawapilau	Genetic Storage	4	No	No	No	No	No
Kolekole	Genetic Storage	12	No	No	No	No	No
Makaha	Genetic Storage	22	Partial 64%	Partial 64%	No	No	No
Manuwai	Manage reintroduction for stability	101	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	53	Partial 92%	No	No	No	Partial 92%

= 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	Partial	No	No	No
Palikea Gulch	Genetic Storage	0	No	No	No	No	No

Action Area: Out

TaxonName: Phyllostegia kaalaensis

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Makaha	Manage reintroduction for stability	0	Yes	Partial	Yes	No	No
Manuwai	Manage reintroduction for stability	0	Yes	Partial	Yes	Yes	No
Waianae Kai	Genetic Storage	0	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 0%= Threat partially controlled, but no mature plants

Threat Control Summary Makua Implementation Plan

Action Area: In

TaxonName: Plantago princeps var. princeps

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
North Mohiakea	Manage for stability	63	Yes	No	No	No	No
Ohikilolo	Manage for stability	0	Yes	Partial	No	No	No
Pahole	Genetic Storage	0	Yes	Partial	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	1	Yes	Partial 100%	Yes	No	No
Konahuanui	Manage for stability	36	No	No	No	No	No
North Palawai	Genetic Storage	1	No	No	No	No	No
Waieli	Manage reintroduction for storage	0	Yes	Partial	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 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	161	Yes	Partial 96%	Partial 93%	No	No
Ohikilolo East and West Makaleha	Manage reintroduction for stability	45	Yes	Partial 100%	Partial 47%	Partial 47%	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	122	Partial 2%	No	Partial 30%	No	No
Waianae Kai	Genetic Storage	4	No	No	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

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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	14	Yes	No	No	No	No
Ohikilolo	Manage for stability	12	Yes	Partial 0%	Partial 0%	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

= 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: Schiedea kaalae

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Kaluanui	Manage for stability	46	No	Partial 100%	No	No	No
Pahole	Manage for stability	67	Partial 100%	Partial 100%	No	Partial 39%	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	No	No	No	No	No
Kaluaa and Waieli	Manage for stability	123	Yes	Partial 100%	Partial 12%	Partial 12%	No
Maakua (Koolaus)	Genetic Storage	3	No	No	No	No	No
Makaua (Koolaus)	Genetic Storage	85	No	No	No	No	No
North Palawai	Genetic Storage	0	Yes	No	No	No	No
South Ekahanui	Manage for stability	151	Yes	Partial 100%	Yes	Partial 95%	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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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	186	Yes	Partial 100%	Partial 53%	Partial 47%	No
Kapuna-Keawapilau Ridge	Manage for stability	67	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	174	Yes	Partial 100%	Yes	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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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	303	Partial 100%	Partial 100%	Partial 100%	Partial 100%	No
Keawapilau to West Makaleha	Manage for stability	38	Yes	Partial 34%	Partial 32%	Partial 3%	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	203	Yes	Partial 100%	Partial 44%	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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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	Yes	No	No	No	No
Kalena	Manage for stability	35	Yes	No	No	No	No
Keaau	Genetic Storage	30	Yes	No	No	No	No
Makaha/Ohikilolo Ridge	Genetic Storage	350	No	No	No	No	No
Ohikilolo	Manage for stability	2322	Partial 100%	Partial 55%	No	No	No
Puhawai	Manage for stability	0	No	No	No	No	No

Action Area: Out

TaxonName: Tetramolopium filiforme

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Waianae Kai	Manage for stability	21	Partial 100%	Partial 0%	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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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	182	Yes	Partial 10%	No	No	No
Puu Kumakalii	Manage for stability	73	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	54	Partial 70%	Partial 70%	Partial 70%	No	No
Kamaileunu	Genetic Storage	35	No	No	No	No	No
Makaha	Manage for stability	25	Partial 28%	Partial 28%	Partial 28%	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

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Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

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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	39	Partial 64%	Partial 67%	No	No	Partial 10%
Kahanahaiki	Manage reintroduction for stability	73	Yes	Partial 100%	No	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	77	Yes	Partial 100%	Partial 100%	No	No
Halona	Genetic Storage	10	No	No	No	No	No
Makaha Makai	Manage for stability	81	Partial 72%	Partial 72%	No	No	No
Makaha Mauka	Genetic Storage	13	No	No	No	No	No
Nanakuli	Genetic Storage	3	No	No	No	No	No
North Mikilua	Genetic Storage	9	No	No	No	No	No
Waianae Kai	Genetic Storage	0	Partial	No	No	No	Partial
West Makaleha	Genetic Storage	0	No	No	No	No	No

= Threat to Taxon within Population Unit

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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	23	No	No	No	No	No
Kahana and South Kaukonahua	Genetic Storage	2	No	No	No	No	No
Makaleha to Mohiakea	Manage for stability	210	Partial 100%	Partial 7%	Partial 1%	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	126	No	Partial 2%	No	No	No
Puukeahiakahoe	Genetic Storage	3	No	No	No	No	No

= 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 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	40	Partial 53%	Partial 25%	No	No	No
Kamananui-Kawainui Ridge	Genetic Storage	6	No	No	No	No	No
Kaukonahua	Genetic Storage	8	Partial 0%	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	22	Partial 55%	No	No	No	No
Poamoho	Manage for stability	20	Partial 50%	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

= 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 Oahu Implementation Plan

Action Area: In

TaxonName: Eugenia koolauensis

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Aimuu	Genetic Storage	8	No	No	No	No	No
Kaiwikoele and Kamananui	Genetic Storage	17	No	Partial 0%	No	No	No
Kaleleiki	Genetic Storage	8	Partial 50%	Partial 50%	No	No	No
Kaunala	Manage for stability	6	Partial 83%	Partial 17%	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	3	Partial 67%	No	No	No	No
Pahipahialua	Manage for stability	2	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%

= 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: Gardenia mannii

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Haleauau	Manage for stability	37	Yes	Partial 97%	Partial 97%	No	No
Helemano and Poamoho	Manage for stability	23	Partial 48%	Partial 4%	No	No	No
Kaiwikoele, Kamananui, and Kawainui	Genetic Storage	13	No	No	No	No	No
Lower Peahinaia	Manage for stability	9	Partial 44%	Partial 78%	Partial 67%	Partial 0%	No
South Kaukonahua	Genetic Storage	2	No	No	No	No	No
Upper Opaeula/Helemano	Genetic Storage	1	Partial 100%	No	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	0	No	No	No	No	No
Kaluaa and Maunauna	Genetic Storage	0	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

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary Oahu Implementation Plan

Action Area: In

TaxonName: Geniostoma cyrtandrae

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
East Makaleha to North Mohiakea	Manage for stability	206	Partial 93%	Partial 80%	Partial 56%	Partial 56%	No

Action Area: Out

TaxonName: Geniostoma cyrtandrae

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Koloa	Manage reintroduction for stability	2	Partial 100%	Partial 100%	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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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%	Partial 4%	No	No	No
Kaukonahua	Manage for stability	55	Partial 5%	No	No	No	No
Lower Opaeula	Manage for stability	11	No	No	No	No	No
Poamoho	Genetic Storage	13	Partial 54%	Partial 8%	No	No	No

Action Area: Out

TaxonName: Hesperomannia swezeyi

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Niu-Waimanalo Summit Ridge	Genetic Storage	1	No	Partial 100%	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary Oahu Implementation Plan

Action Area: In

TaxonName: Phyllostegia hirsuta

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Haleauau to Mohiakea	Manage for stability	12	Yes	Partial 25%	Partial 25%	Partial 25%	No
Helemano and Opaeula	Genetic Storage	1	Partial 0%	Partial 0%	Partial 0%	No	No
Helemano and Poamoho	Genetic Storage	2	Yes	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	15	Partial 87%	Partial 87%	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 100%	Partial 100%	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	7	Yes	Partial 100%	Yes	Yes	No
Waiamano	Genetic Storage	1	No	No	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary 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	0	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	2	Yes	Partial 100%	Yes	Partial 100%	No
Kaluaa	Manage for stability	20	Yes	Partial 100%	Partial 0%	Partial 0%	No
Pualii	Manage reintroduction for stability	0	Yes	Partial	No	No	No
Waieli	Genetic Storage	0	Partial	No	No	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary 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	410	Partial 99%	Partial 89%	Partial 8%	No	No

= Threat to Taxon within Population Unit

No Shading = Absence of threat to Taxon within Population Unit

Ungulate Managed = Culmination of Cattle, Goats, and Pig threats

Yes=All PopRefSites within Population Unit have threat controlled

No=All PopRefSites within Population Unit have no threat control

Partial%=Percent of mature plants in Population Unit that have threat controlled

Partial 100%= All PopRefSites within Population Unit have threat partially controlled

Partial 0%= Threat partially controlled, but no mature plants

Threat Control Summary Oahu Implementation Plan

Action Area: In

TaxonName: Stenogyne kanehoana

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Haleauau	Manage reintroduction for stability	1	Yes	Partial 100%	Partial 0%	No	No

Action Area: Out

TaxonName: Stenogyne kanehoana

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	Slugs Managed	Fire Managed
Kaluaa	Manage reintroduction for stability	5	Yes	Partial 100%	No	No	No
Makaha	Manage reintroduction for stability	0	Yes	Partial	Yes	No	No

= 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

2022-10-12

Genetic Storage Summary   Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Alectryon macrococcus var. macrococcus														
Kahanahaiki to Keawapilau	Manage for stability	0	0	0	0	0	0	0	0	0	0	0	0	0%
Makua	Manage for stability	4	0	2	0	0	0	2	0	0	0	2	2	33%
South Mohiakea	Genetic Storage	0	0	2	0	0	0	1	0	0	0	1	1	50%
West Makaleha	Genetic Storage	1	0	1	0	0	0	1	0	0	0	1	1	50%
Action Area: Out														
Alectryon macrococcus var. macrococcus														
Central Kaluaa to Central Waieli	Manage for stability	2	0	0	0	0	0	0	0	0	0	0	0	0%
Makaha	Manage for stability	6	0	12	0	0	0	15	0	0	0	11	11	61%
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**
13	0	17	0	0	0	19	0	0	0	15	15

Genetic Storage Summary   Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Cenchrus agrimonioides var. agrimonioides														
Kahanahaiki and Pahole	Manage for stability	55	12	66	85	70	0	0	62	39	0	0	48	96%
Kuaokala	Genetic Storage	0	0	1	0	0	0	1	0	0	0	1	1	100%
Action Area: Out														
Cenchrus agrimonioides var. agrimonioides														
Central Ekahanui	Manage for stability	65	2	53	80	47	0	51	40	10	0	29	35	70%
Makaha and Waianae Kai	Manage for stability	6	0	8	9	5	0	9	4	0	0	8	8	57%
South Huliwai	Genetic Storage	32	5	28	44	34	0	33	26	10	0	12	19	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
158	19	156	218	156	0	94	132	59	0	50	111

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	4	0	12	15	15	0	10	14	14	0	7	14	88%
Action Area: Out														
Cyanea grimesiana subsp. obatae														
Kaluaa	Manage for stability	3	1	1	3	3	0	3	3	3	0	3	3	75%
Makaha	Genetic Storage	0	0	1	1	1	0	0	1	1	0	0	1	100%
North branch of South Ekahanui	Manage reintroduction for stability	0	0	2	2	2	2	2	2	2	2	2	2	100%
Palikea (South Palawai)	Manage for stability	12	0	12	17	17	5	1	17	17	5	1	17	71%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Viable 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
19	1	28	38	38	7	16	37	37	7	13	37

Genetic Storage Summary   Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	# of Potential Founders: Current Imm.	# of Potential Founders: Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	Partial Storage Status: # Plants >= 10 Est Viable in SeedLab	Partial Storage Status: # Plants >=1 Microprop	Partial Storage Status: # Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	Storage Goals: # Plants >= 50 Est. Viable in SeedLab	Storage Goals: # Plants >=3 in Microprop	Storage Goals: # Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Cyanea longiflora														
Kapuna to West Makaleha	Manage for stability	14	0	20	29	29	9	20	28	28	9	12	28	82%
Pahole	Manage for stability	79	136	35	61	61	1	29	59	59	1	8	60	100%
Action Area: Out														
Cyanea longiflora														
Makaha and Waianae Kai	Manage for stability	5	0	4	5	5	1	3	5	5	1	3	5	56%

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
98	136	59	95	95	11	52	92	92	11	23	93

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	29	45	27	37	37	0	9	36	36	0	3	36	72%
Kawaiiki (Koolaus)	Manage for stability	2	19	0	0	0	0	0	0	0	0	0	0	0%
Opaeula (Koolaus)	Manage for stability	34	74	7	11	11	0	5	11	11	0	3	12	29%
Pahole to West Makaleha	Manage for stability	636	1786	45	124	124	0	11	124	124	0	9	124	100%
Action Area: Out														
Cyrtandra dentata														
Central Makaleha	Genetic Storage	3	0	0	0	0	0	0	0	0	0	0	0	0%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
704	1924	79	172	172	0	25	171	171	0	15	172

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	0	14	15	15	1	10	15	15	1	10	15	79%
Palikea Gulch	Genetic Storage	1	0	6	7	7	3	7	7	7	3	7	7	100%
South Mohiakea	Genetic Storage	19	4	10	18	18	0	3	16	16	0	3	17	59%
Action Area: Out														
Delissea waianaeensis														
Ekahanui	Manage for stability	0	0	6	6	6	0	5	6	6	0	5	6	100%
Kaluaa	Manage for stability	4	0	5	9	9	0	4	8	8	0	4	9	100%
Kealia	Genetic Storage	2	1	5	6	6	0	1	6	6	0	1	6	86%
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
55	35	54	91	91	4	30	86	86	4	30	88

Genetic Storage Summary   Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Dubautia herbstobatae														
Keaau	Genetic Storage	70	0	0	0	0	0	0	0	0	0	0	0	0%
Makaha/Ohikilolo	Genetic Storage	225	4	0	6	1	0	10	6	0	0	9	9	18%
Ohikilolo Makai	Manage for stability	48	0	1	1	0	0	12	1	0	0	11	11	22%
Ohikilolo Mauka	Manage for stability	125	14	0	4	1	5	35	3	0	5	30	30	60%
Action Area: Out														
Dubautia herbstobatae														
Kamaileunu	Genetic Storage	0	0	1	1	0	1	1	1	0	1	1	1	100%
Makaha	Manage for stability	3	9	29	23	1	11	23	19	1	11	20	22	69%
Waianae Kai	Genetic Storage	10	4	0	5	0	2	2	4	0	2	2	2	20%

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
481	31	31	40	3	19	83	34	1	19	73	75

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	1	0	1	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	66	0	42	77	74	0	0	61	53	0	0	53	100%
North Kahanahaiki	Genetic Storage	115	36	4	14	14	0	0	11	8	0	0	8	16%
Puaakanoa	Manage for stability	133	0	11	51	45	0	0	33	31	0	0	31	62%
Action Area: Out														
Euphorbia celastroides var. kaenana														
East of Alau	Manage for stability	1	0	25	26	26	0	0	24	21	0	0	21	81%
Kaena	Manage for stability	880	274	10	68	67	0	0	66	59	0	0	59	100%
Keawaula	Genetic Storage	36	2	18	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
1277	315	111	270	255	0	0	213	182	0	0	182

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	4	1	61	37	35	0	7	25	20	0	2	24	48%

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
4	1	61	37	35	0	7	25	20	0	2	24

Genetic Storage Summary Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	# of Potential Founders: Current Imm.	# of Potential Founders: Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	Partial Storage Status: # Plants >= 10 Est Viable in SeedLab	Partial Storage Status: # Plants >=1 Microprop	Partial Storage Status: # Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	Storage Goals: # Plants >= 50 Est. Viable in SeedLab	Storage Goals: # Plants >=3 in Microprop	Storage Goals: # Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Flueggea neowawraea														
Kahanahaiki to Kapuna	Manage for stability	5	0	2	3	3	0	3	2	2	0	2	2	29%
Ohikilolo	Manage for stability	1	0	1	1	1	0	1	1	1	0	1	1	50%
West Makaleha	Genetic Storage	6	0	1	1	1	0	4	1	1	0	1	1	14%
Action Area: Out														
Flueggea neowawraea														
Central and East Makaleha	Genetic Storage	4	0	3	1	1	0	5	1	1	0	3	3	43%
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	1	1	100%
Makaha	Manage for stability	7	0	4	2	1	0	10	2	0	0	6	6	55%
Mt. Kaala NAR	Genetic Storage	2	0	2	2	2	0	3	2	1	0	2	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**	
		29	0	14	10	9	0	29	9	6	0	18	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	4	3	61	55	51	0	4	51	47	0	2	47	94%
Action Area: Out														
Gouania vitifolia														
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
4	3	61	55	51	0	4	51	47	0	2	47

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	0	0	1	0	0	0	1	0	0	0	0	0	0%
Action Area: Out														
Hesperomannia oahuensis														
Makaha	Manage for stability	3	1	2	2	2	0	2	1	0	0	0	0	0%
Waianae Kai	Genetic Storage	0	0	2	1	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
3	1	5	3	2	0	3	1	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	14	6	18	17	17	0	30	15	15	0	26	34	100%
Makua	Manage for stability	5	7	40	36	35	0	33	35	34	0	30	36	80%
Action Area: Out														
Hibiscus brackenridgei subsp. mokuleianus														
Haili to Kawaiu	Manage for stability	0	5	18	13	13	0	19	13	12	0	13	15	83%
Waialua	Genetic Storage	49	85	30	23	19	0	55	13	6	0	48	53	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
68	103	106	89	84	0	137	76	67	0	117	138

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	46	28	56	88	87	0	6	78	74	0	5	74	100%
Action Area: Out														
Kadua degeneri subsp. degeneri														
Alaiheihe and Manuwai	Manage for stability	16	13	28	40	39	1	0	38	36	1	0	37	84%
Central Makaleha and West Branch of East Makaleha	Manage for stability	6	3	32	36	35	0	26	33	31	0	8	32	84%
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
68	44	116	164	161	1	32	149	141	1	13	143

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 parvula														
Ohikilolo	Manage for stability	43	13	67	104	100	0	0	99	93	0	0	93	100%
Action Area: Out														
Kadua parvula														
Halona	Manage for stability	15	4	30	69	65	0	20	61	56	0	7	58	100%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Viable Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
58	17	97	173	165	0	20	160	149	0	7	151

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	16	11	0	2	2	5	0	2	2	2	12%
Kaluakauila	Genetic Storage	4	80	0	9	0	3	4	1	0	3	3	5	100%
Keawaula	Genetic Storage	200	50	0	0	0	0	0	0	0	0	0	0	0%
Ohikilolo	Manage for stability	570	11	19	16	0	2	3	13	0	2	3	4	8%
Action Area: Out														
Melanthera tenuifolia														
Kamaileunu and Waianae Kai	Manage for stability	815	246	0	0	0	0	2	0	0	0	2	2	4%
Mt. Kaala NAR	Manage for stability	131	24	0	0	0	0	0	0	0	0	0	0	0%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
1721	411	35	36	0	7	11	19	0	7	10	13

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	1	0	1	2	100%
Makua	Manage for stability	20	4	37	18	18	0	22	17	16	0	14	20	40%
Punapohaku	Genetic Storage	2	0	2	3	3	0	3	3	2	0	2	3	75%
Action Area: Out														
Neraudia angulata														
Halona	Genetic Storage	4	10	16	4	0	0	1	4	0	0	1	1	5%
Leeward Puu Kaua	Genetic Storage	9	0	0	0	0	0	1	0	0	0	1	1	11%
Makaha	Manage for stability (backup site)	3	8	4	6	3	0	10	6	1	0	7	7	100%
Manuwai	Manage for stability	0	4	7	1	1	0	7	1	1	0	3	3	43%
Waianae Kai Makai	Genetic Storage	13	0	0	1	0	0	1	1	0	0	0	0	0%
Waianae Kai Mauka	Manage for stability	7	2	10	6	0	0	7	4	0	0	7	7	41%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
58	28	78	41	27	0	54	38	21	0	36	44

Genetic Storage Summary Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Nototrichium humile														
Kahanahaiki	Genetic Storage	28	1	0	0	0	0	3	0	0	0	3	3	11%
Kaluakauila	Manage for stability	43	64	1	1	0	0	18	0	0	0	17	17	39%
Keaau	Genetic Storage	20	31	0	0	0	0	0	0	0	0	0	0	0%
Keawaula	Genetic Storage	109	22	0	0	0	0	4	0	0	0	4	4	8%
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	1	0	0	0	1	1	2%
Punapohaku	Genetic Storage	178	77	0	0	0	0	30	0	0	0	27	27	54%
Action Area: Out														
Nototrichium humile														
Kaimuhole and Palikea Gulch	Genetic Storage	29	1	12	39	39	0	42	35	34	0	39	43	100%
Kapuna and Keawapilau	Genetic Storage	4	0	4	0	0	0	5	0	0	0	4	4	50%
Kolekole	Genetic Storage	12	0	0	0	0	0	9	0	0	0	8	8	67%
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	53	135	0	0	0	0	16	0	0	0	16	16	32%

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**	
		544	339	17	40	39	0	128	35	34	0	119	123	

Genetic Storage Summary Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Phyllostegia kaalaensis														
Keawapilau to Kapuna	Manage reintroduction for stability	0	0	1	1	1	1	0	0	0	1	0	1	100%
Pahole	Manage reintroduction for stability	0	0	2	0	0	2	0	0	0	2	0	2	100%
Palikea Gulch	Genetic Storage	0	0	3	1	1	3	0	0	0	3	0	3	100%
Action Area: Out														
Phyllostegia kaalaensis														
Waianae Kai	Genetic Storage	0	0	2	1	0	2	1	0	0	2	0	2	100%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
0	0	8	3	2	8	1	0	0	8	0	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	63	75	17	37	36	0	6	34	31	0	5	31	62%
Ohikilolo	Manage for stability	0	0	17	19	18	0	1	14	14	0	0	14	82%
Pahole	Genetic Storage	0	3	5	7	6	0	1	6	5	0	0	5	100%
Action Area: Out														
Plantago princeps var. princeps														
Ekahanui	Manage for stability	1	7	72	69	67	0	2	59	42	0	1	42	84%
Konahuanui	Manage for stability	36	5	0	13	11	0	0	2	0	0	0	0	0%
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
101	90	113	147	140	0	10	117	94	0	6	94

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	76	617	2	1	0	1	0	0	0	1	0	1	2%
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	122	3	0	2	0	0	0	1	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**
203	625	2	3	0	1	0	1	0	1	0	1

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	14	2	58	68	66	0	0	50	34	0	0	34	68%
Ohikilolo	Manage for stability	12	96	54	60	45	0	1	26	17	0	0	17	34%
Action Area: Out														
Sanicula mariversa														
Kamaileunu	Manage for stability	31	182	44	92	92	0	1	77	65	0	0	65	100%
Puu Kawiwi	Genetic Storage	0	0	2	3	3	0	0	3	2	0	0	2	100%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
57	280	158	223	206	0	2	156	118	0	0	118

Genetic Storage Summary Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	# of Potential Founders: Current Imm.	# of Potential Founders: Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	Partial Storage Status: # Plants >= 10 Est Viable in SeedLab	Partial Storage Status: # Plants >=1 Microprop	Partial Storage Status: # Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	Storage Goals: # Plants >= 50 Est. Viable in SeedLab	Storage Goals: # Plants >=3 in Microprop	Storage Goals: # Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Schiedea kaalae														
Pahole	Manage for stability	0	0	2	2	2	2	2	2	2	2	2	2	100%
Action Area: Out														
Schiedea kaalae														
Kahana	Genetic Storage	5	0	4	2	1	9	5	0	0	9	0	9	100%
Kaluaa and Waieli	Manage for stability	0	0	1	1	1	1	0	1	1	1	0	1	100%
Maakua (Koolaus)	Genetic Storage	3	0	0	1	1	6	2	0	0	6	0	6	100%
Makaua (Koolaus)	Genetic Storage	1	0	0	0	0	1	1	0	0	1	0	1	100%
North Palawai	Genetic Storage	0	0	1	1	1	1	1	1	1	1	0	1	100%
South Ekahanui	Manage for stability	8	0	12	17	16	14	12	16	9	14	6	19	95%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
17	0	20	24	22	34	23	20	13	34	8	39

Genetic Storage Summary   Makua Implementation Plan

		# of Potential Founders			Partial Storage Status				Storage Goals				Storage Goals Met	
Population Unit Name	Management Designation	Current Mature	Current Imm.	Dead and Repres.	# Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	# Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	# Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Schiedea nuttallii														
Kahanahaiki to Pahole	Manage for stability	4	0	51	45	41	11	33	38	23	11	32	42	84%
Kapuna-Keawapilau Ridge	Manage for stability	0	0	2	2	2	0	2	2	2	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
4	0	53	47	43	11	35	40	25	11	34	44

Genetic Storage Summary   Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Schiedea obovata														
Kahanahaiki to Pahole	Manage for stability	0	0	5	6	6	1	2	6	6	1	0	6	100%
Keawapilau to West Makaleha	Manage for stability	38	50	83	92	91	0	32	91	89	0	27	90	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
38	50	88	98	97	1	34	97	95	1	27	96

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	34	97	20	0	33	58	8	0	22	25	50%
Kalena	Manage for stability	35	27	10	19	16	0	0	9	8	0	0	8	18%
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	2322	968	39	155	59	0	0	54	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	21	0	0	1	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
2798	1236	88	293	114	0	33	127	27	0	22	44

Genetic Storage Summary Makua Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
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	182	50	1	1	0	0	19	0	0	0	3	3	6%
Puu Kumakalii	Manage for stability	73	4	0	12	0	6	18	3	0	4	7	9	18%
Action Area: Out														
Viola chamissoniana subsp. chamissoniana														
Halona	Manage for stability	16	0	6	4	0	3	3	1	0	3	3	3	14%
Kamaileunu	Genetic Storage	35	0	0	0	0	0	0	0	0	0	0	0	0%
Makaha	Manage for stability	25	6	0	0	0	9	15	0	0	8	11	11	44%
Makaleha	Genetic Storage	19	9	2	8	0	10	10	1	0	9	8	11	52%
Puu Hapapa	Genetic Storage	6	1	7	7	0	6	4	4	0	6	1	6	46%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
396	80	16	32	0	34	69	9	0	30	33	43

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	39	160	8	27	17	0	0	17	4	0	0	4	9%
Kahanahaiki	Manage reintroduction for stability	0	0	1	1	1	0	1	1	1	0	0	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	1	13	13	13	13	0	0	13	10	0	0	12	86%
Halona	Genetic Storage	10	5	0	3	1	0	0	2	0	0	0	0	0%
Makaha Makai	Manage for stability	81	66	18	80	59	0	1	72	32	0	0	32	64%
Makaha Mauka	Genetic Storage	13	0	8	25	16	0	3	22	3	0	1	4	19%
Nanakuli	Genetic Storage	3	1	0	0	0	0	0	0	0	0	0	0	0%
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	256	49	151	108	0	5	128	50	0	1	53

Genetic Storage Summary   Oahu Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Alectryon macrococcus var. macrococcus														
Kahanahaiki to Keawapilau	Manage for stability	0	0	0	0	0	0	0	0	0	0	0	0	0%
Makua	Manage for stability	4	0	2	0	0	0	2	0	0	0	2	2	33%
South Mohiakea	Genetic Storage	0	0	2	0	0	0	1	0	0	0	1	1	50%
West Makaleha	Genetic Storage	1	0	1	0	0	0	1	0	0	0	1	1	50%
Action Area: Out														
Alectryon macrococcus var. macrococcus														
Central Kaluaa to Central Waieli	Manage for stability	2	0	0	0	0	0	0	0	0	0	0	0	0%
Makaha	Manage for stability	6	0	12	0	0	0	15	0	0	0	11	11	61%
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
13	0	17	0	0	0	19	0	0	0	15	15

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	23	302	0	31	31	1	1	31	30	1	0	30	100%
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	210	93	0	12	12	0	0	12	11	0	0	11	22%
Action Area: Out														
Cyanea acuminata														
Kahana and Makaua	Genetic Storage	11	3	0	1	1	0	0	0	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	126	123	0	2	2	0	0	2	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
445	551	0	46	46	1	1	45	41	1	0	41

Genetic Storage Summary   Oahu Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Cyanea grimesiana subsp. obatae														
Pahole to West Makaleha	Manage for stability	4	0	12	15	15	0	10	14	14	0	7	14	88%
Action Area: Out														
Cyanea grimesiana subsp. obatae														
Kaluaa	Manage for stability	3	1	1	3	3	0	3	3	3	0	3	3	75%
Makaha	Genetic Storage	0	0	1	1	1	0	0	1	1	0	0	1	100%
North branch of South Ekahanui	Manage reintroduction for stability	0	0	2	2	2	2	2	2	2	2	2	2	100%
Palikea (South Palawai)	Manage for stability	12	0	12	17	17	5	1	17	17	5	1	17	71%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Viable 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
19	1	28	38	38	7	16	37	37	7	13	37

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	40	24	0	1	1	0	1	1	1	0	0	1	3%
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	22	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
119	61	0	2	2	0	1	2	2	0	0	2

Genetic Storage Summary   Oahu Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Cyrtandra dentata														
Kahanahaiki	Manage for stability	29	45	27	37	37	0	9	36	36	0	3	36	72%
Kawaiiki (Koolaus)	Manage for stability	2	19	0	0	0	0	0	0	0	0	0	0	0%
Opaeula (Koolaus)	Manage for stability	34	74	7	11	11	0	5	11	11	0	3	12	29%
Pahole to West Makaleha	Manage for stability	636	1786	45	124	124	0	11	124	124	0	9	124	100%
Action Area: Out														
Cyrtandra dentata														
Central Makaleha	Genetic Storage	3	0	0	0	0	0	0	0	0	0	0	0	0%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
704	1924	79	172	172	0	25	171	171	0	15	172

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	0	14	15	15	1	10	15	15	1	10	15	79%
Palikea Gulch	Genetic Storage	1	0	6	7	7	3	7	7	7	3	7	7	100%
South Mohiakea	Genetic Storage	19	4	10	18	18	0	3	16	16	0	3	17	59%
Action Area: Out														
Delissea waianaeensis														
Ekahanui	Manage for stability	0	0	6	6	6	0	5	6	6	0	5	6	100%
Kaluaa	Manage for stability	4	0	5	9	9	0	4	8	8	0	4	9	100%
Kealia	Genetic Storage	2	1	5	6	6	0	1	6	6	0	1	6	86%
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
55	35	54	91	91	4	30	86	86	4	30	88

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	2	12	0	0	1	9	9	82%
Kaiwikoele and Kamananui	Genetic Storage	17	26	4	0	0	4	29	0	0	3	25	25	100%
Kaleleiki	Genetic Storage	8	27	17	0	0	0	22	0	0	0	19	19	76%
Kaunala	Manage for stability	6	21	28	0	0	1	35	0	0	1	24	24	71%
Malaekahana	Genetic Storage	0	4	1	0	0	0	5	0	0	0	4	4	100%
Ohiaai and East Oio	Genetic Storage	1	1	1	0	0	1	3	0	0	0	3	3	100%
Oio	Manage for stability	3	1	10	0	0	2	13	0	0	0	10	10	77%
Pahipahialua	Manage for stability	2	1	30	0	0	1	31	0	0	0	18	18	56%
Action Area: Out														
Eugenia koolauensis														
Hanaimoa	Genetic Storage	1	0	2	0	0	0	3	0	0	0	2	2	67%
Palikea and Kaimuhole	Genetic Storage	1	0	1	0	0	0	2	0	0	0	2	2	100%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
47	91	97	0	0	11	155	0	0	5	116	116

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														
Flueggea neowawraea														
Kahanahaiki to Kapuna	Manage for stability	5	0	2	3	3	0	3	2	2	0	2	2	29%
Ohikilolo	Manage for stability	1	0	1	1	1	0	1	1	1	0	1	1	50%
West Makaleha	Genetic Storage	6	0	1	1	1	0	4	1	1	0	1	1	14%
Action Area: Out														
Flueggea neowawraea														
Central and East Makaleha	Genetic Storage	4	0	3	1	1	0	5	1	1	0	3	3	43%
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	1	1	100%
Makaha	Manage for stability	7	0	4	2	1	0	10	2	0	0	6	6	55%
Mt. Kaala NAR	Genetic Storage	2	0	2	2	2	0	3	2	1	0	2	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
29	0	14	10	9	0	29	9	6	0	18	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	1	0	7	0	0	0	5	0	0	0	4	4	50%
Helemano and Poamoho	Manage for stability	23	0	2	2	1	0	14	1	1	0	12	12	48%
Kaiwikoele, Kamananui, and Kawainui	Genetic Storage	13	0	0	0	0	0	1	0	0	0	1	1	8%
Lower Peahinaia	Manage for stability	9	1	3	1	0	0	8	1	0	0	7	7	58%
South Kaukonahua	Genetic Storage	2	0	0	0	0	0	2	0	0	0	2	2	100%
Upper Opaeula/Helemano	Genetic Storage	1	0	0	0	0	0	0	0	0	0	0	0	0%
Action Area: Out														
Gardenia mannii														
Ihiihi-Kawainui ridge	Genetic Storage	0	0	0	0	0	0	0	0	0	0	0	0	0%
Kaluaa and Maunauna	Genetic Storage	0	0	2	0	0	0	2	0	0	0	2	2	100%
Kamananui-Malaekahana Summit Ridge	Genetic Storage	3	0	0	0	0	0	2	0	0	0	2	2	67%
Kapakahi	Genetic Storage	2	0	0	0	0	0	0	0	0	0	0	0	0%
Pukele	Genetic Storage	1	0	0	0	0	0	0	0	0	0	0	0	0%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
55	1	14	3	1	0	34	2	1	0	30	30

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														
Geniostoma cyrtandrae														
East Makaleha to North Mohiakea	Manage for stability	68	0	1	9	9	0	3	9	8	0	2	8	16%

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	1	9	9	0	3	9	8	0	2	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														
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	# of Potential Founders: Current Imm.	# of Potential Founders: Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	Partial Storage Status: # Plants >= 10 Est Viable in SeedLab	Partial Storage Status: # Plants >=1 Microprop	Partial Storage Status: # Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	Storage Goals: # Plants >= 50 Est. Viable in SeedLab	Storage Goals: # Plants >=3 in Microprop	Storage Goals: # Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Phyllostegia hirsuta														
Haleauau to Mohiakea	Manage for stability	9	4	14	7	5	11	11	6	1	11	6	11	48%
Helemano and Opaeula	Genetic Storage	1	4	4	1	1	2	2	1	0	2	1	2	40%
Helemano and Poamoho	Genetic Storage	2	0	1	0	0	0	0	0	0	0	0	0	0%
Kaipapau and Kawainui	Genetic Storage	4	0	0	1	1	4	1	0	0	4	0	4	100%
Kaukonahua	Genetic Storage	0	0	0	0	0	0	0	0	0	0	0	0	0%
Kawaiiki	Genetic Storage	0	0	0	0	0	0	0	0	0	0	0	0	0%
Koloa	Manage for stability	9	2	1	5	3	6	4	2	1	6	1	7	70%
Action Area: Out														
Phyllostegia hirsuta														
Hapapa to Kaluaa	Genetic Storage	1	3	12	8	7	10	13	6	4	10	6	11	85%
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 Viable 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
33	16	33	22	17	33	32	15	6	33	14	35

Genetic Storage Summary   Oahu Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Phyllostegia kaalaensis														
Keawapilau to Kapuna	Manage reintroduction for stability	0	0	1	1	1	1	0	0	0	1	0	1	100%
Pahole	Manage reintroduction for stability	0	0	2	0	0	2	0	0	0	2	0	2	100%
Palikea Gulch	Genetic Storage	0	0	3	1	1	3	0	0	0	3	0	3	100%
Action Area: Out														
Phyllostegia kaalaensis														
Waianae Kai	Genetic Storage	0	0	2	1	0	2	1	0	0	2	0	2	100%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
0	0	8	3	2	8	1	0	0	8	0	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	0	0	8	7	7	7	1	3	2	7	0	7	88%
Action Area: Out														
Phyllostegia mollis														
Ekahanui	Manage for stability	0	0	2	2	2	2	2	2	0	2	1	2	100%
Kaluaa	Manage for stability	0	0	1	1	1	0	0	1	1	0	0	1	100%
Pualii	Manage reintroduction for stability	0	0	1	1	1	1	0	0	0	1	0	1	100%
Waieli	Genetic Storage	0	0	6	5	5	6	0	4	4	6	0	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
0	0	18	16	16	16	3	10	7	16	1	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	63	75	17	37	36	0	6	34	31	0	5	31	62%
Ohikilolo	Manage for stability	0	0	17	19	18	0	1	14	14	0	0	14	82%
Pahole	Genetic Storage	0	3	5	7	6	0	1	6	5	0	0	5	100%
Action Area: Out														
Plantago princeps var. princeps														
Ekahanui	Manage for stability	1	7	72	69	67	0	2	59	42	0	1	42	84%
Konahuanui	Manage for stability	36	5	0	13	11	0	0	2	0	0	0	0	0%
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
101	90	113	147	140	0	10	117	94	0	6	94

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	0	0	2	2	2	2	2	2	2	2	2	2	100%
Action Area: Out														
Schiedea kaalae														
Kahana	Genetic Storage	5	0	4	2	1	9	5	0	0	9	0	9	100%
Kaluaa and Waieli	Manage for stability	0	0	1	1	1	1	0	1	1	1	0	1	100%
Maakua (Koolaus)	Genetic Storage	3	0	0	1	1	6	2	0	0	6	0	6	100%
Makaua (Koolaus)	Genetic Storage	1	0	0	0	0	1	1	0	0	1	0	1	100%
North Palawai	Genetic Storage	0	0	1	1	1	1	1	1	1	1	0	1	100%
South Ekahanui	Manage for stability	8	0	12	17	16	14	12	16	9	14	6	19	95%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
17	0	20	24	22	34	23	20	13	34	8	39

Genetic Storage Summary Oahu Implementation Plan

Population Unit Name	Management Designation	# of Potential Founders: Current Mature	Current Imm.	Dead and Repres.	Partial Storage Status: # Plants >= 10 in SeedLab	# Plants >= 10 Est Viable in SeedLab	# Plants >=1 Microprop	# Plants >=1 Army Nursery	Storage Goals: # Plants >= 50 in SeedLab	# Plants >= 50 Est. Viable in SeedLab	# Plants >=3 in Microprop	# Plants >=3 Army Nursery	Storage Goals Met: # Plants that Met Goal	% Completed Genetic Storage Requirement
Action Area: In														
Schiedea trinervis														
Kalena to East Makaleha	Manage for stability	296	351	14	92	91	1	1	91	89	1	0	89	100%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Viable Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
296	351	14	92	91	1	1	91	89	1	0	89

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														
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	182	50	1	1	0	0	19	0	0	0	3	3	6%
Puu Kumakalii	Manage for stability	73	4	0	12	0	6	18	3	0	4	7	9	18%
Action Area: Out														
Viola chamissoniana subsp. chamissoniana														
Halona	Manage for stability	16	0	6	4	0	3	3	1	0	3	3	3	14%
Kamaileunu	Genetic Storage	35	0	0	0	0	0	0	0	0	0	0	0	0%
Makaha	Manage for stability	25	6	0	0	0	9	15	0	0	8	11	11	44%
Makaleha	Genetic Storage	19	9	2	8	0	10	10	1	0	9	8	11	52%
Puu Hapapa	Genetic Storage	6	1	7	7	0	6	4	4	0	6	1	6	46%

Total Current Mature	Total Current Imm.	Total Dead and Repres.	Total # Plants w/ >=10 Seeds in SeedLab	Total # Plants w/ >=10 Est Vaible Seeds in SeedLab	Total # Plants w/ >=1 Microprop	Total # Plants w/ >=1 Army Nursery	Total # Plants w/ >=50 Seeds in SeedLab	Total # Plants w/ >=50 Est Viable Seeds in SeedLab	Total # Plants w/ >=3 in Microprop	Total # Plants w/ >=3 Army Nursery	Total # Plants that Met Goal
396	80	16	32	0	34	69	9	0	30	33	43

Five Year Management Plan for *Geniostoma cyrtandrae*, 2022

Geniostoma cyrtandrae

Scientific name: ***Geniostoma cyrtandrae***

Synonyms: ***Labordia cyrtandrae***

Hawaiian name: Kamakahala

Family: Loganiaceae

Federal status: Listed Endangered October 10, 1996

Requirements for MIP Stability

- 2 Manage for Stability (MFS) Population Units (PUs)
- 50 reproducing individuals in each MFS PU
- Stable Population Structure
- Threats Controlled
- Complete genetic representation of all PUs in storage

Description and Biology

Geniostoma cyrtandrae is a shrub 0.7-1.5 m (2.3-4.9 ft) tall with opposite leaves that are crowded at branch tips. The leaf blades are 15-30 cm (6.0-12 in) long and 4-14 cm (1.6-5.5 in) wide. The upper surfaces of the leaves are glabrous and the lower surfaces are moderately or sometimes sparsely hairy. The flowers are borne 8-80 or more in compound paniculate cymes. The flowers' corollas are tubular, pale greenish yellow or pale yellow, and measure 20-35 mm (0.79-1.4 in) in length. The capsules are lanceoloid-ellipsoid in shape, and are 32-35 mm (1.3-1.4 in) long (Wagner 1990).

G. cyrtandrae is sporadically fertile year-round, but is most often observed flowering from

March through June and fruiting from July through October. The plants are functionally dioecious, with male and female flowers on separate plants. *G. cyrtandrae* belongs to a section of the genus whose species are apparently bird pollinated (Motley and Carr 1998). Upon ripening, *Geniostoma* fruits split open to reveal their juicy, orange to greenish pulp, in which are embedded numerous seeds. This suggests that fruits of *Geniostoma* species are bird dispersed. A small amount of vegetative reproduction has been observed in *G. cyrtandrae*, where branches have rooted to form separate individuals.

Known Distribution and Habitat: *G. cyrtandrae* is endemic to Oahu and is known from both the Waianae and Koolau Mountains. In the Koolaus the species has been documented from various locations along the mountain range on both the windward and leeward sides. In the Waianaes, the species has been recorded primarily from the windward slopes of the mountain range from Kaala to Puu Kalena. A specimen of *G. cyrtandrae* collected in 1909 in Makaha Valley represents the only record of the species on the leeward side of the mountain range. The elevational range for the species in the Waianae Mountains is 744-1,137 m (2,440 ft to 3,730 ft), and 430-701 m (1,411 ft to 2,300 ft) in the Koolau Mountains. *G. cyrtandrae* typically grows in gulch bottoms, and on gulch slopes, sometimes in steep terrain. In the Koolau Mountain Range, *G. cyrtandrae* has only been found in wet vegetation. In the Waianae Mountains it occurs mostly in wet vegetation, but extends into the mesic forests as well. In both mountain ranges, the *G. cyrtandrae* habitats are often dominated by ohia lehua (*Metrosideros polymorpha*) and uluhe (*Dicranopteris linearis*). In the Waianae Mountains, other common associated native species include *Boehmeria grandis*, mamaki (*Pipturus albidus*), haiwale (*Cyrtandra waianaensis*), and olomea (*Perrotettia sandwicensis*).

Taxonomic Background: *G. cyrtandrae* originally included in the endemic Hawaiian genus *Labordia* with 14 other species. *Labordia* has since been placed in the Genus *Geniostoma* (Gibbons *et al.* 2012), a genus of about 24 species from Malaysia to southern Japan and the Bonin Islands, southward and eastward to Australia (Queensland), New Zealand, and Henderson Island in the Tuamotus, also in the Mascarene Islands. Hawaii has 15 endemic species of *Geniostoma. G. cyrtandrae* is endemic to Oahu and is most similar to *G. hirtellum*, which occurs on several islands including Oahu (Wagner *et al*. 1990).

Table 1. Historic collections of *G. cyrtandrae* on Oahu. Data compiled from Bishop Museum Herbarium Records provided by Bishop Museum, 2022.

Area	Year	Collector
Punaluu and Kaipapau	1908	C.N. Forbes
Makaha Valley	1909	C.N. Forbes
Waialae Iki Ridge	1917	C.N. Forbes
Punaluu	1932	O. Degener
Waipio, Kipapa Gulch	1933	F.R Fosberg
Maakua Gulch	1933	F.R. Fosberg
Kipapa	1935	O. Degener
Waimano	1935	O. Degener
Analulu	1935	O. Degener
Haleauau Gulch	1977	P.K. Higashino
Haleauau Valley	1992	S. Perlman
Kaalaea	1995	K.R. Wood
Mount Kaala	2007	S. Ching-Harbin

Table 2. Reproductive Biology Summary of *G. cyrtandrae.*

	Observed Phenology*			Reproductive Biology		Seeds	
MFS Population Unit	Flower	Immature Fruit	Mature Fruit	Breeding System	Suspected Pollinator	Average # Per Fruit	Dormancy
East Makaleha to North Mohiakea	March-June	April-Oct.	April-Jan.	Dioecious	Likely insect	72 ± 61	Physiological Dormancy (PD)

*Observed Phenology is based on field observations at each site. Actual duration of reproductive status is likely longer that those observed.

Plant Morphology and Habitat (Images)

Figure 1. Habit of *G. cyrtandrae* (left); Mature plant with compound paniculate cymes (inflorescence) (right)

Figure 2. Inflorescence, a compound paniculate cyme (left); Open flowers, showing tubular corolla (right)

Figure 3. Male flower (left); Female flower (right)

Figure 4. Dehisced, mature fruit (left); Immature fruit (right)

Figure 5. Hand pollinating *G. cyrtandrae* (left); Pollinated flowers (right)

Figure 6. Seedlings in growth chamber (left); Immature fruit showing rat damage (right)

Table 3. Habitat characteristics of each Population. Average Annual Rainfall data is from the Rainfall Atlas of Hawaii (Giambelluca et al. 2013 and 2014). All other data from ANRPO observations.

MFS PU	**Pop. Ref. Code**	**Elev. (feet)**	**Slope**	**Canopy Cover**	**Topo.**	**Aspect**	**Average AnnualMax.Temp. (F)**	**Average Annual Rainfall (mm)**
East Makaleha to North Mohiakea	ALA-A Reintro	3950	Moderate	Closed	Lower slope	N/NE	76	1634
East Makaleha to North Mohiakea	ALA-B Reintro	3967	Moderate	Int.	Upper Slope	N/NE	76	1634
East Makaleha to North Mohiakea	ALA-C Reintro	3822-3967	Flat	Closed	Crest	N	77	1620
East Makaleha to North Mohiakea	ALA-G *In situ*	2750-3720	Steep	Int.	Upper Slope	N	77	1579
East Makaleha to North Mohiakea	ALA-H *In situ*	3600-3700	Steep	Int.	Lower Slope	NW	77	1620
East Makaleha to North Mohiakea	ALA-I *In situ*	3770	Moderate	Open	Mid Slope	SE	77	1584

MFS PU	Pop. Ref. Code	Elev. (feet)	Slope	Canopy Cover	Topo.	Aspect	Average AnnualMax.Temp. (F)	Average Annual Rainfall (mm)
East Makaleha to North Mohiakea	ALA-J *In situ*	3583	Vertical	Open	Lower slope	NE	77	1577
East Makaleha to North Mohiakea	ALA-K *In situ*	3284-3566	Moderate	Int.	Mid Slope	S	76	1631
East Makaleha to North Mohiakea	ALA-L *In situ*	3570-3691	Steep	Int.	Upper Slope	SW	76	1631
East Makaleha to North Mohiakea	ALA-M *In situ*	3900	Moderate	Closed	Gulch Bottom	SW	76	1642
East Makaleha to North Mohiakea	ALA-N *In situ*	3727	Moderate	Int.	Gulch Bottom	S	76	1642
East Makaleha to North Mohiakea	ALA-O Reintro	3630	Moderate	Int.	Upper Slope	N/NE	76	1631
East Makaleha to North Mohiakea	ALA-P *In situ*	3445-3537	Steep	Int.	Lower Slope	SE	76	1584
East Makaleha to North Mohiakea	ALA-Q *In situ*	3560	vertical	Open	Upper Slope	SW	76	1584
East Makaleha to North Mohiakea	ALA-R *In situ*	3616	Moderate	Int.	Lower Slope	NW/W	77	1571
East Makaleha to North Mohiakea	ALA-S Reintro	3629-3675	Flat/ Moderate/ Steep	Closed/ Int.	Mid and Upper Slope	N/S/E/W	76	1631
East Makaleha to North Mohiakea	ALA-T *In situ*	3615-3655	Moderate/ Vertical	Open	Mid Slope	E/SE	76	1584
East Makaleha to North Mohiakea	ALA-U *In situ*	3412	Steep	Open	Lower Slope	N	77	1620

MFS PU	Pop. Ref. Code	Elev. (feet)	Slope	Canopy Cover	Topo.	Aspect	Average AnnualMax.Temp. (F)	Average Annual Rainfall (mm)
East Makaleha to North Mohiakea	ALA-V *In situ*	3238-3307	Steep	Closed	Mid Slope	W	77	1574
East Makaleha to North Mohiakea	ALA-W Reintro	3845-3875	Flat/ Moderate	Closed	Upper Slope	SE/SW	77	1584
East Makaleha to North Mohiakea	KAO-A *In situ*	2913	Steep	Int.	Lower Slope	N	78	1420
East Makaleha to North Mohiakea	LEH-A *In situ*	2970-3180	Vertical	Closed	Gulch Bottom	NE	77	1604
East Makaleha to North Mohiakea	LEH-B *In situ*	3050	Moderate	Int.	Lower Slope	NW	77	1604
East Makaleha to North Mohiakea	LEH-D *In situ*	3556	Moderate	Int.	Lower Slope	NE	77	1615
East Makaleha to North Mohiakea	SBW-A *In situ*	3200-3580	Steep	Int.	Gulch Bottom	E	77	1530
East Makaleha to North Mohiakea	SBW-C *In situ*	2600-2700	Steep	Int.	Upper Slope	N	78	1422
East Makaleha to North Mohiakea	SBW-D *In situ*	2631	Moderate	Open	Mid Slope	NE	78	1422
Koloa	KOL-B Reintro	2300	Moderate	Int.	Gulch Bottom	N	78	4265

Int.= Intermediate

Table 4. List of Associated Species (six letter code = first three letters of genus, followed by first three letters of species), in alphabetical order, for each MFS Population Unit (PU) for both canopy and understory. Bold text indicates endemic and indigenous taxa.

PU	PRS	Canopy	Understory
East Makaleha to North Mohiakea	ALA-A-W KAO-A LEH-A-D SBW-A-D	**BoeGra, ChePla, CheTri, CibGla, CibMen, CopFol, CopOch, CyrWai, DubLax, FreArb, HydArg, IleAno, LepTam, MelChr, MelClu, MetPol, MetTre, PerSan, PipAlb, PsyHat, SysSan**, BudAsi, PsiCat, TooCil	**AdeTam, AspCon, AthMic, CheTri, CibGla, CopOch, CopFol, DipSan, FreArb, GenWai, HydArg, IleAno, KadCen, MacAng, MelClu, MetPol, NerGra, OdoChi, PepMem, PhyGra, PipAlb, SadCya, SadPal, SmiMel, SyzSan, TecGau, VacCal, VacRet,** BegFol, BudAsi, CliHir, HedGar, JunPla, RhyCad, RubArg, RubRos
Koloa	KOL-B	**AntPla, CheTri, DicLan, DubLax, FreArb, HydArg, MetPol, MelSpp, MyrLes, PhyGra, PsyHat, WikOahOah**	**AdeTam, CibCha, DubLax, HydArg, PhyGra, PsyHat, SadCya, SyzSan**, AngEve, BleApp, ChrPar, CliHir, DepPet, PsiCat, PteGlo

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Figure 7. Map of current and historic *G. cyrtandrae* populations.

Current Status

Since the finalization of the OIP in 2008 the total number of plants of *G. cyrtandrae* has increased largely due to outplanting efforts in the MFS PU East Makaleha to North Mohiakea and the Manage Reintroduction for Stability (MRFS) PU, Koloa. Plant numbers peaked in 2015 with 328 mature plants and have declined since then (Figure 8). This decline is largely due to losses of outplanted individuals at the Koloa PU between 2013 and 2015 (Figure 9). Between 2013 and 2022 the Koloa PU declined by 98%, whereas the East Makaleha to North Mohiakea PU declined by only 37%. Little to no recruitment has been observed at reintroductions during this period. The number of known wild plants has remained relatively stable since 2008 with 71 mature plants known at the finalization of the OIP and 68 remaining today. There was one mature individual known from Manana Gulch in the central, leeward Koolaus; however, this plant was observed dead in 2012. Currently, all remaining wild plants occur in the Waianae Mountains in the East Makaleha to North Mohiakea PU. Of the total *G. cyrtandrae* remaining today, both outplanted and wild, 99% occur in the Waianae Mountains. To date eight reintroductions have been attempted for this taxon, six in the Waianae Mountains and two in the Koolaus. PUs for *G. cyrtandrae* include one MFS and one MRFS (Table 5). One PU currently meets stabilization goals for more than 50 mature plants; however genetic storage remains low at 16% (Table 6). All threats are partially controlled at the East Makaleha and North Mohiakea PU, while threat control for rodents and slugs at Koloa is lacking.

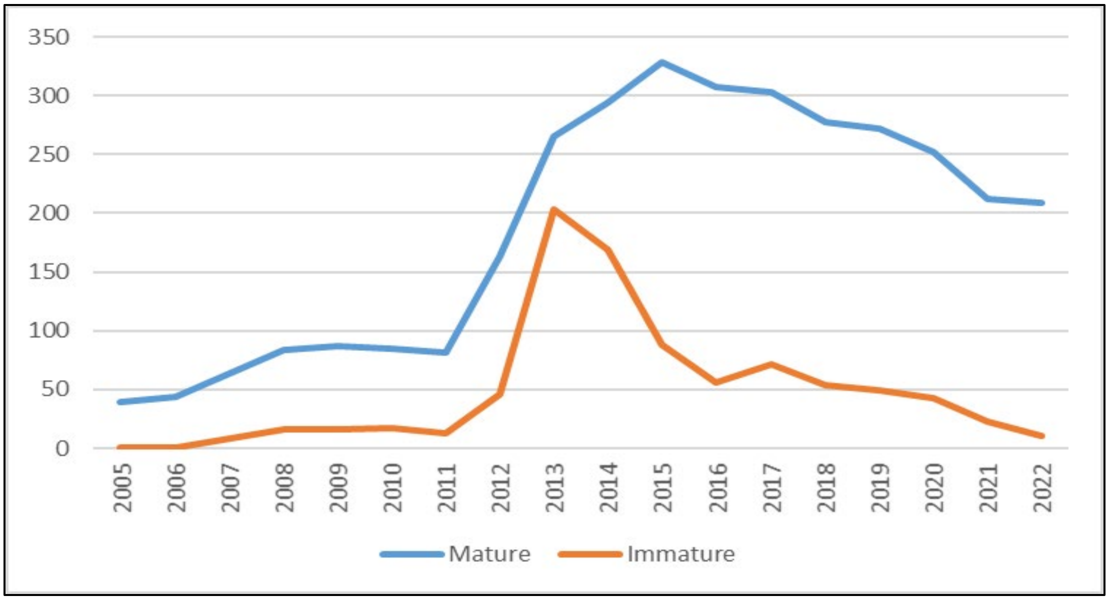

Figure 8. Total number of mature plants compared with total number immature plants and for all MFS PUs over time.

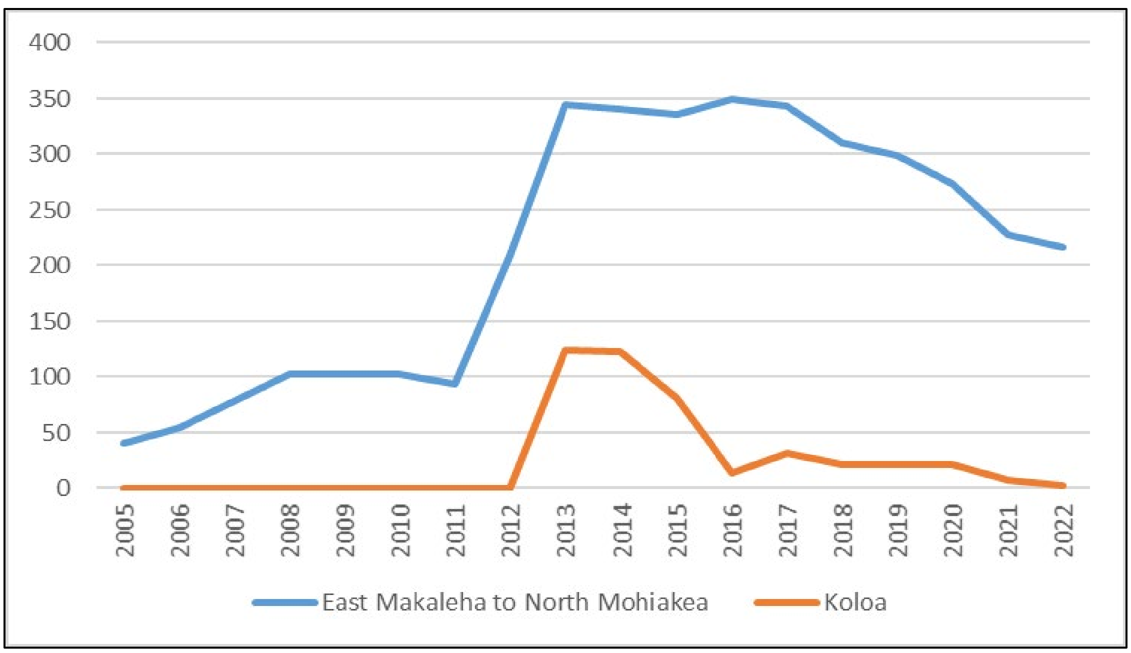

Figure 9. Total number of plants for each MFS PU over time.

Table 5. Population Units for *G. cyrtandrae*. MFS = Manage for Stability; MRFS= Manage Reintroduction for Stability.

Population Unit	Management Designation	PU Type	Action Area (In/Out)	Management Units for Threat Control
East Makaleha to North Mohiakea	MFS	*In situ*/Reintro	In	Kaala NAR, Kaala Army, Lihue, Makaha No MU, Kaomokunui No MU, Makaleha East, Makaleha East No MU
Koloa	MRFS	Reintro	Out	Koloa

Table 6. Stabilization Goal Status. Yes/No/Partial refers to if control is in place for each PU.

	PU Stability Target		MU Threat Control					Genetic Storage
Population Unit	50 reproduc-ing plants	Stable Population Structure	Ungulate	Slugs	Rodent	Fire	Weeds	% Completed
East Makaleha to North Mohiakea	Yes	No	Partial 93%	Partial 56%	Partial 56%	No	Partial 80%	16%
Koloa	No	No	Yes	No	No	No	Partial 100%	N/A

Shading=Threat to Taxon within Population Unit

No Shading= Absence of threat to Taxon within Population Unit

Population Trends and Structure: Manage for Stability Population Units

Monitoring data would suggest that *G. cyrtandrae* is a long-lived species. Wild plants have been observed to survive up to 24 years or longer and outplants 18 years or longer. See Table 7 for current plant numbers for each MFS PU. Specific population trend and structure information for each MFS PU is provided in the following sections.

Table 7. Current Plant Numbers

Population Unit	Current Matures	Current Immatures	Current Seedlings
East Makaleha to North Mohiakea	207	10	0
Koloa	2	1	0

East Makaleha to North Mohiakea

This PU consists of 29 Population Reference Sites (PRSs), with 23 *in situ* and six reintroduction PRSs across seven management units on the windward side of the Waianae Mountain range. The remaining 68 mature wild plants are scattered across this PU in relatively low densities. No remaining wild PRS has more than 17 mature plants, and the vast majority have less than five plants. The reintroduction at ALA-S has the highest number of plants of any PRS in this PU with 109 surviving mature and 5 immature plants with 11 wild founders represented (Figure 10). This reintroduction was established in 2012 and plant numbers at this PRS peaked in 2016 with 166 mature plants and has since declined by 34%. Plant survivorship at this site is 54.33% since 2012, the highest of any reintroduction in this PU. To date no recruitment has been observed at this site or any other reintroduction in this PU, except for ALA-W (a reintroduction), where one F1 seedling has been observed.

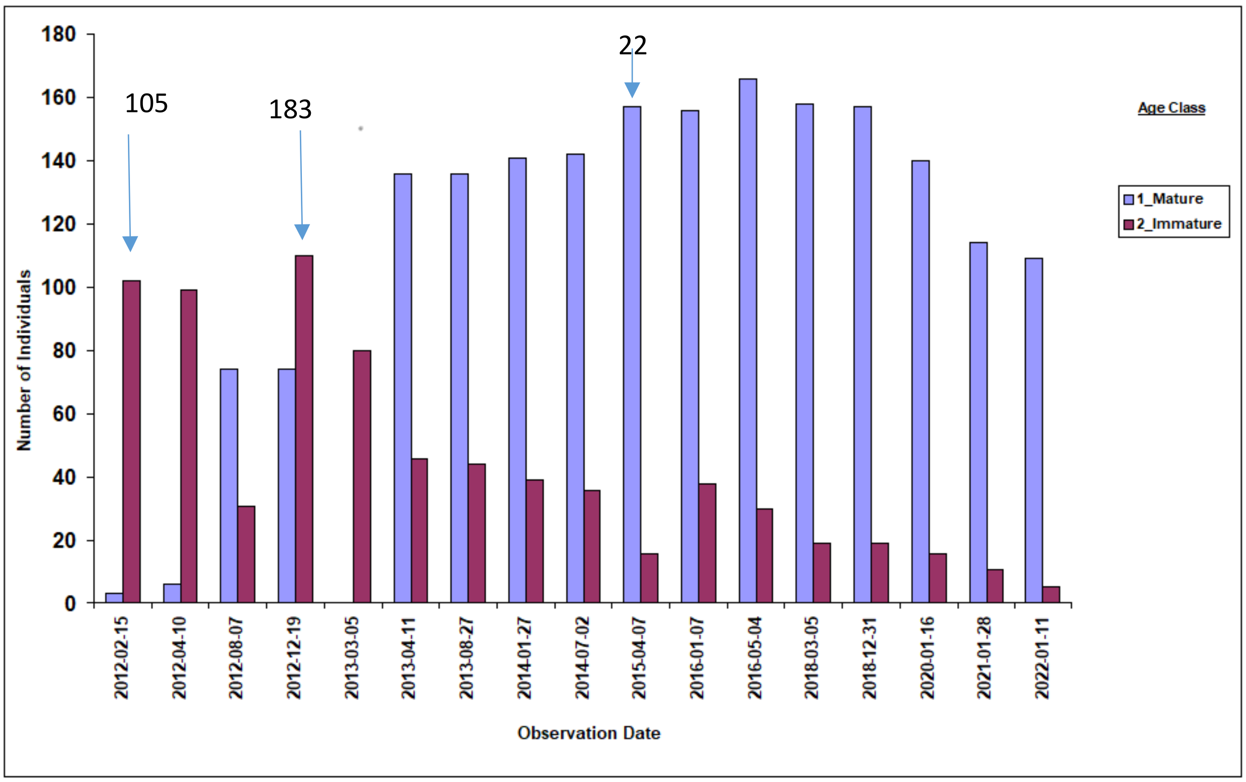

Figure 10. *G. cyrtandrae* Reintroduction ALA-S population structure for mature and immature plants, and seedlings. Arrows and numbers indicate when outplants were added.

Koloa

The Koloa PU located in the northeast Koolau Mountains consists of two reintroduction PRSs, KOL-A and KOL-B. Koloa is a Manage Reintroduction for Stability PU and there are no wild plants known from this MU. All plants remaining in this PU were established as reintroductions. The KOL-A and KOL-B reintroductions were established in 2013 and 2017 respectively. KOL-A was initially outplanted with 124 plants representing Waianae founders (LEH-C) and was further augmented with 40 plants in winter 2013. This outplanting declined rapidly between 2013 and 2016 and the last living plants were observed in 2018 (Figure 11). KOL-B was initially outplanted with 17 plants and in August of 2020 an Ohia tree fell on site negatively impacting multiple individuals as well as letting more light into the site allowing both *Clidemia hirta* and *Pterolepis glomerata* to thrive and compete with outplants. Plant numbers have since declined to two matures and one immature plant. Efforts were made in the last year to locate an appropriate site to establish a new reintroduction in Koloa. Areas adjacent to the *Phyllostegia hirsuta* reintroduction KOL-A were identified as a potential reintroduction site. Slopes surrounding the grassy bowl offer a majority native canopy with a solid mossy understory with variable light levels, which should support a sustainable *G. cyrtandrae* outplanting. In addition, threat control can be effectively consolidated at this site, including both rodent and slug control.

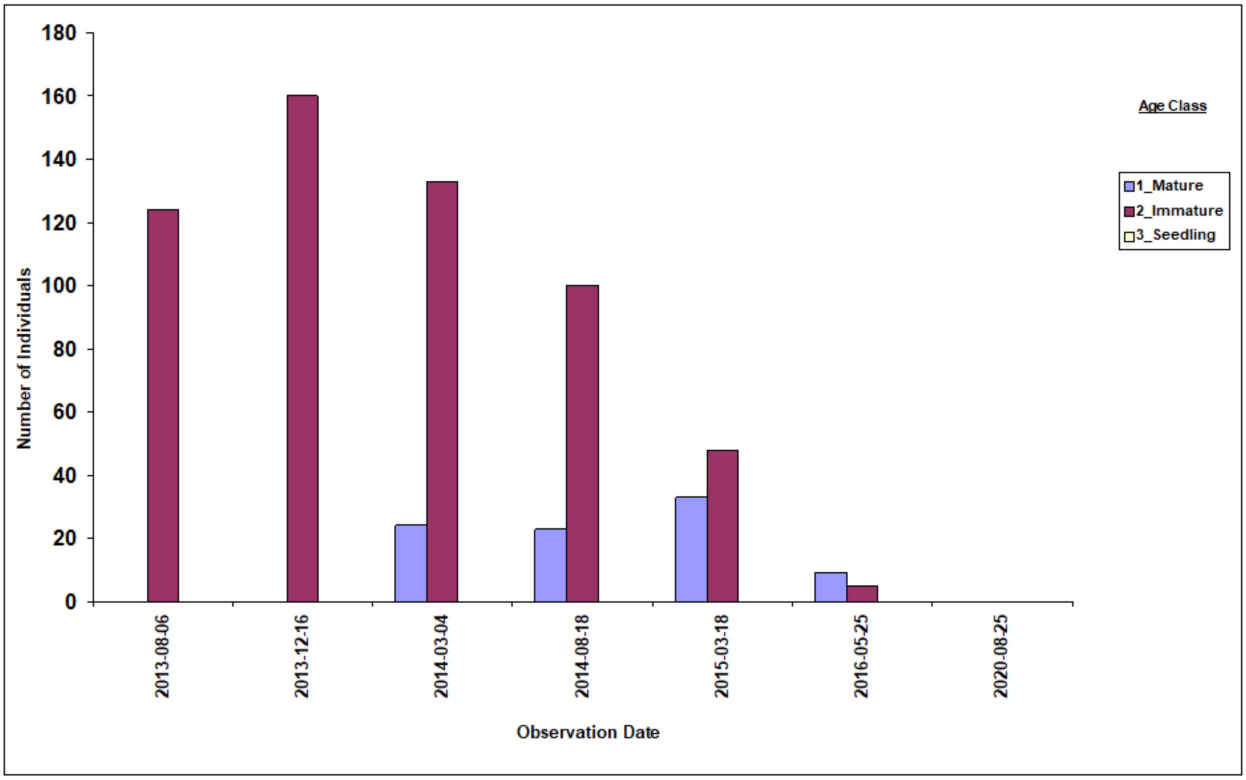

Figure 11. *G. cyrtandrae* reintroduction KOL-A population structure for mature and immature plants, and seedlings.

Outplanting considerations from 2008 OIP

"The range of *L. cyrtandrae* overlaps the ranges of several other species of *Labordia*. In the Waianae Mountains, the *Labordia*s potentially occurring near *L. cyrtandrae* are *L. waiolani*, *L. kaalae*, and *L. tinifolia*. In the Koolau Mountains, the potential species are *L. sessilis*, *L. fagraeoidea*, *L. hosakana*, *L. tinifolia*, *L. hirtella*, and *L. waiolani*. A study involving artificial hybridization of various species of *Labordia*, including *L. cyrtandrae*, has shown that there is a lack of genetic barriers that prevent hybridization between *Labordia* species. While natural hybridization could possibly occur in *Labordia* due to the lack of genetic barriers, it apparently rarely happens among *Labordia* species at present (Motley and Carr 1998). Some *Labordia* plants have been suspected to be hybrids (Wagner *et al.* 1990), but these suspicions have not been verified. Hybridization concerns with respect to the outplanting of *L. cyrtandrae* are therefore minimal."

Current Outplanting Considerations

To date eight reintroductions have been attempted for this taxon with six reintroductions in the Waianae Mountains on Kaala and two in the Koolaus in the Koloa MU. Since only one of the two MFS PUs currently meets stabilization goals for mature plants, a new site will be planted in 2023 to augment the Koloa PU. Specific outplanting sites will be selected based on habitat composition, site aspect, and accessibility for monitoring and threat control. Given these criteria, an area adjacent to the *P. hirsuta* KOL-A reintroduction has been preselected for the new Koloa *G. cyrtandrae* reintroduction. Propagules for this new reintroduction will be propagated using stored seeds; however, in order increase the number of wild founders represented in the outplanting, some plants made need to be air layered.

G. cyrtandrae is highly vulnerable to the impacts of climate change with a vulnerability score of 0.698 (scale 0-1 (not vulnerable – extremely vulnerable)) (Fortini *et al.* 2013). When selecting future outplanting sites climate variables should be considered. Dr. Lucas Fortini (USGS) is currently developing future climate range maps, examples of which were originally presented at the 2019 IT meeting, for the majority of ANRPO management taxa. Two maps will be developed for each taxon, one based on current climate conditions and the other on past conditions. The range map based on present climate uses current climate conditions at a taxon's sites as a baseline, and predicts where these climate conditions will exist in 30 years. The range map based on past climate uses historical climate conditions at a taxon's sites as a baseline, and predicts where these climate conditions will exist in future. The 'past climate' range map is a more conservative model, as it is assumed that current climate conditions are already impacted by climate change. These maps can be used as guides for future reintroduction and management site selection. However, these maps are models that provide us more information regarding future range changes, but do not account for habitat quality.

Reintroduction Plan

The proposed outplanting sites are designed to maintain population size to meet the stability goal for the number of reproducing individuals (Table 8). Currently only the East Makaleha to North Mohiakea PU meets this goal.

Table 8. Future proposed outplantings sites for *G. cyrtandrae* to meet the stabilization goal of 50 reproducing individuals per Population Unit (PU). The propagule type for each planting will be immature plants grown from seeds or air layers from wild plants.

Manage for Stability Population Units	Reintroduction Site(s)	Propagule Source	Total Number of Plants to be planted	2023	2024	2025	2026	2027
Koloa	KOL-C	All stock	150	25	25	50	25	25

Reintroductions will be prioritized to augment PUs that do not currently meet stabilization goals for the total number of mature plants. Outplanting numbers may need to increase if survival is poor, or if recruitment and development into mature plants is not observed. As the Koloa PU has the fewest number of plants, establishing a new reintroduction in this PU with be the focus of outplanting efforts for this taxon over the next five years. The outplanting site will be established in areas adjacent to the current *P. hirsuta* KOL-A reintroduction. This area offers the most suitable habitat for this taxon and is accessible for both monitoring and effective threat control. In February 2017, 17 plants representing LEH-C stock were outplanted in the Opaeula MU. This reintroduction was last monitored in May 2022 and 16 of the original outplants survived. There are currently 10 mature and six immatures at this site. ANRPO is currently discussing the future management of this site and is strongly considering augmenting this site with more outplants between the 2024 and 2027.

Monitoring Plan

All Manage for Stability PUs will be monitored annually, with priority given to the largest PRSs, using the HRPRG Rare Plant Monitoring Form to record population structure and the age class, reproductive status and vigor of all known plants. The sites will also be surveyed for new seedlings and juvenile plants. New founders and those without 50 viable seeds in genetic storage will be collected during monitoring to increase genetic diversity for future outplanting populations, as well as to meet genetic storage goals. Monitoring data will serve to document population trends and structure, which will be used to guide in situ management strategies in the future. PRSs that have not been monitored for six years or longer should be prioritized for monitoring. In addition to monitoring, genetic storage collection at these sites should be prioritized. These PRSs include: ALA-H, I, J, K, P, U, V; KAO-A; LEH-A, B, D; and SBW-A, C, and D. New outplantings will be monitored twice a year after outplanting, and then annually in subsequent years. All other reintroduction sites will be monitored annually.

Threats

The major threats to *G. cyrtandrae* include pigs, rats, alien slugs and snails, and alien plants. Pigs damage this species' habitat and directly harm plants through predation, trampling, and rooting for food sources. Rats threaten this species through predation of its plant parts and fruits, while introduced slugs and snails threaten this species by feeding on its leaves, stems, and seedlings. Alien plants negatively impact this species by altering habitat conditions and competing for moisture, nutrients, light, and space. Specifically *Hedychium gardernarium*, *Rubus argutus*, *C. hirta* and *P. glomerata* directly compete with *G. cyrtandrae* for space and resources and degrade or alter microhabitats that will support recruitment of seedlings. This taxon seems to be rather attractive to slug species. Observations of slugs feeding on outplants at ALA-S are common.

Genetic Storage Plan

G. cyrtandrae seeds are desication tolerant, but are sensitive to storage at negative temperatures (Chau *et al*. 2019). These freeze sensitive seeds are stored at 5ºC at 20%RH. Currently, the East Makaleha to North Mohiakea PU meets 16% of its genetic storage goals. The recollection interval for this taxon is set for ≥ 15 years and is expected to increase following the results of the next viability test scheduled for 2025. Wild and outplanted plants do not always produce enough viable seed to meet genetic storage goals. Pollen collections and hand pollination efforts at both *in situ* and reintroduction sites should be the focus of future efforts to increase viable seed set for propagation and storage. Average seed viability for *G. cyrtandrae* collections in storage at ANRPO is 34.72%. Viability varies considerably across accessions and seeds tend to mold readily, especially seed that has been stored for longer periods of time. Plants at eight reintroduction sites will be hand pollinated and seeds will be collected. Additionally, efforts will be made to pollinate and collect seed from wild plants at sites that have not been visited in over six years. Recollection intervals will be extended until a decline in viability is detected.

Table 9. Action plan for how to maintain genetic storage representation, and provide propagules for reintroductions.

What propagule type is used for meeting genetic storage goal?	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 + Pollen	*In situ* and reintroduction sites	Seed Storage: -5C / 20% RH	≥15 years	Yes	Collect pollen, hand pollinate flowers and collect seed at *in situ* and reintro sites- Seed Storage

Management Discussion

The primary goal for this taxon for the next five years will be to establish a new reintroduction in the Koloa PU and to monitor MFS PRSs in the East Makaleha to North Mohiakea PU that have not been monitored in the past six years or longer. During these monitoring events natural resource staff should assess the potential for hand pollination to promote viable seed set. Multiple return visits will be necessary to pollinate and collect seed of new wild founders to further build genetic storage for this taxon and to ensure a greater diversity of wild founders are available for outplanting. There are currently 68 wild plants remaining *in situ* and only 17 wild founders represented at reintroduction sites. If hand pollination of flowers and seed collection is not a functional strategy at some *in situ* sites, air layering should be considered as a propagule collection method. Over the course of five years 150 plants will be outplanted at KOL-C to increase plant numbers in the Koloa PU in order to meet stabilization goals. The site is located near the *P. hirsuta* KOL-A reintroduction and supports suitable habitat, access for monitoring and threat control, especially for rats and slugs, can be easily and effectively employed. In addition, ANRPO is also considering continued outplanting at the reintroduction established in the Opaeula MU in 2017. Survivorship of outplants is high and it would be a reasonable management decision to manage this reintroduction and the reintroduction planned at KOL-C. Eventually ANRPO may decide to manage one of the sites over the other base on performance. The reintroduction in the Opaeula MU is erroneously labeled as HEL-A. If ANRPO decides to continue to manage this site the PRS should be changed to OPA-A.

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Five Year Management Plan for *Gouania vitifolia*, 2022

Gouania vitifolia

Scientific name: ***Gouania vitifolia***

Hawaiian name: Oahu Chewstick

Family: Rhamnaceae

Federal status: Listed Endangered June 27, 1994

Requirements for MIP Stability

- 1 Manage for Stability (MFS) Population Unit (PU)
- 50 reproducing individuals in each MFS PU
- Stable Population Structure
- Threats Controlled
- Complete genetic representation of all PUs in storage

Description and Biology

The genus *Gouania* contains approximately 50-70 species pantropical in distribution with three species in the Hawaiian flora. Hawaiian species are of Indo-Pacific affinities but may have been derived from two independent colonization events, one for *G. vitifolia* and one for the other species (Wagener et al. 1990).

Gouania vitifolia is a short-lived perennial vine or climbing shrub with tendrils. Leaves are papery in texture with a moderate to dense covering of short, soft hairs on both surfaces. Leaves are elliptic to broadly oval in shape with toothed (coarsely crenate to serrate-denata) or lobed margins and 3 to 8 cm (1.2 to 3.2 in) long and 2 to 4.8 cm (0.3 to 0.04 in) wide. Small white flowers are arranged in axillary spikes 0.8 to 7 cm (0.3 to 2.8 in) long. The winged (2-3) fruits are 9-10 mm (0.4 in) long and contain small, oval, glossy, and dark brown seeds about 3.4 to 5 mm (0.1 to 0.2 in) long (Wagener et al. 1990).

Flowering of *G. vitifolia* has been observed November through June and fruiting November through August. The reproductive biology of this species is classified as self-incompatible and is described as being functionally dioecious with polygamous flowers (St. John, 1969). However, Sakai et al. (1995) describe the breeding system of *Gouania* in Hawaii as monoecious or andromonoecious. Further study of this species breeding system may be warranted. *Gouania vitifolia* is likely insect pollinated; however, seed dispersal mechanisms are unknown. Plants appear to survive for 10 to 18 years in the wild and tend to form large clonal, viney mats.

Known Distribution and Habitat: *G. vitifolia* is endemic to the Hawaiian Islands. Historically this species was known from the islands of Oahu, Maui, and Hawaii, however, it is currently known to be extant on Oahu and Hawaii. On Oahu, *G. vitifolia* historically was known from the northwest Waianae Mountains, in Makaleha, Keaau, and Waianae Kai valleys (US Fish and Wildlife 2007). Today the only known remaining wild plants exist in Keaau. *Gouania vitifolia* on Oahu occurs on the sides of ridges and gulches in dry to mesic forests at elevations of 39 to 978 m (128 to 3,208 ft).

Taxonomic Background: *G. vitifolia* is one of three endemic species of *Gouania* in the Hawaiian Islands. *G. hillebrandii* and *G. meyenii* are described as erect to sprawling shrubs as compared to the climbing habit of *G. vitifolia*. *G. hillebrandii* is currently extant on Molokai, West Maui, and Hawaii Island, and *G. meyenii* on Kauai and Oahu. All three *Gouania* species are listed as endangered.

Table 1. Historic collections of *G. vitifolia* on Oahu. Data compiled from Bishop Museum Herbarium Records provided by Bishop Museum, 2022.

Area	Year	Collector
Waianae	1840	US Exploring Expedition
Keaau Valley	1929	G.W Russ
Keaau Valley	1932	O. Degener
Waianae Kai	1990	J.K. Obata
Keaau Valley	2005	S. Perlman

Table 2. Reproductive Biology Summary of *G. vitifolia.*

	Observed Phenology*			Reproductive Biology		Seeds	
MFS Population Unit	Flower	Immature Fruit	Mature Fruit	Breeding System	Suspected Pollinator	Average # Per Fruit	Dormancy
Keaau	Nov.-June	Jan.-Aug.	Nov.-Aug.	Functionally Dioecious	Insect	2-3	Physical (PY)

*Observed Phenology is based on field observations at each site. Actual duration of reproductive status is likely longer that those observed.

Plant Morphology and Habitat (Images)

Figure. 1. *G. vitifolia* inflorescence, axillary spike with actinomorphic flowers (left); Papery leaves with toothed margins (right)

Figure 2. Immature fruit (left); Mature fruit (right)

Figure 3. Mature fruit and Seed (left); Propagated seedling with cotyledons (right)

Figure 4. Climbing habit of *G. vitifolia* at Keaau (left); Tendril (right)

Table 3. Habitat characteristics of each Population. Average Annual Rainfall data is from the Rainfall Atlas of Hawaii (Giambelluca et al. 2013 and 2014). All other data from ANRPO observations.

MFS PU	Pop. Ref. Code	Elev. (feet)	Slope	Canopy Cover	Topo.	Aspect	Average AnnualMax.Temp. (F)	Average Annual Rainfall (mm)
Keaau	KEA-A *in situ*	360	Moderate-Steep	Open	Mid Slope	N/NW	84	652
Keaau	KEA-B reintro	787	Moderate	Open	Mid Slope	N	82	619

Table 4. List of Associated Species (six letter code = first three letters of genus, followed by first three letters of species), in alphabetical order, for each MFS Population Unit (PU) for both canopy and understory. Bold text indicates endemic and indigenous taxa.

PU	PRS	Canopy	Understory
Keaau	KEA-A,B	**DioSan, DodVis, ErySan, MyoSan, PolSan, PsyOdo, SapOah**, FicMic, LeuLeu, MomCha, SchTer	**ArtAus, CheOah, ColAus, CocOrb, DodVis, DorDec, PepBla, PluZey, SidFal**, AbuGra, AgeAde, AgeCon, AgeRip, BudAsi, ComDif, ConBon, ConCan, IpoCai, KalCre, MalCor, MegMax, MesPec, StaGig

Image Redacted Sensitive Information Available Upon Request

Figure 5. Map of current and historic *G. vitifolia* populations.

Current Status

There are currently two existing Population Units (PU) of *G. vitifolia* on Oahu, Keaau and Waianae Kai. Keaau is designated as a Manage for Stability (MFS) PU and Waianae Kai as a Genetic Storage (GS) PU (Table 5 and 6). When the species was listed in 1994, the only known occurrences were two areas totaling eight individuals in Waianae Kai. However, since listing the number of wild individuals increased in Keaau PU, largely due to increased survey efforts, whereas the Waianae Kai PU declined (US Fish and Wildlife 2007). In August, 2018, a wildfire, thought to be started by arson, burned 2,023 ha (5,000 acre) in the Waianae, Keaau, and Makaha valleys. The fire destroyed many *G. vitifolia* plants in the Keaau Forest Reserve at the *in situ* Population Reference Site (PRS) KEA-A. In 2011 there were five plants remaining at the Waianae Kai occurrence, WAI-A; however, there has been much discussion about whether or not these five plants were in fact one individual. In 2017, one or multiple plants engulfed the entire fence enclosure surrounding this occurrence. A complete census was conducted in April 2022 and all plants observed alive in 2017 were observed dead. In addition, no new plants were found. As such the WAI-A PRS is currently extirpated. There is little hope that this PU will be able to recover from the seed bank as plants have never been observed producing seed; regardless, ANRPO will make some effort to monitor WAI-A for new plants. A large erosion or rock fall event from the cliffs above the site is likely responsible for the death of the remaining plants, through smothering of stems. In response to the 2018 fire ANRPO established a reintroduction, KEA-B, in the winter 2020 within the Keaau Hibiscus MU and enclosure near the KEA-C *Hibiscus brackenridgei* subsp. *mokuleianus*, and DOFAW augmented the remaining wild plants at KEA-A the same year. ANRPO is currently managing genetic storage for this taxon and the reintroduction at KEA-B in the Hibiscus fence, while DOFAW is managing the *in situ* KEA-A site, and the augmentation, KEA-E, in the fence at the Keaau Forest Reserve.

Table 5. Population Units for *G. Vitifolia.* MFS = Manage for Stability; GS = Manage for Genetic Storage.

Population Unit	Management Designation	PU Type	Action Area (In/Out)	Management Units for Threat Control
Keaau	MFS	*In situ* and reintro	In	Keaau No MU
Waianae Kai	GS	*In situ*	Out	Waianae Kai No MU

Table 6. Stabilization Goal Status. Yes/No/Partial refers to if control is in place for each PU.

	PU Stability Target		MU Threat Control					Genetic Storage
Population Unit	50 reproduc-ing plants	Stable Population Structure	Ungulate	Slugs	Rodent	Fire	Weeds	% Completed
Keaau	No	No	Yes	No	No	No	Partial 20%	94%
Waianae Kai	---------	---------	Yes	No	No	No	No	0%

Shading=Threat to Taxon within Population Unit

No Shading= Absence of threat to Taxon within Population Unit

Population Trends and Structure: Manage for Stability Population Units

It is assumed that *G. vitifolia* lives between 10 and 18 years in the wild. ANRPO monitoring data supports this assumption with wild plants observed living at least 13 years in the wild. See Table 7 for current plant numbers for each MFS PU. Specific population trend and structure information for each MFS PU is provided in the following sections.

Table 7. Current Plant Numbers

Population Unit	Current Matures	Current Immatures	Current Seedlings
Keaau	5	50 + 43 (state augmentation)	0

Keaau

This PU consists of three PRSs: KEA-A, KEA-B, and KEA-E. KEA-A is the *in situ* or wild occurrence, KEA-B is a reintroduction and KEA-E is an augmentation of KEA-A. Both KEA-A and E are located in the DOFAW Gouania fence and KEA-B is in the ANRPO Hibiscus fence. The Keaau PU was first monitored at KEA-A in 2005 with 50 plants and the population peaked in 2012 with 60 mature plants, one immature plant, and one seeding and remained relatively stable until the fire of 2018. Due to the impacts of the fire, the population crashed to just 2 mature plants in August 2018. Thorough monitoring in May 2022 revealed two additional mature plants and three immatures (Figure 6). In winter of 2020, ANRPO established the KEA-B reintroduction in the Hibiscus fence. Twenty-five plants were initially planted and 34 were added in the winter of 2021. Survivorship at KEA-B since initial planting is 81.36% and current population structure is one mature plant and 47 immature plants. DOFAW staff outplanted 43 plants to augment the wild plants at KEA-A in winter 2020, but a follow-up monitoring has not yet taken place.

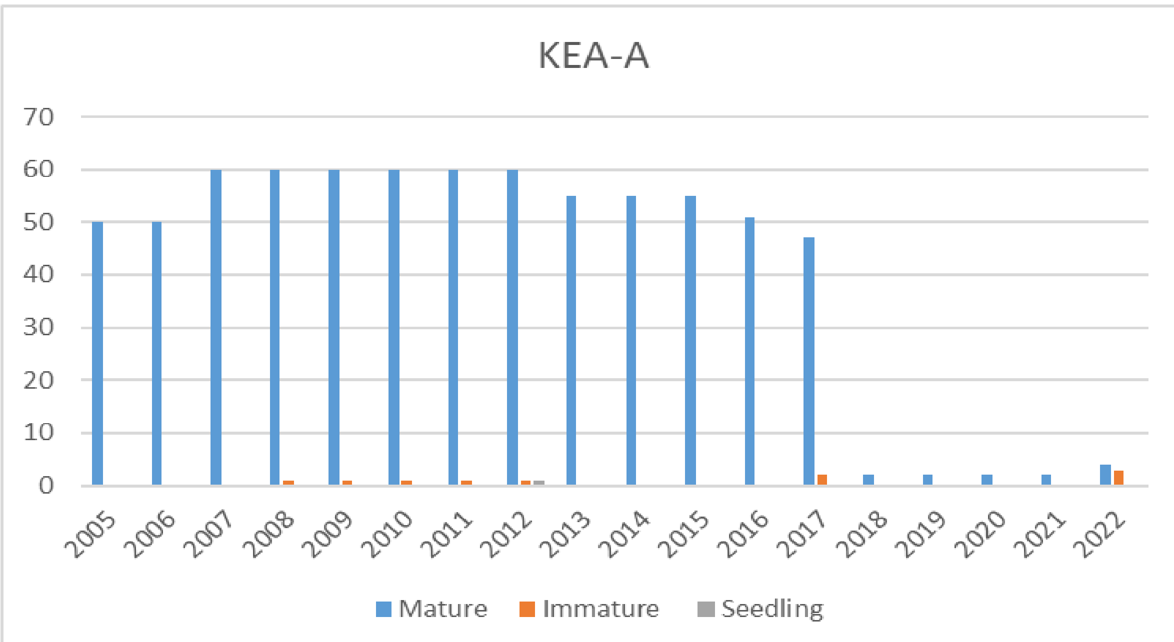

Figure 6. *G. vitifolia in situ* KEA-A population structure for mature and immature plants, and seedlings.

Current Outplanting Considerations

Outplantings for *G. vitifolia* were first initiated in winter 2020 in response to the 2018 fire which resulted in a 96% decline in the Keaau population unit. ANRPO will continue to manage the reintroduction in the Keaau Hibiscus fence, adding more plants to the site through time to achieve representation of 50 or more wild founders on site. Twenty-three founders are currently represented in this reintroduction. DOFAW staff will continue to manage the augmentation of the wild site, KEA-A, at KEA-E. ANRPO will support DOFAW efforts to expand this augmentation through limited support with site preparation and by supplying propagules for outplanting. ANRPO currently has no plans to establish new PUs. Most of ANRPO's focus has been on securing genetic storage, and ensuring an adequate supply of propagules for future reintroduction efforts. Complete stabilizations goals were never established for this taxon as the Keaau PU is situated within the Army training low fire risk zone, on the edge of the Action Area. Depending on the final outcomes of the current consultation with the Fish and Wildlife Service, ANRPO may have to expand conservation measures for this taxon. An expansion of the Action Area would likely require the designation of a minimum of two additional Manage Reintroduction for stability (MRFS) PUs outside of the Action Area. Future MRFS PU could include Makaha, Manuwai, Waianae Kai, Kealia, Kaluakauila or Kuaokala. If DOFAW decides to establish a new MRFS PU at one of these locations, ANRPO will support this effort by propagating plants for the reintroduction.

G. vitifolia is highly vulnerable to the impacts of climate change with a vulnerability score of 0.577 (scale 0-1 (not vulnerable – extremely vulnerable)) (Fortini *et al.* 2013). When selecting future outplanting sites beyond Keaau, climate variables should be considered. Dr. Lucas Fortini (USGS) has developed future climate range maps, examples of which were originally presented at the 2019 IT meeting, for the majority of ANRPO management taxa. Two maps were developed for *G. vitifolia*, one based on current climate conditions and the other on past conditions. The range map based on present climate uses current climate conditions at a taxon's sites as a baseline, and predicts where these climate conditions will exist in 30 years. The range map based on past climate uses historical climate conditions at a taxon's sites as a baseline, and predicts where these climate conditions will exist in future. The 'past climate' range map is a more conservative model, as it is assumed that current climate conditions are already impacted by climate change. Figure 7 shows current climate conditions (left) and future climate conditions (right) base on present climate. These maps can be used as guides for future reintroduction and management site selection. However, these maps are models that provide us more information regarding future range changes, but do not account for habitat quality.

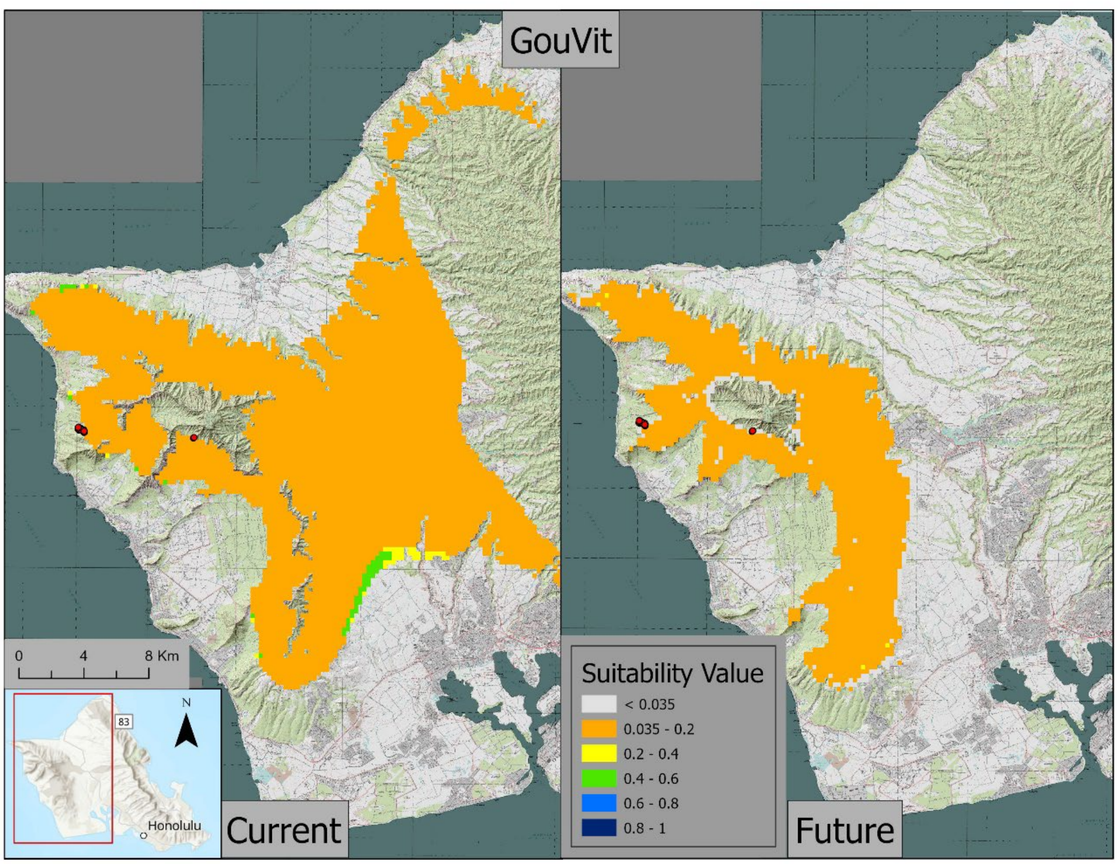

Figure 7. Map presenting current climate conditions (left) and climate conditions 30 yrs in the future (right)

Reintroduction Plan

The proposed outplanting sites are designed to maintain population size to meet the stability goal for the number of reproducing individuals (Table 8).

Table 8. Future proposed outplantings sites for *G. vitifolia* to meet the stabilization goal of 50 reproducing individuals per Population Unit (PU). The propagule type for each planting will be immature plants grown from seeds from wild plants or the living collection at Kahua.

Manage for Stability Population Units	Reintroduction Site(s)	Propagule Source	Total Number of Plants to be planted	2023	2024	2025	2026	2027
Keaau	KEA-B	KEA-A	75	0	25	25	25	0

ANRPO will continue to manage the KEA-B reintroduction. Staff will continue to outplant propagules until 50 wild individuals are represented in this reintroduction. Beyond this, plants will be added to support stabilization goals of 50 reproducing individuals. Plants will be outplanted in small numbers through time, rather than in one outplanting event, to ensure common species outplants already planted on site are of size to serve as habitat (natural trellises) for *G. vitifolia*. Special consideration should be given not to plant *G. vitifolia* in close proximity to outplants or wild plants of *Hibiscus brackenridgei* subsp. *mokuleianus*. *G. vitifolia* is an aggressive climber and can smother the other plants.

Monitoring Plan

KEA-B will be monitored annually using the HRPRG Rare Plant Monitoring Form to record population structure and the age class, reproductive status and vigor of all known plants. This site will also be surveyed for new seedlings and juvenile plants. Monitoring data will serve to document population trends and structure, which will be used to guide *in situ* management strategies in the future.

Threats

The major threats to *G. vitifolia* in the Keaau PU include ungulates, alien plants, and fire. Goats and pigs damage this species' habitat and directly harm plants through predation, trampling, and rooting for food sources. Alien plants negatively impact this species by altering habitat conditions and competing for moisture, nutrients, light, and space. Alien invasive plants also exacerbate potential fire conditions through increased fuel loads. Current threat control strategies at KEA-B include the removal and herbicide treatment of invasive plant species competing with outplants and to reduce fuels. From a fire protection standpoint the goal is to remove invasive species, largely *Megathyrsus maximus*, *Melinis repens*, and *Leucaena leucocephala*, in a 15-meter buffer straddling the fence and within the interior to reduce fuel loads. Particular focus is given to controlling invasive species around individual outplants. Maintaining the 15-meter buffer is ongoing, which requires a significant input of labor. Active restoration efforts within the fence are replacing ecological space previously occupied by invasive plants with common native species. Much of these efforts have been focused in the "South Bowl" where *M. maximus* has dominated. The 2007 Re-initiation of the 1999 Biological Opinion lists rodents as threat to *G. vitifolia*. To date rodent damage on this taxon has not been observed, and therefore rodents are not controlled at KEA. However, if rodent damage is observed in the future, an appropriately scaled trap grid can be installed quickly.

Genetic Storage Plan

Gouania vitifolia seeds are desiccation tolerant and store at negative temperatures. Therefore, these seeds exhibit orthodox storage behavior, making them prime candidates for genetic storage in conventional seed bank conditions (Table 9). Currently, Keaau PU is at 94% genetic storage complete. Seed collections made from the living collection established at Kahua, the seed orchard located at Schofield Barracks, will be used to maintain genetic storage goals and as a source of propagules for future outplantings. Testing for the proposed re-collection interval for seed storage at ≥15 years is currently ongoing; based on past testing results, the re-collection interval likely to continue to increase. Germination protocols have been established and seeds are found to have physical dormancy. This may suggest seeds are likely to form a persistent soil seed bank and will likely have long-term *ex situ* storage potential. Average seed viability for *G. vitifolia* collections in storage at ANRPO is relatively low at 34.94%. Initial viability of incoming collections from both wild and cultivated sources varies considerably, ranging from 0- 100%. Re-collection intervals will continually be extended until a decline in viability is detected.

Due to this species potential for long-term storage at negative 20ºC, living collections will not be maintained in the ANRPO nursery. Plants will be grown instead to fulfill propagation needs for outplanting and the establishment of seed orchards. Thirty-two wild founders with ≤ 50 viable seeds in storage were selected and propagated and together with plants remaining in the living collection. These plants, previously held at the Pahole Rare Plant Facility (Nike), were combined to establish an orchard at Kahua on Schofield Barracks to increase the number of viable seeds to satisfy genetic storage goals and ensure a ready supply of propagules for future restoration efforts. The orchard was established in 2018, once it was determined that *G. vitifolia* would survive and thrive at the site. The first seed collection was made from Kahua in August 2019 and in July 2020, collections began flowing in. As of July 1st, 2022, ANRPO has met its goals for 47 founders from the Keaau PU. Once goals are met for 50 founders, ANRPO will continue to maintain the Kahua seed orchard and new founders if and when they become available. Future collections will be used to create backup storage at Lyon Arboretum and ANRPO will also make seeds available to partner organizations for restoration activities. Once backup storage is established at Lyon Arboretum, the living collection will be retired or moved to a new location off U.S. Army lands, such as Koko Crater Botanical Garden.

Table 9. Action plan for how to maintain genetic storage representation and provide propagules for reintroductions.

What propagule type is used for meeting genetic storage goal?	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	*Inter situ* collections made from living collections established at Kahua, Schofield Barracks	Seed Storage: -18C / 20% RH	≥15	Yes	Seed storage

Management Discussion

The primary goal for this taxon for the next five years will be to manage the reintroduction at KEA-B and the seed orchard at Kahua. Full monitoring will be conducted annually at KEA-B and threat control will continue with particular focus on reducing fuel loads on site through continued maintenance of the 15-m buffer around the MU and the removal of flammable alien grass around outplants. The expansion of the reintroduction will continue with the addition of 75 plants between 2024 and 2026 ensuring outplants of 50 wild individuals are represented and to maintain 50 reproducing individuals on site. Seed collected at Kahua will be used to establish duplicate collections at Lyon Arboretum. ANRPO expects to initiate these collections in 2023. Given that there are far less than 50 individual founders left in the wild, *G. vitifolia* is in a phase of quasi-extinction, where environmental or demographic stochasticity could result in extirpation from the wild (Fish and Wildlife 2007). Seeds from the Kahua orchard will be provided to DOFAW to support continued efforts to augment the remaining wild founders at KEA-A, or to establish an additional reintroduction in a less fire-vulnerable location. Also, seed will be made available to partner organizations to augment and restore populations on Hawaii Island and to reintroduce plants at historic locations on Maui.

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Updated Five Year Management Plan for *Cyanea grimesiana* subsp. *obatae*, 2009, 2022

Cyanea grimesiana subsp. *obatae*

Scientific name: *Cyanea grimesiana* subsp. *obatae*

Hawaiian name: *Haha, ohawai*

Family: Campanulaceae (Bellflower family)

Federal status: Listed endangered July 27, 1994

Requirements for Stability

- 4 Manage for Stability (MFS) Population Units (PUs) (4 due to presence in two action areas)
- 100 reproducing individuals in each PU (short-lived perennial with large fluctuations in population size and recent history of decline)
- Stable population structure
- Threats controlled
- Complete genetic representation of all PUs in storage

Description and biology

Cyanea grimesiana subsp. *obatae* is a shrub 1-3.2 m tall, and is either single-stemmed or sparingly branched. The leaves are pinnately divided, measure 27-58 cm long, and are clustered towards the tips of the stems. The six to 12 flowered inflorescences are borne among the leaves. The corollas are curved, usually yellowish white with purple and measure 55-80 mm long. The berries are orange at maturity, and measure 18-30 mm long.

As with other *Cyanea* spp. with their long tubular flowers, this taxon is thought to have been pollinated by nectar-feeding birds. It is capable of self-pollination, evidenced by the fact that isolated plants produce viable seeds. The taxon's orange berries are indicative of seed dispersal by fruit-eating birds. *Cyanea grimesiana* subsp. *obatae* presumably lives for less than 10 years like other *Cyanea* spp. of its size, and is thus a short-lived taxon for the purposes of the Implementation Plan (MIT 2003).

Known distribution and habitat: *C. grimesiana* subsp. *obatae* was discovered in 1965 and until the 1990s, was known only from the southern and central Waianae Mountains. The species is now also known from the Mokuleia region of the northern Waianae Mountains and from Makaha Valley. It ranges from 550-670 meters in elevation.

Cyanea grimesiana subsp. *obatae* grows in mesic forests, usually in partly sunny to shady locations in gulch bottoms or on gulch slopes. The plants often grow on steep to vertical embankments consisting of rock or a mix of rock and soil.

Taxonomic background: *Cyanea grimesiana* includes two subspecies, subsp. *obatae* and subsp. *grimesiana*, and has been recorded primarily in the Koolau Mountains of Oahu, but has also been found in the northern and central Waianae Mountains and on Molokai. The two subspecies are distinguished by the size and shape of their calyx lobes. Certain *Cyanea* populations on Molokai, Maui, Lanai, and Hawaii formerly included in *C. grimesiana* have recently been recognized as constituting three separate species (Lammers 1998).

Population trends (From 2009): Most of the *C. grimesiana* subsp. *obatae* population units have not been known for very long, but many of those that have been tracked for at least 15 or 20 years have either died out or declined markedly. The known Ekahanui plants had died by 2004. The wild population at the Palikea (South Palawai) site has grown significantly from 18 individuals in 1999 to 52 in 2009. The plant in Central Kaluaa was discovered in 2004 and an immature plant was observed there in 2009. The South Kaluaa plant died in 2005. The Makaha plant was discovered in 2005. The Palikea Gulch PU was discovered in 1999 and has not yet matured.

Table 1. Updated Reproductive Biology Summary of *Cyanea grimesiana* subsp. *obatae.*

	Observed Phenology*			Reproductive Biology		Seeds	
MFS Population Unit	Flower	Immature Fruit	Mature Fruit	Breeding System	Suspected Pollinator	Average # Per Fruit	Dormancy
Kaluaa	March-Oct.	May-Dec.	July-Feb.	Hermaphroditic	Bird	354 ± 296	Dormant MD or MPD**
North Branch of South Ekahanui	May-Dec.	July-March	Sept.-March	Hermaphroditic	Bird	400 ± 289	Dormant MD or MPD**
Pahole to West Makaleha	July-Dec.	Sept.-Jan.	Oct. to Jan.	Hermaphroditic	Bird	328 ± 234	Dormant MD or MPD**
Palikea (South Palawai)	July-Nov.	Sept.-Jan.	Oct.-March	Hermaphroditic	Bird	570 ± 239	Dormant MD or MPD**

*Observed Phenology is based on field observations at each site. Actual duration of reproductive status is likely longer that those observed.

** MD= Morphological Dormancy; MPD= Morphophysiological Dormancy

Plant Morphology and Habitat (Images)


Figure 1. Flowering plant in south Ekahanui (left); Flowering plant in Makaha (right)

Figure 2. Flowering plant in Makaha (left); Reintroduction at Kaluaa, planting on gulch slopes in mesic forest (right)

Figure 3. Immature fruit (left); Mature fruit (left)

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ARMY NATURAL RESOURCES PROGRAM O'AHU

Figure 4. Map of current and historic *C. grimesiana* subsp. *obatae* populations

Current Status

Since the finalization of the MIP in 2003 the total number of plants of *C. grimesiana* subsp. *obatae* have increased through time largely due to outplanting efforts. A huge peak in plant numbers was observed in the winter of 2016/2017 as the result of over 900 plants outplanted at the PAK-C reintroduction in Palikea. Since the establishment of the PAK-C reintroduction, total plant numbers have declined 27% (Figure 5). Significantly higher plant numbers were observed at all MFS PUs for this taxon in 2022 as compared to 2005, except for Kaluaa where plant numbers declined by 34% despite outplanting efforts (Figure 6). Currently, the known PUs for *C. grimesiana* subsp. *obatae* total 1,201 plants, with 821 mature plants, 378 immature plants, and two seedlings. This represents an 85% increase in total number of plants since 2005. High mortality rates of outplanted individuals have been observed and natural regeneration or recruitment at reintroduction sites has been limited through time with few F1 individuals surviving to maturity. However, to date recruitment has been observed in all MFS PUs at some point in time and two of the four MFS PUs support F1 regeneration at all age classes and one with immature plants only. PUs for *C. grimesiana* subsp. *obatae* include three MFS PUs, one Manage Reintroduction for Stability (MRFS) PU and one Genetic Storage (GS) PU (Table. 2). One MFS PU currently meets one stabilization goal, with more than 100 reproducing individuals. Two PUs meet a different stabilition goal, with 100% genetic storage complete (Table 3). None of the four MFS PUs meet stabilization goals for threats controlled, however, all threats are at least partially controlled at all PUs.

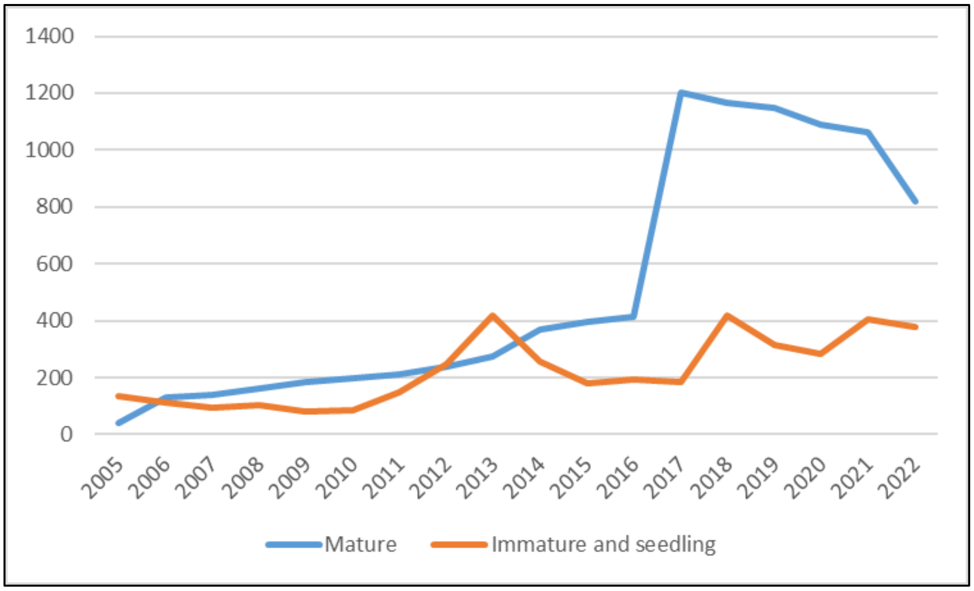

Figure 5. Total number of mature plants compared with total number of immature and seedlings for all PU over time.

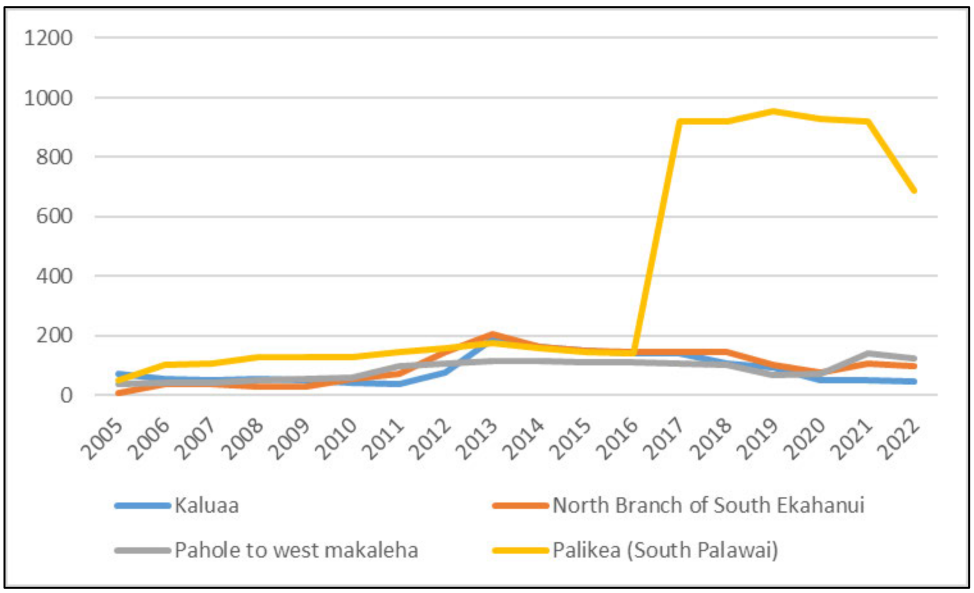

Figure 6. Total number of plants for each MFS PU over time.

Table 2. Population Units for *C. grimesiana* subsp. *obatae.* MFS = Manage for Stability; GS = Manage for Genetic Storage.

Population Unit	Management Designation	PU Type	Action Area (In/Out)	Management Units for Threat Control
Kaluaa	MFS	*In situ*/Reintro	Out	Kaluaa and Waieli
North Branch of South Ekahanui	MRFS	Reintro	Out	Ekahanui
Pahole to West Makaleha	MFS	*In situ*/Reintro	In	West Makaleha, Pahole
Palikea (south Palawai)	MFS	*In situ*/Reintro	Out	Palikea
Makaha	GS	Reintro	Out	Makaha II

Table 3. Stabilization Goal Status. Yes/No/Partial refers to if control is in place for each PU.

	PU Stability Target		**MU Threat Control**					Genetic Storage
Population Unit	100 reproduc-ing plants	Stable Population Structure	Ungulate	Slugs	Rodent	Fire	Weeds	% Completed
Kaluaa	No	No	Yes	Partial 20%	Partial 70%	No	Partial 100%	60%
North Branch of South Ekahanui	No	No	Yes	Partial 100%	Partial 100%	No	Partial 100%	100%
Pahole to West Makaleha	No	No	Yes	Partial 33%	Partial 38%	No	Partial 100%	88%
Palikea (South Palawai)	Yes	No	Yes	Yes	Yes	No	Partial 100%	71%
Makaha	---------	-----------	Yes	Partial 100%	Yes	No	Partial 100%	100%

Shading=Threat to Taxon within Population Unit

No Shading= Absence of threat to Taxon within Population Unit

Population Trends and Structure: Manage for Stability Population Units

The MIP assumed *C. grimesiana* subsp. *obatae* to live less than 10 years and treated it as short-lived taxa for purposes of the Implementation Plan. However, monitoring data revealed that plants from reintroductions survive for up to 14 years. More monitoring data for specific founder plants is needed to better understand longevity of *C. grimesiana* subsp. *obatae in situ.* See Table 4 for current plant numbers for each MFS PU. Specific population trend and structure information for each MFS PU is provided in the following sections.

Table 4. Current Plant Numbers.

Population Unit	Current Matures	Current Immatures	Current Seedlings
Kaluaa	21	26	0
North Branch of South Ekahanui	60	38	0
Pahole to West Makaleha	63	62	0
Palikea (South Palawai)	662	23	2

Kaluaa

This PU is located in the southern Waianae Mountains in the Kaluaa and Waieli MU and consists of five PRS sites, KAL-A, KAL-B, KAL-C, KAL-D, and KAL-E. KAL-A and KAL-B are the *in situ* PRSs within this PU. The last plant at KAL-A was observed dead in 2005, while KAL-B has four mature plants and two immature plants remaining. Of the three reintroduction PRSs, KAL-D has the largest number of plants remaining with six mature plants and 20 immature plants, whereas KAL-E has 10 mature plants and just three immature plants, one of which is a F1 recruit. The Kaluaa PU peaked in 2015 due to outplanting efforts with 128 mature plants, but declined 80% by 2022. This decline would suggest that outplants of this taxon exhibit a high rate of mortality. Trends observed at KAL-D are reflective of overall population trends in this PU through time (Figure 7).

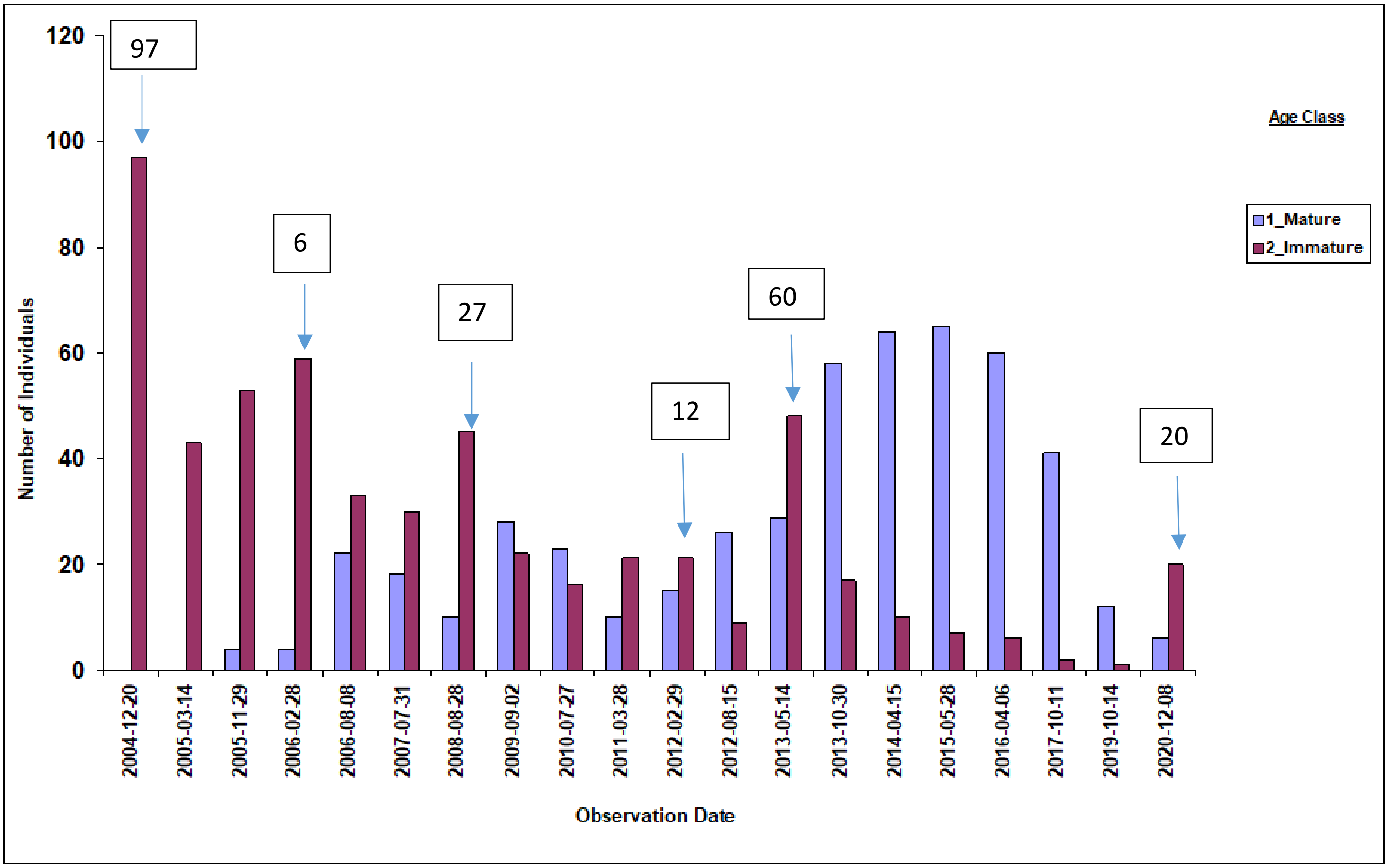

Figure 7. *C. grimesiana* subsp. *obatae* reintroduction KAL-D population structure for mature and immature plants, and seedlings. Numbers with arrows indicate when outplants were added to the site.

North Branch of South Ekahanui

This PU consist of just two PRSs in the Ekahanui MU in the southern Waianae Mountains. EKA-A is the *in situ* PRS and the last remaining plants on site were observed dead in 2004. The reintroduction at EKA-C is the only other PRS in this PU. The PU's population structure has remained relatively stable through time. Plant numbers increased to 83 mature plants in 2015 and only decline 28% by 2022 (Figure 8). Although plants have been added to this site through time, it currently sustains 10 F1 mature plants and 3 F1 immature plants.

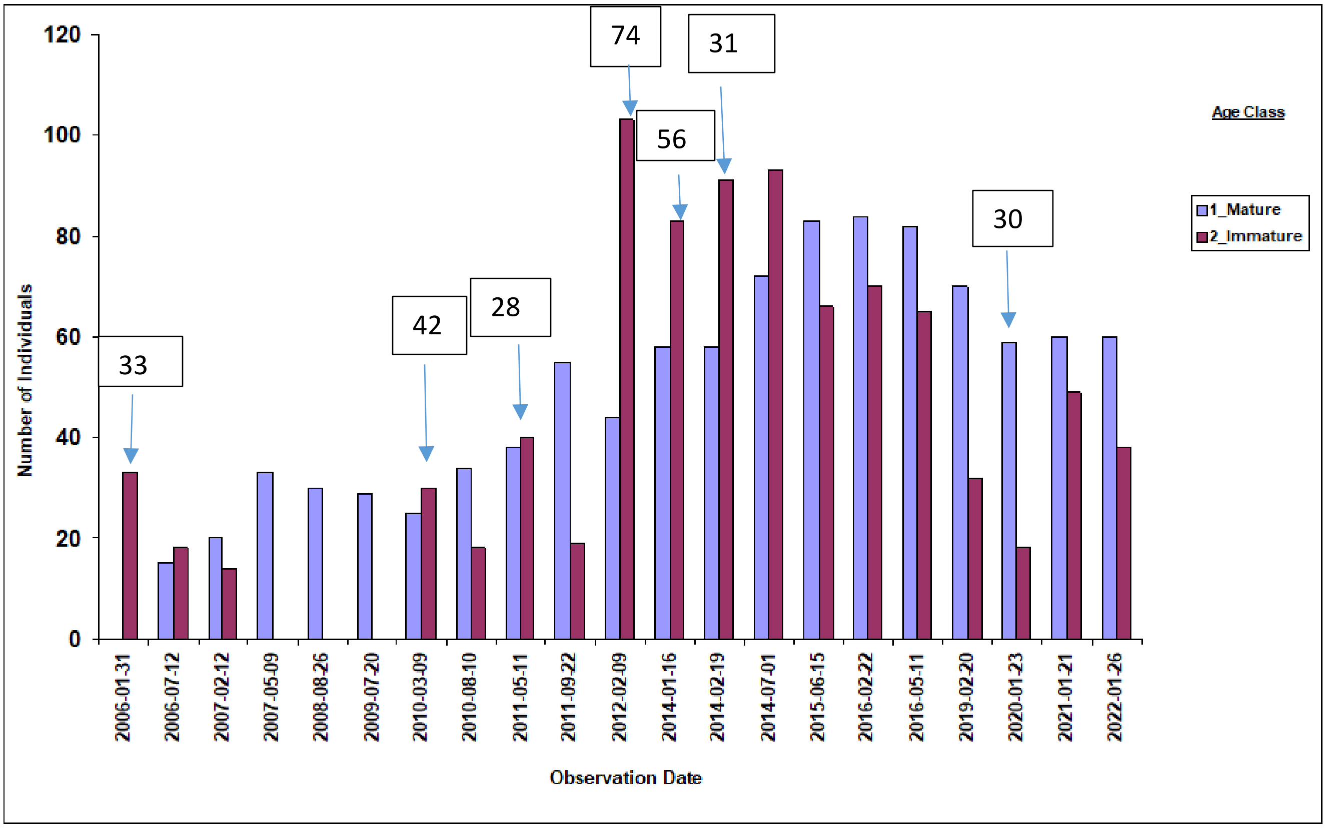

Figure 8. *C. grimesiana* subsp. *obatae* reintroduction EKA-C population structure for mature and immature plants, and seedlings. Numbers with arrows indicate when outplants were added to the site.

Pahole to Makaleha West

This PU consists of six PRSs in the Makaleha West and Pahole MUs in the Northern Waianae Mountains. There are three *in situ* PUs, one in Makaleha West MU (LEH-A) and two in the Pahole MU (PAH-A and B). The last remaining plants at PAH-A were observed dead in 2005 and PAH-B has only one mature plant remaining. In addition, three reintroductions were established in this PU, LEH-B, PAH-C, and PAH-D. PAH-C is the largest site with 32 mature plants and 62 immature plants. LEH- B and PAH-D have 21 and 1 mature plants respectively and there are currently no immature plants at either site. The trend in this PU is similar and intermediate to that of the North Branch of South Ekahanui and Kaluaa PUs. Plant numbers increased through time due to outplanting efforts and a consistent decline (42%) was observed since the peak in mature plants in 2015 (Figure 9). There is currently no F1 regeneration supported at any reintroduction in this PU, however, recruitment at PAH-C has been observed frequently in past observations.

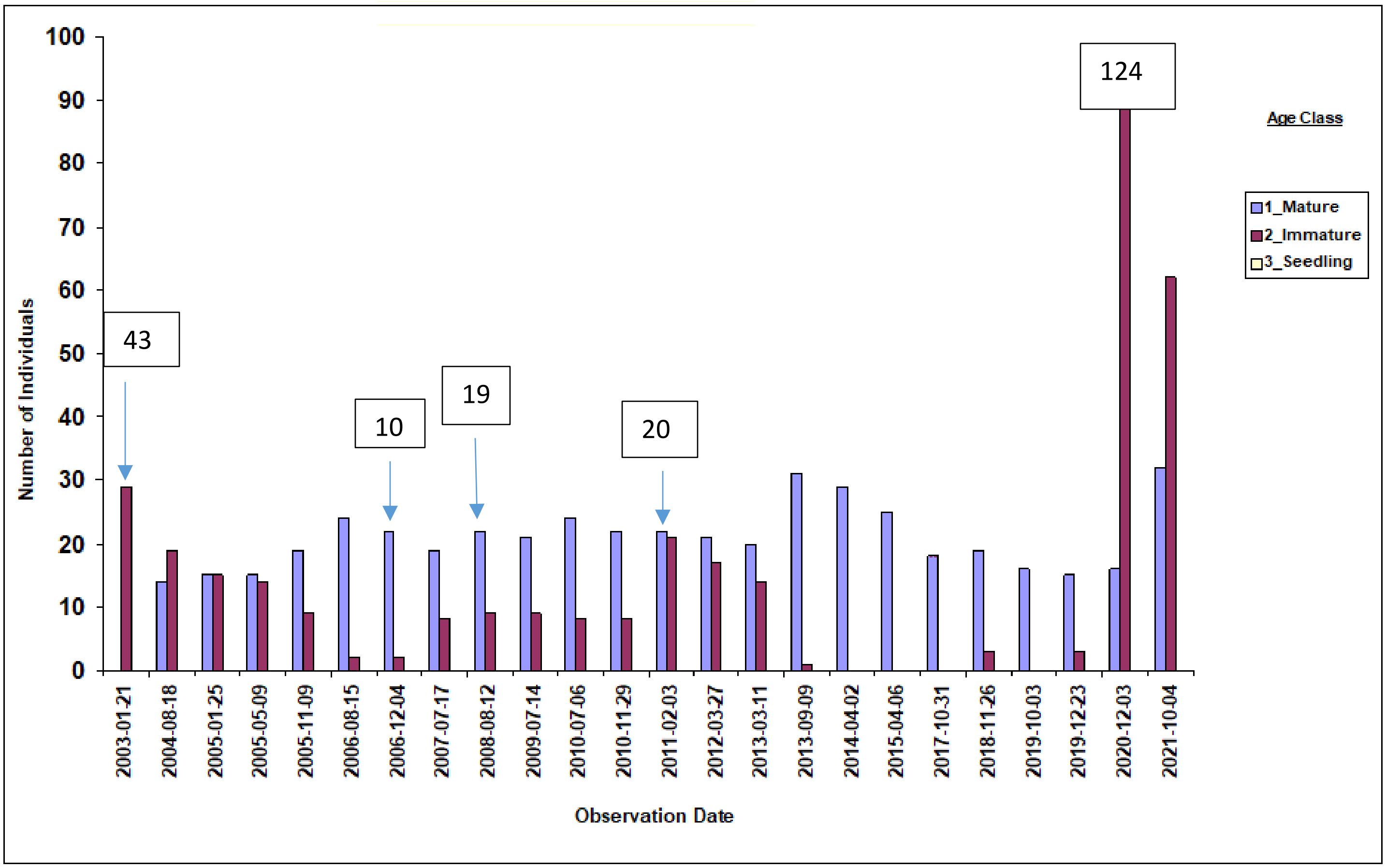

Figure 9. *C. grimesiana* subsp. *obatae* reintroduction PAH-C population structure for mature and immature plants, and seedlings. Numbers with arrows indicate when outplants were added to the site.

Palikea (South Palawai)

This PU consists of one *in situ* and two reintroduction PRSs in the Palikea MU in the southern Waianae Mountains and supports the largest number of *C. grimesiana* subsp. *obatae* plants for this taxon. This is largely due to the establishment of the reintroduction, PAK-C, in winter 2016/2017 with over 800 plants. This PU also hosts the largest *in situ* PRS, PAK-A, currently with 12 mature plants. F1 regeneration has been observed at both the PAK-C and PAK-B reintroductions. Two of the 97 mature plants at PAK-B are F1 mature plants and PAK-C sustains 21 F1 immatures and 2 F1 seedlings, however, recent causal observations would suggest this number is higher. Recruitment has also been observed well outside of the PAK-C reintroduction footprint. Seedlings and immature plants have been observed nearby through time in the South Palikea snail enclosure, the Banyan Breezeway restoration site, and at the *Phyllostegia hirsuta* PAK-A reintroduction. These observations suggest that animals are dispersing fruits. Survivorship of outplants at PAK-C is 68.36% and the total number of mature plants declined by 31% since establishment (Figure 10).

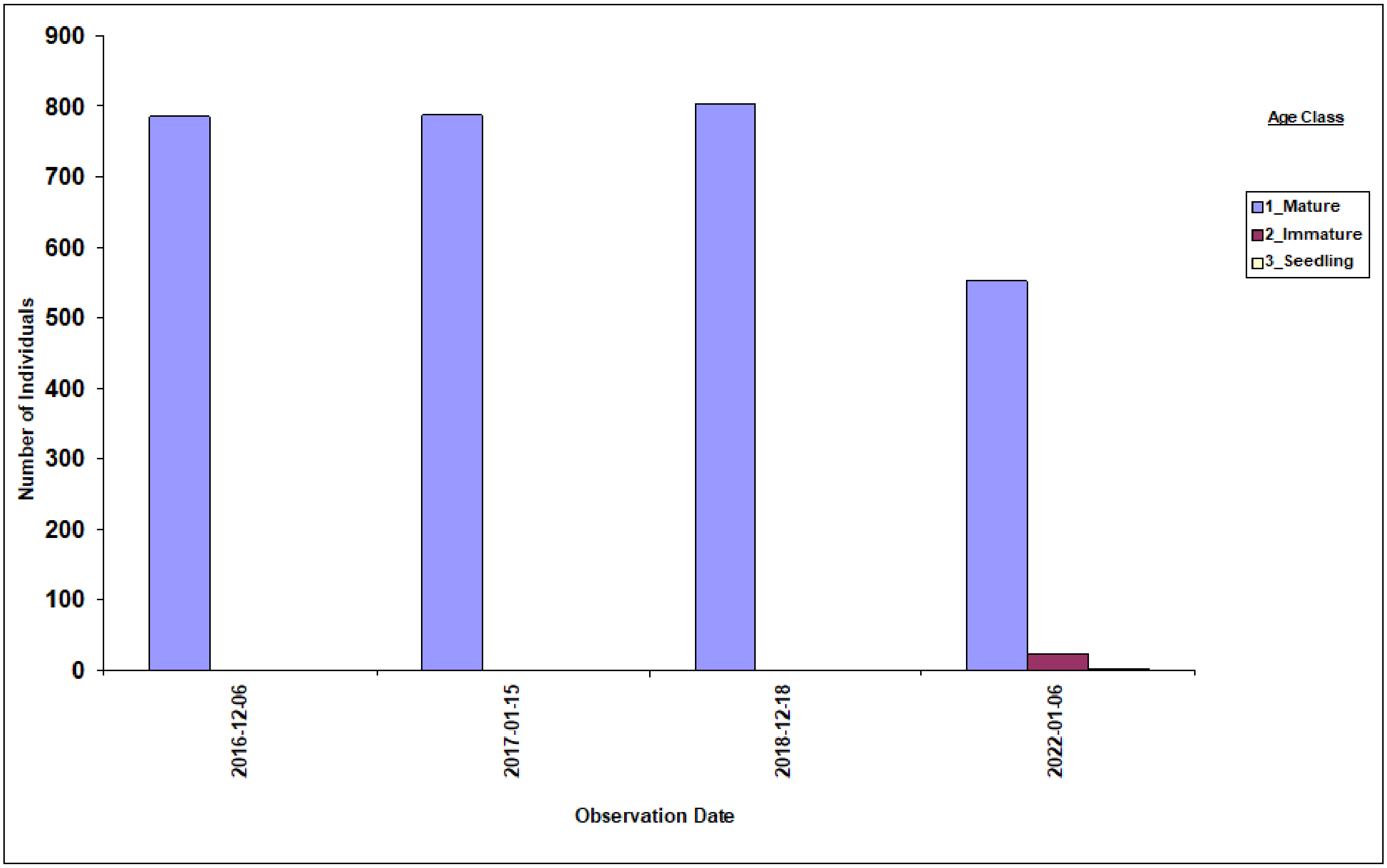

Figure 10. *C. grimesiana* subsp. *obatae* reintroduction PAK-C population structure for mature and immature plants, and seedlings.

Current Outplanting Considerations

C. grimesiana subsp. *obatae* is vulnerable to the impacts of climate change with a vulnerability score of 0.497 (scale 0-1 (not vulnerable – extremely vulnerable)) (Fortini *et al.* 2013). When selecting future outplanting sites climate variables should be considered. Dr. Lucas Fortini (USGS) has developed future climate range maps, originally presented at the 2019 IT meeting, for the majority of ANRPO taxa. Two maps were developed for *C. grimesiana* subsp. *obatae*, one based on current climate conditions and the other on past conditions. The range map based on present climate uses current climate conditions at a taxon's sites as a baseline, and predicts where these climate conditions will exist in 30 years. The range map based on past climate uses historical climate conditions at a taxon's sites as a baseline, and predicts where these climate conditions will exist in future. The 'past climate' range map is a more conservative model, as it is assumed that current climate conditions are already impacted by climate change. Figure 11 shows current climate conditions (left) and future climate conditions (right) base on present climate. These maps can be used as guides for future reintroduction and management site selection. However, these maps are models that provide us more information regarding future range changes, but do not account for habitat quality.

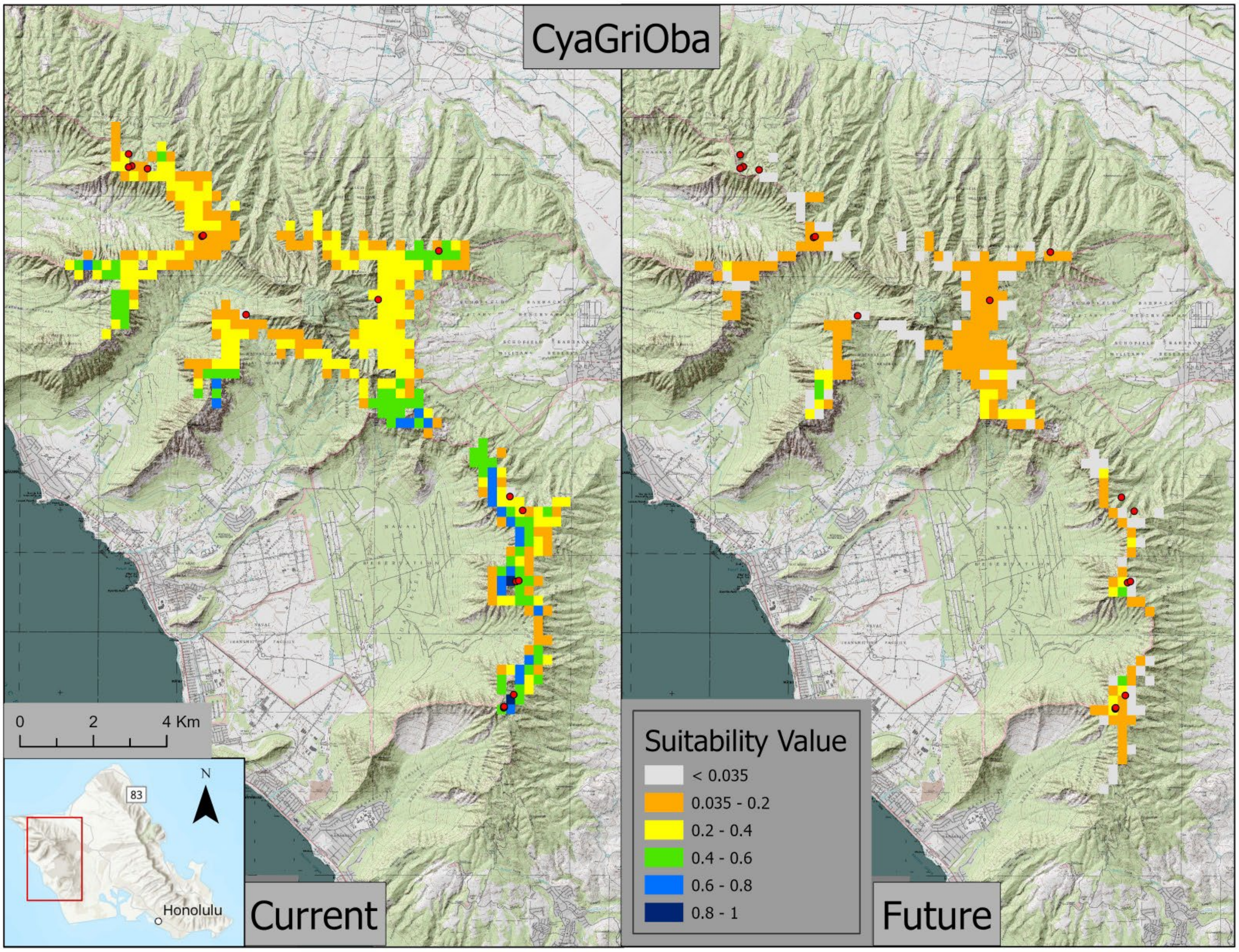

Figure 11. Map presenting current climate conditions (left) and climate conditions 30 yrs in the future (right)

Reintroduction Plan

The proposed outplanting sites are designed to maintain population size to meet the stability goal for the number of reproducing individuals (Table 5). Currently only the Palikea PU meets goals for 100 reproducing individuals.

Table 5. Future proposed outplantings sites for *C. grimesiana* subsp. *obatae* to meet the stabilization goal of 100 reproducing individuals per Population Unit (PU). The propagule type for each planting will be immature plants grown from seeds from wild plants or cuttings collected from seed propagated stock.

Manage for Stability Population Unit(s)	Reintroduction Site(s)	Propagule Source (PU)	Total Number of Plants to be planted	2023	2024	2025	2026	2027
Kaluaa	KAL-D	KAL-A, B	150	100	25	25	0	0
Kaluaa	KAL-E	KAL-A,B	75	0	0	0	50	25
North Branch of South Ekahanui	EKA-C	EKA-A	150	100	25	25	0	0
Pahole to West Makaleha	PAH-C	PAH-A,B; LEH-A	150	100	25	25	0	0

Reintroductions will be prioritized to augment PUs that do not currently meet stabilization goals for the total number of mature plants. Outplanting numbers may need to increase if survival is poor, or if recruitment and development into mature plants is not observed. Outplanting will continue at three of the four MFS PUs as they currently do not meet stabilization goals of 100 mature plants, however, if survivorship were to fall to zero at any of the sites listed in table X over the next five years, new reintroduction sites will be selected and planted.

Monitoring Plan

All PRS within Manage for Stability PU will be monitored annually using the HRPRG Rare Plant Monitoring Form to record population structure and the age class, reproductive status and vigor of all known plants. Surveying for regeneration, new seedlings and juvenile plants, on site will be prioritized at all PRS. New founders and those without 50 viable seeds in genetic storage will be collected during monitoring to increase genetic diversity for future outplanting populations, as well as to meet genetic storage goals. Monitoring data will serve to document population trends and structure, which will be used to guide *in situ* management strategies in the future. Observations of threats impacting plant resources should be clearly documented so that the appropriate control measures can be employed in a timely manner.

Threats

The major threats to *C. grimesiana* subsp. *obatae* include ungulates, rats, alien slugs and snails, and alien plants. Pigs damage this species' habitat and directly harm plants through predation, trampling, and rooting for food sources. Rats threaten this species through predation of its plant parts and fruits, while introduced slugs and snails threaten this species by feeding on its leaves, stems, and seedlings. Alien plants negatively impact this species by altering habitat conditions and competing for moisture, nutrients, light, and space. More specifically incursions of invasive plants can degrade or alter microhabitats necessary for recruitment of *C. grimesiana* subsp. *obatae* seedlings. All known threats to this taxon are currently partially or fully controlled at all MFS PUs. Slugs are expected to greatly reduce the potential for regeneration at both *in situ* and reintroduction sites and efforts are underway to expand slug control for this taxon. All new reintroduction sites for this taxon will be considered for slug control based on the presence or absence of native snail species of concern. The concern is to minimize non-target impacts of Ferroxx AQ, the molluscicide containing iron phosphate, used to control alien slugs and snails.

Genetic Storage Plan

Cyanea grimesiana subsp. *obatae* seeds tolerate desiccation but are freeze sensitive. Seeds are currently stored at 5°C and -80°C at 20%RH. Storage at -80°C is currently experimental and more viability data through time in storage is necessary to determine whether or not -80°C is an appropriate long-term storage method for this taxon and other *Cyanea* species. 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. Besides collections of fruit made for genetic storage and propagation, all other fruit has been left to mature on the plants. Seeds in storage have not shown a decline in viability and the recollection interval for this taxon is ≥ 20 years (Table 6). The 20 year viability test is scheduled for 2026-12-08. Re-collection intervals will continually be extended until a decline in viability is detected.

Average seed viability for *C. grimesiana* subsp. *obatae* collections in storage at ANRPO is 67.90%. Seeds from reintroductions and *in situ* sites will be collected and maintained in genetic storage to preserve representation from individual populations. New wild plants will be tracked closely to maturity and seeds will be collected to bring new founders into the genetic storage collection. Seed collections from reintroductions will be used to maintain genetic storage goals of ≥ 50 viable seeds and to ensure propagules are available for reintroduction. Currently, two PUs, Makaha and North Branch of South Ekahanui, meet requirements with 100% genetic storage complete. Future seed collection efforts should be focused at the three PU with incomplete genetic storage; Kaluaa (60%), Pahole to West Makaleha (88%), and Palikea (South Palawai) (71%).

Table 6. Action plan for how to maintain genetic storage representation, and provide propagules for reintroductions.

What propagule type is used for meeting genetic storage goal?	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* and reintroductions	Seed Storage: 5C/ 20% RH	≥20 years	Yes	Maintain reintroductions for recollection to refresh seed storage

Management Discussion

The primary goal for this taxon for the next five years will be to continue to augment established reintroductions with outplants in the Kaluaa, North Branch of South Ekahanui, and Pahole to West Makaleha PUs. Outplants have exhibited relatively high mortality rate at all sites. Continued outplantings will increase the number of plants at sites to meet stabilization goals, but more importantly will build population structure across all age classes by promoting regeneration or recruitment at reintroduction sites. Outplantings at the Palikea PU are not planned as the PU currently supports 662 mature plants, 23 immatures, and two seedlings. Regeneration has been observed in all PU through time; however, mortality of recruits has been high and few plants have been observed transitioning to the mature age class. Currently the EKC- C reintroduction supports 10 mature F1 recruits and a few immatures, and PAK-C hosts 21 F1 immatures and 2 seedlings; however, recent casual observations identified additional seedlings and one mature F1 plant. Two of the F1 matures currently at EKA-C were first observed as mature plants in 2014. Field staff will continue to employ strategies that promote natural recruitment at reintroduction sites. These strategies primarily include the control of rodents, weeds, and slugs. ANRPO is currently expanding Ferroxx AQ use in all MFS PUs. Monitoring at all MFS PRSs will be conducted annually and developing population structure will be closely monitored. Data on age class distribution and survivorship will be collected and management will be adapted accordingly. Efforts should be made to continue to develop strategies to promote seedling establishment. Seed sow trials on varying substrates or habitat conditions across reintroduction sites should be considered to better understand seedling survivorship across various microhabitats and the rate of transition to the mature age class. More informally, field teams could also carry out seed sows and smears across sites to increase the likelihood of seedling establishment. Laboratory studies conducted by Michelle Akamine (ANRPO 2017) found a significant reduction in viability of seeds left in rotting fruits or undispersed fruit, thus seed sows could be an effective use of seeds that would otherwise “die on the vine”.

The PAK-C reintroduction was initially established as a common garden study including plants resulting from self-pollinations and intra- and inter-population crosses representing all known populations of *C. grimesiana* subsp. *obatae*. Data was collected from 163 randomly selected individuals from across the planting between 2019 and 2020 to measure the fitness of these individuals to better understand the potential genetic consequences (outbreeding depression) or benefits (heterosis) of mixing populations in reintroductions. Mixing populations in reintroduction efforts has the potential to increase reintroduction success by increasing genetic variation and reducing inbreeding depression and the negative effects of genetic drift, demonstrated by the increased fitness of offspring. However, on the other hand crossing of plants from different populations may also have negative consequences, such as outbreeding depression that may reduce fitness of progeny. Plants with small population sizes may be suffering from inbreeding depression that could limit ability to withstand changes in the environment leading to increased risk of extinction; genetic rescue (mixing populations) may be the only strategy to increase reintroduction success and population stabilization. The analysis of the data is currently underway and results are forthcoming. Because of morphological differences between plants of different populations it was recommended in the initial Five Year Management Plan not to mix populations, but to establish reintroductions with founders from single populations. Given that populations of *C. grimesiana* subsp. *obatae* are small, it is likely that the results of this study will suggest mixing stock of founders across populations or using progeny of inter-population crosses used in this study to establish reintroductions. If this is the case, mixed stock reintroduction should be established in each MFS PU. In addition, it could be beneficial to establish large reintroductions, 500+, that might be attractive to native and novel pollinators and dispersers.

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Updated Five Year Management Plan for *Pritchardia kaalae*, 2009, 2022

Pritchardia kaalae

Scientific name: *Pritchardia kaalae*

Hawaiian name: Loulu

Family: Arecaeae (Palm Family)

Federal status: Listed endangered October 10, 1996

Requirements for Stability

- 3 Manage for Stability (MFS) Population Units (PUs)
- 25 reproducing individuals in each PU (long-lived perennial)
- Stable population structure
- Threats controlled
- Complete genetic representation of all PUs in storage

Description and biology

P. kaalae is a fan palm reaching up to 10 m tall (Lau pers. comm. 2000). It is a tree-like plant with a single erect trunk surmounted by a cluster of fronds. The species' inflorescences are very long, nearly reaching the frond tips to often extending well beyond the fronds. The flowers are borne in one or more bunches on the inflorescence. The fruits of *P. kaalae* are globose, and measure about 2 cm in diameter.

*Pritchardia*s usually, if not always, bear perfect (possessing male and female reproductive parts) flowers. *P. kaalae* is most likely self-compatible, as cultivated trees of other species of *Pritchardia* produce viable seeds even when isolated. Not much is known about the pollination of Hawaiian *Pritchardia*s. However, with respect to palms in general, it had been traditionally believed that all are wind pollinated. Recent research, however, indicates otherwise. Uhl and Dransfield (1987) predict that "most palms will be shown to be insect pollinated, or that both wind and insects are involved." The longevity of individuals of this species has not been documented, although they undoubtedly live for many decades. (MIT 2003)

Known distribution and habitat: *P. kaalae* has been found only in the northern Waianae Mountains. The great majority of the trees are on either Ohikilolo Ridge or on the northern side of Kaala from East Makaleha Valley to Manuwai Gulch. The few known trees beyond the major concentrations are in Makaha and on the ridge between Waianae Kai and Schofield Barracks Military Reservation. The recorded range in elevation for this species is from 460-945 meters.

In some parts of Hawaii, the current distribution of *Pritchardia* is apparently at least partially determined or influenced by the planting of trees by native Hawaiians (Hodel 1980). This is especially evident in the Kona region of Hawaii Island where there are no sites where *P. affinis* can be considered truly wild. All of the currently known older trees are in areas that were densely populated at the time of western contact. In the case of *P. kaalae*, however, there does not seem to be any evidence of native Hawaiian influences in the distribution of the species (Lau pers. comm. 2000).

Pritchardia kaalae is found in the mesic zone on moderately steep slopes to very steep cliffs. Many of the trees in the lower elevations are in forests dominated by lama (*Diospyros sandwicensis*) and/or ohia (*Metrosideros* spp.). The highest trees are in the upper wetter zone of the mesic forest, which is often dominated by lehua ahihi (a species of ohia, *Metrosideros tremuloides*). The steeper, open cliffs where this species grows are vegetated largely with shrubs, grasses and sedges, and small trees.

Taxonomic background: *Pritchardia* is a genus restricted to the tropical Pacific islands and the Hawaiian Islands. It includes about 25 species, about 20 of which are endemic to the Hawaiian Islands. The taxonomy of the Hawaiian species of *Pritchardia* are difficult because characteristics used to distinguish the species appear to be highly plastic (Read and

Hodel 1999). *Pritchardia kaalae*'s extremely long inflorescences sets the species apart from all other Hawaiian *Pritchardia* species except one.

The Waianae Mountains to the south of Kolekole Pass are devoid of *Pritchardia*- of any kind, with the exception of a *Pritchardia* colony south of Pohakea Pass in North Palawai Gulch. There are only two mature trees and one juvenile in the colony. These plants are the only members of what is considered to be an undescribed species most closely related to *P. martii*, the dominant species of *Pritchardia* in the Koolau Mountains (Gemmill 1998).

Table 1. Updated Reproductive Biology Summary of *P. kaalae*..

	Observed Phenology*			Reproductive Biology		Seeds	
MFS Population Unit	Flower	Immature Fruit	Mature Fruit	Breeding System	Suspected Pollinator	Average # Per Fruit	Dormancy
All	Year-round	Year-round	Year-round	Hermaphroditic	Wind + Insect	1	Dormant MPD**

*Observed Phenology is based on field observations at each site. Actual duration of reproductive status is likely longer that those observed.

** MPD= Morphophysiological Dormancy

Plant Morphology and Habitat (Images)

Figure 1. Immature (green) and mature (dark brown/black) fruit.

Figure 2. Inflorescence and flowers (left); germinating seed (right)

Figure 3. Image of *P. kaalae* wild plants at Ohikilolo (left); *P. kaalae* immature plants and seedlings

Image Redacted
Sensitive Information
Available Upon Request

Figure 4. Map of current and historic *P. kaalae*

Current Status

Since the finalization of the MIP in 2003 the total number of plants and specifically mature plants of *P. kaalae* have increased through time and remained stable (Figure 5). This increase is due to expanded survey efforts, the establishment of reintroductions, and effective threat control. The resource response to the exclusion of ungulates from *P. kaalae* habitat and the reduction of the rat populations predating on fruit from this taxon through trapping has been extremely positive, making *P. kaalae* the poster child for Hawaiian rare plant stabilization. One PU, Makaleha to Manuwai, has minimum threat control in place, but still maintains stabilization goals for the mature age class, with 122 known matures. However, since rat control is limited in this PU the immature and seedling age classes are almost non-existent. Currently only one Population Reference Site (PRS), LEH-A, in this PU has rat control in place as the remaining PRSs are scattered widely with only a handful of individuals at each site. The rat grid at LEH-A was re-established in 2021 and ANRPO is monitoring the resource response to rat control every four months. Staff are collecting data to better understand measures of resource response, reproductive status of each individual and recruitment. Data collection will continue through 2024. Currently, the known PUs for *P. kaalae* total 1,995 plants, with 315 mature plants, 1,203 immature plants, and 477 seedlings. PUs for *P. kaalae* include two MFS PUs, one Manage Reintroduction for Stability (MRFS) PU, and two Genetic Storage (GS) PUs (Table 2). All three MFS PUs currently meet stabilization goals for 25 mature plants and genetic storage for this taxon is currently 0% (Table 3). On December 23, 2013 the Coconut Rhinoceros Beetle (CRB) was detected on Joint Base Pearl Harbor-Hickam on coconut trees. CRB is a major pest of palms in India, the Philippines, Palau, Fiji, Wallis, Nukunono, American and Western Samoa and Guam. Due to the presence of CRB on Oahu, management efforts over the next five years will primarily focus on monitoring *P. kaalae* occurrences for CRB damage and developing strategies to protect this taxon both *in situ* and *ex situ*.

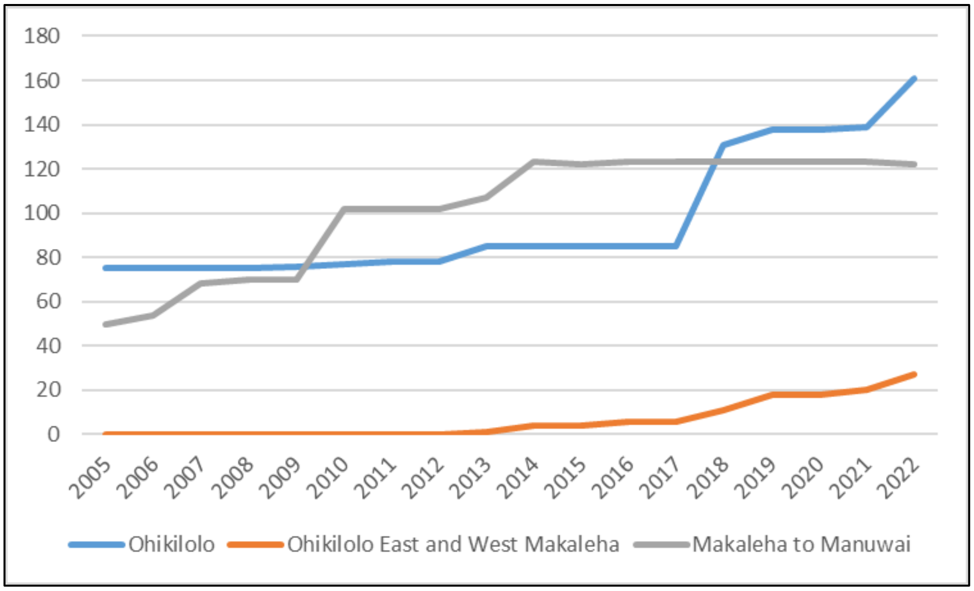

Figure 5. Total number of mature plants for each MFS PU over time

Table 2. Population Units for *P. kaalae.* MFS = Manage for Stability; GS = Manage for Genetic Storage.

Population Unit	Management Designation	PU Type	Action Area (In/Out)	Management Units for Threat Control
Ohikilolo	MFS	*In situ*/reintro	In	Ohikilolo
Ohikilolo East and West Makaleha	MFS	reintro	In	Ohikilolo, Makaleha West
Makaleha to Manuwai	MFS	*In situ*	Out	Manuwai, Kaomokunui No MU, East Makaleha, East Makaleha No MU
Makaha	GS	*In situ*	Out	Makaha No MU
Waianae Kai	GS	*In situ*	Out	Waianae Kai No MU

Table 3. Stabilization Goal Status. Yes/No/Partial refers to if control is in place for each PU.

	PU Stability Target		MU Threat Control					Genetic Storage
Population Unit	25 reproduc-ing plants	Stable Population Structure	Ungulate	Slugs	Rodent	Fire	Weeds	% Completed
Ohikilolo	Yes	Yes	Yes	No	Partial 93%	No	Partial 96%	0%
Ohikilolo East and West Makaleha	Yes	Yes	Yes	No	Partial 100%	No	Partial 100%	0%
Makaleha to Manuwai	Yes	No	Partial 2%	No	Partial 30%	No	No	0%
Makaha	----------	---------	No	No	No	No	No	0%
Waianae Kai	-----------	-------------	No	No	No	No	No	0%

Shading=Threat to Taxon within Population Unit

No Shading= Absence of threat to Taxon within Population Unit

Population Trends and Structure: Manage for Stability Population Units

Pritchardia kaalae is treated as a long-lived taxon for purposes of the Implementation Plan. Hawaiian *Pritchardia* are expected to live for many decades, however, longevity has not been documented. See Table 4 for current plant numbers. for each MFS PU.

Table 4. Current Plant Numbers

Population Unit	Current Matures	Current Immatures	Current Seedlings
Ohikilolo	161	941	477
Ohikilolo East and West Makaleha	27	254	0
Makaleha to Manuwai	122	3	0

Monitoring Plan

Due to the realities of CRB on Oahu the largest PRS in each MFS PU will be visited biannually to monitor for potential CRB damage and to collect data on population structure. These PRSs will be monitored using the HRPRG Rare Plant Monitoring Form to record population structure and the age class, reproductive status and vigor of all known plants. Biannual monitoring will take place at: MMR-A, B, D ,E, H, and I in the Ohikilolo PU; LEH-D and MMR-G in the Ohikilolo East and West Makaleha PU; and LEH-A in the Makaleha to Manuwai PU. Previously reintroduction sites were monitored annually, however, frequency will be increase to monitor for CRB damage. All other PRSs will be monitored intermittently depending on the number of plants at each site and the accessibility of each site and priority will be given to sites that have not been monitored in the last five years.

Threats

The major threats to *P. kaalae* include ungulates, rats, and alien plants. Goats and pigs damage this species' habitat and directly harm plants through predation, trampling, and rooting for food sources. Rats threaten this species through predation of its plant parts and fruits. It is clear that in the absence of rat control, regeneration of *P. kaalae* is severely limited. Alien plants negatively impact this species by altering habitat conditions and competing for moisture, nutrients, light, and space. *P. kaalae* has responded extremely well to both rat and ungulate control. Once these threats were addressed, recruitment increased exponentially. Also, *P. kaalae* seedlings are very sturdy and persist much better in weedy areas than other rare plant taxa. All known threats to this taxon are currently partially or fully controlled at two MFS PUs, Ohikilolo and Ohikilolo East and West Makaleha. Rat control at *P. kaalae* LEH-A in the Makaleha to Manuwai PU was installed in 2021; however, the remainder of the PRSs in this PU have no threat control in place. CRB, pest native to the Asian tropics, was detected on Oahu in 2013. This major invasive pest was accidentally introduced to the western and central Pacific Islands. CRB damages palms by boring into the center of the crown (meristematic tissue) and damaging young leaves and tissue while feeding on sap. Damage is expressed as V-shaped cuts in the fronds or holes in the midrib as leaves mature. Palm species are this species primary host, however, CRB is known to feed on non-palm secondary hosts. Observations from living collections at Leeward Community College have shown that CRB feeds happily on and can severely damage endemic *Pritchardia*, which often times can result in death. Since 2013 the distribution and number of CRB have increased across lowland, urban Oahu, despite eradication efforts and more recent monitoring efforts show CRB moving closer to montane forest systems which host *Pritchardia* habitat. For example, to date CRB has been detected at Kaala, Palehua, and Pualii. For more information on CRB distribution on Oahu and recent detections, see Chapter 9, Alien Invertebrate Management . CRB has the potential to devastate *P. kaalae* populations and undermine recovery efforts to date.

Genetic Storage Plan

Research developed at Christina Walters' lab at the National Center for Genetic Resources Preservation (NCGRP) in Fort Collins Colorado, suggest *P. kaalae* seeds are not orthodox, nor are they recalcitrant. These seeds have non-conventional storage characteristics and are classified as Intermediate Storage behavior. There is some potential for short term storage of *P. kaalae* seed, and/or embryos, although, there is a need for further research to develop long term storage strategies. ANRPO is currently collaborating with the Lyon Arboretum Micropropagation Laboratory to develop storage protocols for *P. kaalae* in cryostorage at -194°C. Christina Walters' lab has had some success with storage at more conventional temperatures, 5° C and -18° C with viabilities between 30-60% for collections stored for 11, 16, and 20 years; however only 11% of embyros that germinated resulted in whole plants. Given these results, ANRPO will continue to build research collections at the ANRPO Seed Conservation Laboratory at 5° C and -18° C and viability tests will be carried out at Lyon Arboretum.

Work to establish protocols will continue over the course of the five-year plan until functional protocols are established, at which point, ANRPO will collaborate with Lyon Arboretum to represent founders in storage (Table 5).

Due to the complex storage characteristics of *P. kaalae,* short term genetic storage plans will involve the utilization of a nursery living collection. In the first two years of the five-year plan, a containerized living collection will be established in the ANRPO nursery. Two years will allow ANRPO staff time to collect and propagate seed from a maximum of 50 founders each from both the Ohikilolo and Makaleha to Manuwai PUs and 4 founders from the Waianae Kai PU. ANRPO will also support DOFAW efforts to collect seed from the Waianae Kai PU. Recent observations suggest that the plants in this PU are not *P. kaalae*, as they do not share the same morphological characteristics. The plants at Waianae Kai have inflorescences shorter than the fronds or petioles, and the fruits are significantly smaller with a tighter spacing on the inflorescence. Fruit collection efforts will primarily be focused at reintroductions and accessible *in situ* PRSs. ANRPO currently maintains 68 founders sourced from the Ohikilolo PU and 27 founders from the Makaleha to Manuwai PU in multiple reintroductions. Secondarily, ANRPO will attempt to collect fruit from less accessible PRSs in the Makaleha to Manuwai PU to bring additional founders not represented in reintroductions into genetic storage.

This will require additional nursery space if IP genetic storage goals are applied: 3 plants per founder for a total of 312 plants. Plants will be maintained in the ANRPO nursery for a maximum of two years, at which point, it is anticipated that living collection plants will outgrow their containers and will need to be planted at *ex situ*/*inter-situ* sites, such as botanical gardens or similar context. One shortcoming of the nursery living collection is that there is no way to vegetatively propagate palm species and thus no way to replace plants or founders once they are lost except to recollect seed as needed. This means that team actions dedicated to *P. kaalae* will increase during the five-year plan.

In years three to five, ANRPO will work collaboratively to establish an in-ground living collection at an *ex situ*/*inter-situ* site to maintain genetic representation of all founders. The site would serve as a seed source to supply outplanting and other genetic storage efforts once the plants become mature. If in-ground living collections are established on Oahu, strategies need to be developed to protect plants from the potential impacts of CRB. Other options would be to establish living collections working with partner organizations off Island, or out of state. Lucas Fortini (USGS) has developed a tool predicting habitat suitability for CRB across the State, which can be used to identify potential living collection sites.

Table 5. Action plan for how to maintain genetic storage representation, and provide propagules for reintroductions.

What propagule type is used for meeting genetic storage goal?	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.*
Seed propagated plants	Primarily reintroductions	Living collection- Greenhouse and Botanic Garden	None	Yes	Initially living collections until long term storage protocols for embryos and/or seed are developed

Management Discussion

The primary goals for this taxon for the next five years will be biannual monitoring of the largest and most accessible MFS PRS for CRB damage and to develop strategies to protect *P. kaalae* from the impacts of CRB. Genetic storage for this taxon is currently 0% and since *P. kaalae* seed cannot be stored in conventional seed banking conditions, building a living collection for this taxon will be our highest priority. Research is ongoing at both ANRPO and Lyon Arboretum to develop functional long-term storage protocols for seeds and/or embryos. To date the most promising storage condition is cyrostorage; however, there is some evidence that seeds can be stored more conventionally at 5C and -18° C, if embryos are germinated in mircropropagation. ANRPO will continue to work with the CRB-Pritchardia working group to monitor CRB distribution on Oahu, support research to better understand breeding conditions, and feeding trials to identify potential non-palm host species in the Hawaiian flora. See Chapter 9 for additional discussion of CRB.

Initial seed collection efforts to build a living collection will be focused at reintroductions and the largest and most accessible PRSs. In order to accommodate the increased propagation of *P. kaalae* and the resulting containerized plants to build the living collection, ANRPO will need to develop a strategy to maximize existing greenhouse space and discuss expanding the shaded nursery yard. Identifying botanic gardens on Oahu, off island, or out of state to establish the in-ground component of the living collection will be a major priority in this five year management plan. If an in-ground living collection is established on Oahu, Koko Crater and Foster Botanic Gardens are the best candidates as they are most isolated from current CRB distributions. For an outline of five year actions see Table 6.

Table 6: Five Year Action Plan. Notes on key actions for Manage for Stability Population Units (MFS PU).

MFS PU	MIP Year 19 Oct. 2022- Sept. 2023	MIP YEAR 20 Oct. 2023- Sept. 2024	MIP Year 21 Oct. 2024-Sept. 2025	MIP Year 22 Oct. 2025-Sept. 2026	MIP Year 23 Oct. 2026-Sept. 2027
All	• Monitor large and Accessible MFS PRS 2x per year • Monitor GS PRS as much as possible • Collect fruit from Reintros and large PRS • Propagate PriKaa • Develop Greenhouse/ • nursery strategy to accommodate PriKAA • Identify locations for in-ground living collection	• Monitor large and Accessible PRS 2x per year • Monitor GS PRS as much as possible • Collect fruit from Reintros and large PRS • Propagate PriKaa • Identify locations for in-ground living collections	• Monitor large and Accessible PRS 2x per year • Monitor GS PRS as much as possible • Collect fruit from Reintros and large PRS • Propagate PriKaa • Plant in-ground living collections	• Monitor large and Accessible PRS 2x per year • Monitor GS PRS as much as possible • Collect fruit from Reintros and large PRS • Propagate PriKaa • Plant in-ground living collections	• Monitor large and Accessible PRS 2x per year • Monitor GS PRS as much as possible • Collect fruit from Reintros and large PRS • Propagate PriKaa • Plant in-ground living collections

References:

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Management Plan for the Translocation of *Achatinella mustelina* ESU-A at the Kahanahaiki Snail Enclosure

February 2022

Army Natural Resources Program on Oahu (ANRPO)

Image Redacted
Sensitive Information
Available Upon Request

Figure 1: Map of Kahanahaiki snail enclosures, Pahole snail enclosure (State) and historic ESU-A snail populations.

A new predator-resistant enclosure was constructed at Kahanahaiki in 2021 to protect *Achatinella mustelina* (Figure 1) in ESU-A. This new enclosure will replace the existing enclosure which was built in 1998, however, the existing enclosure will be maintained until all snails are relocated into the new enclosure. Figure 2 shows an aerial view of both the old and new Kahanahaiki enclosures.

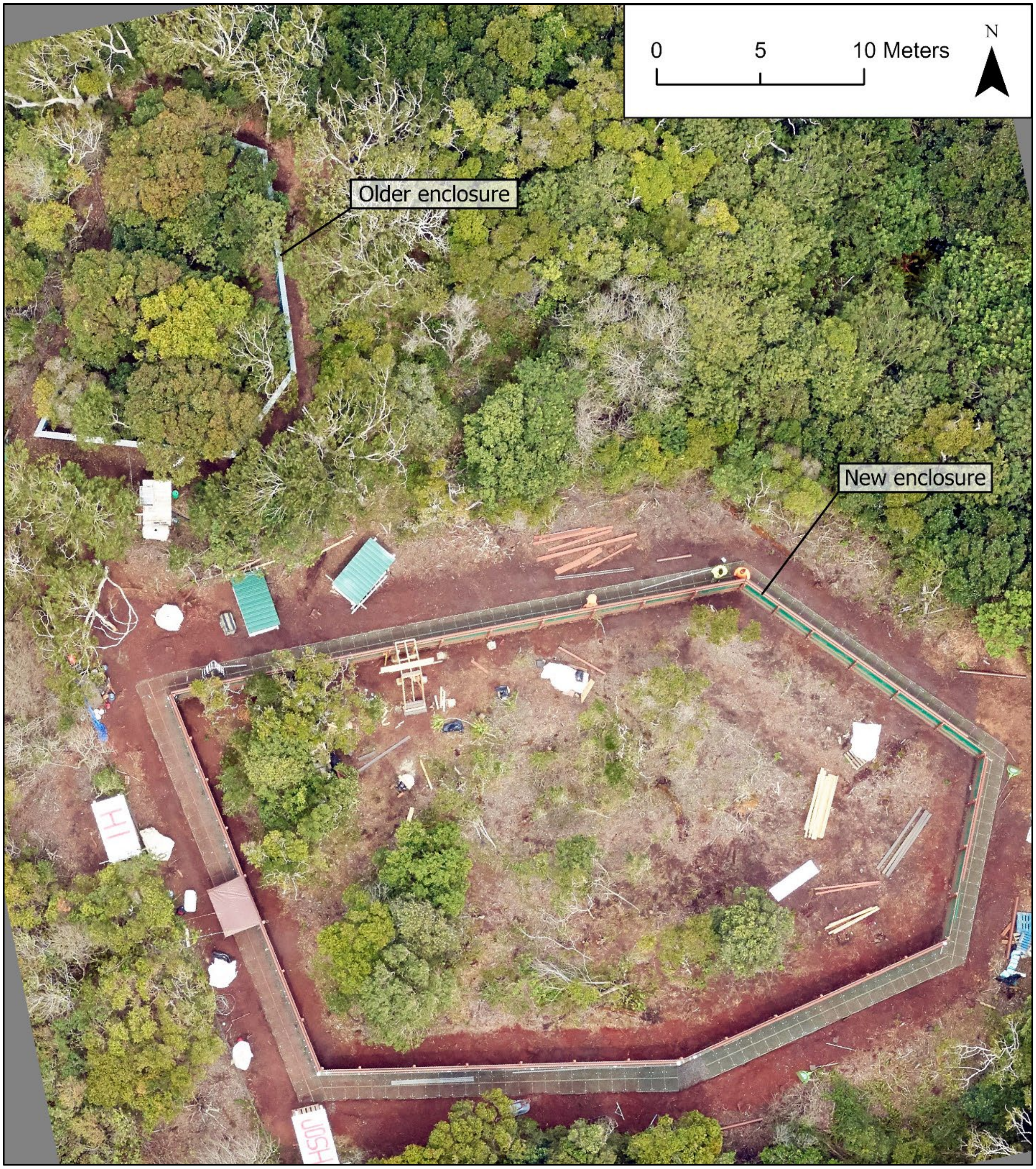

Figure 2: Aerial view of new Kahanahaiki enclosure and old enclosure taken March 2021 during construction.

Originally, the translocations were not planned until after the habitat in the new enclosure became more suitable for snails. Roughly one-third of the new enclosure is canopied, and restoration is underway in the open areas (ANRPO 2021a) (Figure 2). It was assumed that the existing enclosure could be reasonably maintained until vegetation filled in more in the open areas.

However, the aging structure has become increasingly difficult to maintain, and damage often occurs resulting in holes in the wall which allow predators entry. The electric barrier, though still functional, has not been updated and still consists of four 16-gauge round copper wires which are susceptible to breaks. In December 2021 there was another rat incursion and a clutch of hatched *Euglandina rosea* eggs were found inside the old enclosure. The old enclosure is filled with a substantial amount of leaf litter making it difficult to search thoroughly. Two sweeps were conducted and although no *E. rosea* were found, it is possible that they were too small to find in the large amount of leaf litter that is in the enclosure. *Achatinella mustelina* have been found in the leaf litter on several occasions and are highly susceptible to predation by *E. rosea.*

Conducting the *E. rosea* removal protocol requires complete removal of all leaf litter (ANRPO 2021b). This is extremely time consuming as each individual leaf must be inspected for *A. mustelina* before removal. Additionally, the electric barriers have become increasingly unreliable, and would need to be re-wired and walls patched to prevent continual incursion of *E. rosea*.

Given these circumstances, ANRPO has determined that further attempts to protect *A. mustelina* from predators at the old enclosure are no longer tenable, and that they will be more successfully managed and protected at the new, predator-free enclosure. Though restoration efforts remain in the early stages, shrub and fern cover is expanding rapidly, and the open areas are becoming less barren. ANRPO has determined that the current vegetation at the new enclosure, while not ideal, is sufficient for *A. mustelina* habitation. In other enclosures undergoing restoration, such as 3 Points and Palikea North, snails have been observed successfully using areas undergoing active restoration. To protect the population, prompt translocation of snails from the old to the new enclosure has become a top priority for ANRPO. Rather than spending time to clear the old enclosure of predators, and continuing repeated efforts to repair all damage so it is fully functional over the next several years, moving the snails now is the most efficient and the best way to protect them. The old enclosure will be maintained by patching small holes and fixing broken wires as needed until translocations are completed, but no major structural repairs or complete re-wiring will be done. Ground shell plots will continue in the old enclosure on a quarterly basis until translocations are complete.

The *Euglandina rosea* removal protocol was completed in the new enclosure and a total of three live *E. rosea* were found during 13 sweeps. The enclosure was declared predator free in September 2021. Sweeps will continue on a quarterly basis. The most recent quarterly sweep was completed on January 27, 2022 and no *E. rosea* were found. A24s and rat tracking tunnels have been installed. No signs of rats or *Trioceros jacksonii* ssp. *xantholophus* have been observed inside the new enclosure. We remain confident that the enclosure remains predator free.

Design

The new Kahanahaiki enclosure measures ca. 0.065 ha and has a similar design to the Palikea North snail enclosure (OANRP 2018a). The wall structure consists of 4”x4” reinforced plastic posts in concrete footings with a 2”x12” baseboard installed 5” below ground level and a 2”x6” top board installed at a height of 60” for the frame (Figure 3). A high-density polyethylene (HDPE) geomembrane sheet creates the wall barrier. The rat hood is attached at the top edge of the HDPE geomembrane and has a minimum 6” diameter. To prevent incursion from the bottom of the fence and to control erosion, the HDPE geomembrane extends from the wall by a foot, lies on the ground and is held down by Georunner filled with gravel. The *Euglandina rosea* barriers consist of an angle barrier, a cut mesh barrier, and an electrical barrier. The angle barrier is attached to the wall, and the bottom edge is a minimum of 8” above the ground to allow for ease of checking under the angle. The cut mesh barrier is attached just above the angle and the electrical barrier is installed on a 2”x1.5” board just below the hood.

Figure 3: Kahanahaiki enclosure design: two views of the outside wall with predator barriers. Barriers include the rat hood at the top and electric wires, cut mesh and angle for *E. rosea*.

Habitat Restoration

Habitat restoration has begun as planned in the Kahanahaiki Snail Enclosure Restoration Plan (OANRP 2021c). Although there are mature native trees present in the enclosure, including several adult *Nestegis sandwicensis,* we expect the habitat to take at least five years to reach vegetation cover and restoration goals. Until then, there are clusters of canopy species consisting of *Metrosideros polymorpha, N. sandwicensis,* and *Psydrax odorata* which can be used as a release site.

Outplanting began in October 2021 and over 500 native plants have been planted within the enclosure walls. Species included: *Alyxia stellata, Antidesma platyphyllum, Asplenium kaulfussii, Ceodes brunoniana, Dianella sandwicensis, Dodonaea viscosa, Hibiscus arnottianus, Ilex anomala, Kadua affinis, M. polymorpha, Microlepia strigosa, Myrsine lessertiana, Plachonella sanwicensis,* and *Psychotria mariniana.*

Figure 4: Recent outplanting of over 500 native species inside the enclosure.

Achatinella mustelina **Translocation and Monitoring**

<u>Translocation</u>

During the last timed count at the old enclosure, a total of 132 snails were counted. Assuming a 25% detection rate, it is likely that there is a population of over 500 snails inside the old enclosure. Our goal is to move at minimum 400 snails into the new enclosure. Several translocation events are planned as follows:

1st Translocation: Ground sweep during the day to collect any *A. mustelina* in the leaf litter (any *E. rosea* found during the sweep will be removed). Collection at night when snails are most active. Ladders and pickers will be utilized.

2nd Translocation: Ground sweep during the day to collect any *A. mustelina* in the leaf litter (any *E. rosea* found during the sweep will be removed). *Psidium cattleanium* trees will be cut branch by branch by tree climbers and staff will search all branches for *A. mustelina*. There will be four searchers for each tree climber. All branches will remain inside the old enclosure until the leaves fall off and branches are able to be thoroughly searched.

3rd Translocation: Ground sweep during the day to collect any *A. mustelina* in the leaf litter (any *E. rosea* found during the sweep will be removed). Collection at night when snails are most active. Ladders and pickers will be utilized.

Translocation events will be scheduled 3 weeks apart. Between translocation events, staff will translocate any snails found within reach inside the old enclosure immediately. Additional translocation events will be scheduled if needed to reach our goal of 400 snails. The old enclosure will be surveyed at 6 months and 12 months post translocations to collect any remaining snails that were missed.

Release

All snails will be released into the north-west corner of the new enclosure, located next to the crossover. Canopy species in the release site include *N. sandwicensis* and *M. polymorpha*. We will not be constructing a temporary enclosure around the release site since there is good habitat in the area surrounding the release site. However, if snails are frequently observed in the exposed soil section in the south-east corner, a temporary enclosure will be constructed to keep snails within the good habitat area.

Figure 5. Aerial view of enclosure with release site outlined in red. Photo taken in March 2021 before restoration begun. Note that the right side of the photo is North.

Figure 6: Panoramic view inside the new enclosure taken February 2022 from the crossover on the North side. Proposed release site is located in the North-West corner of enclosure outlined in red.

Figure 7: Ground view of release site.

Monitoring

Timed-count monitoring (TCM) will be used to quantify population trends and assess if the released snail populations are self-sustaining over time. During TCM, the release site will be systematically surveyed by a team of two personnel for one hour (two person hours total) during the day, with the total number of observed snails documented. The location of each snail identified will be communicated between the surveyors to minimize double counting. To ensure consistency between survey periods, a minimum of one personnel with previous experience conducting timed-count monitoring will be present.

Additionally, untimed sweeps of the rest of the enclosure will be conducted after TCM to determine any disperal of *A. mustelina* throughout the enclosure. The wall (inside and out) as well as the angle will be checked for *A. mustelina*. Any snails found outside will be collected and returned to the new enclosure.

Mortality will be documented by collecting shells from the ground. Ground shell plot (GSP) monitoring will be done by searching for snails on the ground within a marked plot encompassing the release site. Each shell will be examined to ensure that it does not contain a live snail. All shells will be removed, documented by size class, and retained in an open container (secured to prevent it from blowing over) inside the release area to mitigate erroneous mortality observations.

Immediately after the first translocation, TCM and GSP monitoring will occur every three weeks for nine weeks to determine if there are any immediate catastrophic die-offs associated with the release. Barring unsatisfactory mortality rates, the monitoring interval will then reduce to quarterly. A catastrophic die-off is unlikely since the enclosure site is a known snail site, live snails were found inside the enclosure after it was constructed, and it is in very close proximity to the old enclosure so the fungal community on plants should be the same.

Old Enclosure Maintenance

Staff will continue to maintain the old enclosure for at least one year post translocation to ensure snails missed will still be protected. The electric barrier will be repaired and holes in the wall will be patched as needed. A final survey for snails will be done 12 months after the first translocation event and if less than 10 snails are found then ANRPO will consider decommissioning the old enclosure.

Timeline

Activity	**Planned Date**
1st translocation event	March 7, 2022
Monitor snails every 3 weeks for 9 weeks (TCM, GSP)	March 2022
Opportunistic translocations	March-April 2022
2nd translocation event-trim large *Psidium cattleianum* in old enclosure	March 28, 2022
3rd translocation event	April 25, 2022
Quarterly TCM/GSP starts	May 2022
6 month survey in old enclosure	November 2022
12 month survey in old enclosure	April 2023

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ANRPO. 2021a. Appendix 5-7 Vegetation Monitoring at the Newly Constructed Kahanahaiki Snail Enclosure, April 2021 *in* 2021 Status Report for the Makua and Oahu Implementation Plans.

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ARMY NATURAL RESOURCES PROGRAM ON OAHU
MONITORING PROGRAM

VEGETATION MONITORING AT THE NEWLY CONSTRUCTED KAHANAHAIKI SNAIL ENCLOSURE, APRIL 2022

INTRODUCTION

Year 1 vegetation monitoring was conducted by the Army Natural Resources Program on Oahu (ANRPO) at the newly constructed snail enclosure at Kahanahaiki Management Unit (MU) in April 2022 in accordance with the restoration plan for the enclosure (ANRPO 2021a). The predator resistant enclosure was constructed to replace the small and aging adjacent enclosure in association with the management of *Achatinella mustelina* ESU-A snails (Figure 1). Prior to construction and weed removal, vegetation in this area included mixed native and non-native components in the understory and canopy. This area was previously a "hotspot" for *A. mustelina*, particularly within clusters of *Nestegis sandwicensis* (a preferred host tree for snails from this ESU) in the western portion of the enclosure. Clearing in association with the construction of the enclosure included removal of non-native vegetation (mainly *Psidium cattleianum*, *Schinus terebinthifolius*, and *Clidemia hirta*) in the canopy and understory within the enclosure area, as well as trimming of both non-native and native trees as necessary along the corridor. The eastern portion of the enclosure, which had been dominated by *P. cattleianum*, was largely open following clearing. Baseline vegetation monitoring occurred in April 2021 (following construction completion and after the vast majority of the weed clearing was complete) (ANRPO 2021b). Common native outplantings began in March 2021, and included 542 outplants prior to Year 1 vegetation monitoring (Table 1). Restoration strategies include filling canopy light gaps, and establishing a mid-story and connectivity across all vegetation layers, to include a diverse range of known *A. mustelina* hosts. Weed control within the enclosure occurs at least once per quarter, and clearing to maintain a vegetation gap along the enclosure wall will occur when necessary.

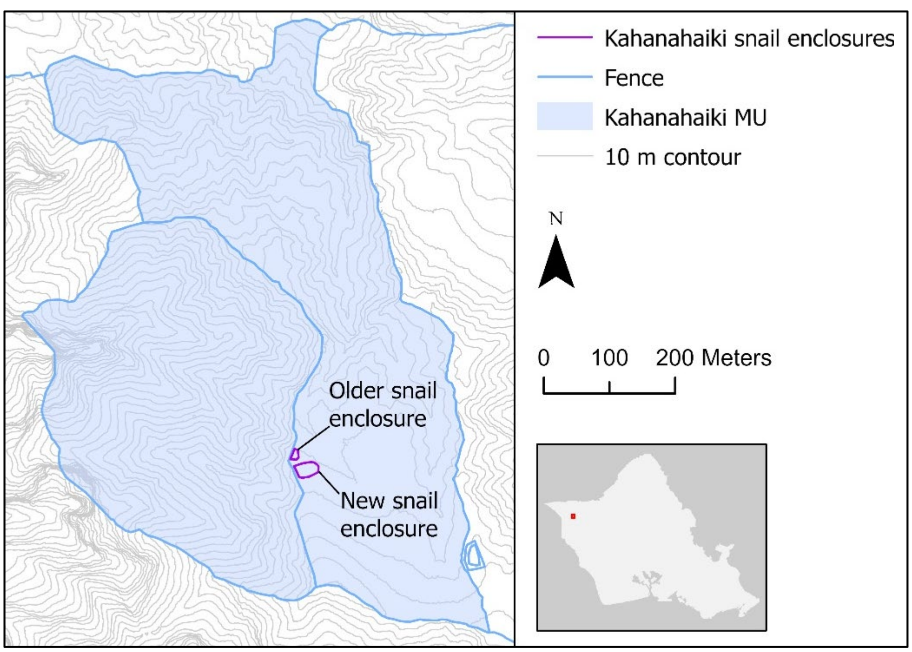

Figure 1: Locations of snail enclosures at Kahanahaiki MU.

Table 1: Species outplanted in association with native vegetation restoration at the new Kahanahaiki snail enclosure prior to Year 1 vegetation monitoring.

Taxon	2021-03	2021-10	Total
Antidesma platyphyllum	17	43	**60**
Ceodes brunoniana	4	28	**32**
Dianella sandwicensis		98	**98**
Dodonaea viscosa		35	**35**
Hibiscus arnottianus subsp. *arnottianus*		21	**21**
Ilex anomala		6	**6**
Kadua affinis	21	67	**88**
Metrosideros polymorpha	27	72	**99**
Microlepia strigosa		64	**64**
Myrsine lessertiana	10	4	**14**
Planchonella sandwicensis		6	**6**
Psychotria mariniana		19	**19**
Total	**79**	**463**	**542**

The primary objective of monitoring is to assess if vegetation cover goals in the restoration plan are being met, or if progress is being made towards those goals in the interim, in conjunction with restoration efforts to achieve a native plant dominated community favorable for *A. mustelina*. Native vegetation cover goals by stratum include:

0 – 2 m above ground level (AGL): > 50% by 3 years after construction completion
>2 m AGL: > 50% by 5 years and > 75% by 8-10 years after construction completion
Total AGL: > 75% by 5 years and beyond after construction completion

A secondary objective is to assess if weed cover goals in the plan are being met. This includes maintaining low weed cover (< 10%), and having zero tolerance for specific taxa (*Psidium cattleianum*, *Macfadyena unguis-cati*, *Elephantopus mollis*, *Setaria palmifolia*, *Pterolepis glomerata*, *Casuarina glauca*, *Triumfetta semitriloba*, *Montanoa hibiscifolia*, *Nephrolepis brownii*, *Passiflora suberosa*, and non-native grasses).

METHODS

Canopy and understory cover: Point intercept monitoring was used to document 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 pole was used to determine "hits" in the understory (live vegetation that touches the pole, including leaves, branches and trunks) along an outstretched measuring tape at regular intervals. Vegetation "hits" in the understory were recorded from 0 – 2 m above ground level (AGL). A laser pointer held against the pole was used to determine laser "hits" in the canopy (above 2 m AGL) at these same intercept points, where the point fell within the perimeter of a tree's canopy. Locations where no vegetation was intercepted were recorded as non-vegetated. Point intercepts (Baseline: n = 422; Year 1: n = 427) were located every 0.5 m along seven transects spaced 3 m apart and oriented at a bearing of 60°. Locations of sampled points are not permanent. Approximations of percent cover were obtained from the proportion of "hits" among all intercepts.

Canopy openness: Hemispherical photography was used to document canopy openness (the amount of direct light passing through the canopy). Photographs were taken using a fish-eye lens at 2 m AGL, aimed 180° from the forest floor every 10 m along the point intercept transects (Baseline: n = 36; Year 1: n = 39). Canopy openness was measured using Gap Light Analyzer (GLA), Version 2.0 software (Frazer *et al*. 1999).

Supplemental data: An Unmanned Aerial Vehicle (UAV) was used to acquire baseline imagery of the enclosure in March 2021 and April 2022. Permanent photopoints were established for visual documentation of change in each cardinal direction for each of 5 points in July 2021. During the course of vegetation monitoring, a supplemental species diversity list was created documenting all species that happened to be observed, but not intercepted, to help document change in the presence or absence of species that have low cover, or are uncommon, and therefore less likely to be documented during point intercept monitoring.

Monitoring schedule: The restoration plan recommended that vegetation monitoring occur after 1, 3 and 5 years, after which the interval may be extended to every 3-5 years to track change in association with vegetation restoration. Once native vegetation fills in, the monitoring interval could be extended to every 5 years.

Analysis: Canopy openness was estimated from hemispheric photographs using Gap Light Analyzer (GLA), Version 2.0. Statistical analysis included Fisher's exact tests for the point intercept data, and logistic regression using generalized linear modeling (GLM) for canopy openness. Species cover changes were all < 10%, and were not analyzed to mitigate the probability of detecting a change when none exists (Type I error). Significance determinations were based on $\alpha = 0.05$. All analyses were performed using the software R, Version 4.1.2 (R Core Team 2021).

RESULTS

In Year 1 there were significant increases in both native and non-native understory and total cover, as well as decreases in understory and total non-vegetated cover (Table 2). Canopy cover remained unchanged. Native vegetation continued to cover over one-quarter of the enclosure in the canopy (dominated by trees of *M. polymorpha*, *N. sandwicensis*, and *Psydrax odorata*), and increased to over one-third of the enclosure in the understory (still primarily the sedge *Carex meyenii*, but also a notable amount of naturally recruited *Scaevola gaudichaudiana*), with total AGL cover increased to nearly 50% (Tables 3 and 4). Most of the increased native understory cover consisted of shrub and tree taxa. Non-native cover increased to encompass over one-fifth of the enclosure in the understory (primarily *Conyza bonariensis*, *Youngia japonica*, and *Oxalis corniculata*, which was present in a few large patches), but remained absent in the canopy. Three quarters of the canopy remained non-vegetated, while non-vegetation area was reduced to < 50% in the understory. Canopy openness remained unchanged (GLM: $p = 0.996$), with median openness of 100% for both years. Fifty-six taxa (48% native) were present in the enclosure (27 intercepted, 24 anecdotally observed) (Table 5). Most restoration outplant taxa were intercepted and/or anecdotally observed. Native vegetation remained most densely clustered along the western end of the enclosure, with most of the increased cover occurring in the central and eastern portion of the enclosure (Figure 2).

Non-native cover goals were not met, as there was an influx of weeds in the more open areas. Though zero-tolerance taxa (*Digitaria violascens*, *Melinis minutiflora*, *Oplismenus hirtellus*, *Paspalum conjugatum*, *P. suberosa*, and *P. cattleianum*) were present in the enclosure, their cover was very low (0.2%).

The changes in vegetation cover in Year 1 are readily visible in the UAV imagery (for total vegetation cover) (Figure 3) as well as in photopoint images (for visual representation of sub-canopy vegetation) (Figures 4-8).

Table 2: Vegetation percent cover by stratum over time within the new Kahanahaiki snail enclosure from point intercept monitoring. P-values obtained from Fisher's exact tests for Baseline and Year 1 data. Statistically significant results are in boldface. Arrows indicate increase (↑) or decrease (↓) in cover.

	Baseline	Year 1	p
Understory			
Native	28.7	37.0	**0.011↑**
Non-native	4.0	21.3	**0.000↑**
Non-vegetated	69.2	46.6	**0.000↓**
Canopy			
Native	27.5	25.1	0.436
Non-native	0.0	0.0	NA
Non-vegetated	72.5	74.9	0.436
Total AGL*			
Native	38.6	48.5	**0.005↑**
Non-native	4.0	21.3	**0.000↑**
Non-vegetated	59.2	37.0	**0.000↓**

*Above ground level

Table 3: Species percent cover by stratum within the new Kahanahaiki snail enclosure over time, listed in order of highest to lowest cover in Year 1. Native taxa are in boldface. [1]Taxon represented in restoration efforts. [2]Zero tolerance weed.

Taxon	Baseline	Year 1
Understory		
Carex meyenii	18.5	15.0
Conyza bonariensis	0.0	8.7
Youngia japonica	0.0	6.3
Scaevola gaudichaudiana	0.0	6.1
Psydrax odorata	3.6	5.4
Nestegis sandwicensis	3.6	4.0
Oxalis corniculata	0.0	3.5
Alyxia stellata	4.5	3.3
Microlepia strigosa[1]	0.9	2.8
Metrosideros polymorpha[1]	1.7	1.9
Crassocephalum crepidioides	0.0	1.6
Gamochaeta purpurea	0.0	1.6
Diospyros sandwicensis	2.4	1.2
Cocculus orbiculatus	0.2	1.2
Coprosma foliosa	0.9	0.9
Acacia koa	0.0	0.9
Dodonaea viscosa[1]	0.0	0.9
Sonchus oleraceus	0.5	0.5
Ceodes brunoniana[1]	0.0	0.5
Hibiscus arnottianus* subsp. *arnottianus[1]	0.0	0.5
Kadua affinis[1]	0.0	0.5
Pipturus albidus	0.0	0.5
Oplismenus hirtellus[2]	1.2	0.2
Odontosoria chinensis	0.2	0.2
Bidens torta	0.0	0.2
Clidemia hirta	0.0	0.2
Planchonella sandwicensis[1]	0.0	0.2
Psidium cattleianum[2]	1.2	0.0
Schinus terebinthifolius	0.5	0.0

Table 3 (continued).

Taxon	Baseline	Year 1
Understory (continued)		
Ageratina riparia	0.2	0.0
Carex wahuensis	0.2	0.0
Cordyline fruticosa	0.2	0.0
Leptecophylla tameiameiae	0.2	0.0
Nephrolepis exaltata	0.2	0.0
Passiflora suberosa[2]	0.2	0.0
Canopy		
Metrosideros polymorpha[1]	10.9	10.1
Nestegis sandwicensis	10.2	8.7
Psydrax odorata	7.8	6.1
Diospyros sandwicensis	3.8	5.9
Alyxia stellata	3.3	1.9
Psychotria mariniana[1]	0.7	0.0

Table 4: Vegetation percent cover over time by growth form and stratum at the new Kahanahaiki snail enclosure.

	Native		*Non-native*	
	Baseline	Year 1	Baseline	Year 1
Understory				
Fern	1.4	3.0	0.0	0.0
Grass	0.0	0.0	1.2	0.2
Herb	0.0	0.2	0.5	20.8
Sedge	18.7	15.0	0.0	0.0
Shrub	5.7	11.2	0.5	0.2
Tree	10.2	15.7	1.7	0.0
Vine	0.0	0.0	0.2	0.0
Canopy				
Shrub	3.3	1.9	0.0	0.0
Tree	27.5	24.8	0.0	0.0

Table 5: All species intercepted (I) or anecdotally observed (A) in the understory and/or canopy over time within the new Kahanahaiki snail enclosure. Native taxa are in boldface. [1]Taxon represented in restoration efforts. [2]Zero tolerance weed.

Taxa	Baseline	Year 1	Taxa	Baseline	Year 1
Acacia koa		I	***Hibiscus arnottianus* subsp. *arnottianus*[1]**		I
Ageratina riparia	I	A	***Ilex anomala*[1]**		A
Ageratum conyzoides		A	***Kadua affinis***[1]	A	I
Alyxia stellata	I	I	***Leptecophylla tameiameiae***	I	
***Antidesma platyphyllum*[1]**	A	A	*Melinis minutiflora*[2]	A	A
Bidens alba		A	***Metrosideros polymorpha***[1]	I	I
Bidens torta	A	I	***Microlepia strigosa*[1]**	I	I
Buddleja asiatica		A	***Myrsine lessertiana***[1]	A	A
Carex meyenii	I	I	***Nephrolepis exaltata***	I	A
Carex wahuensis	I	A	***Nestegis sandwicensis***	I	I
***Ceodes brunoniana*[1]**	A	I	***Odontosoria chinensis***	I	I
Chamaecrista nictitans	A		*Oplismenus hirtellus*[2]	I	I
Clidemia hirta	A	I	*Oxalis corniculata*	A	I
Cocculus orbiculatus	I	I	*Oxalis debilis*	A	
Conyza bonariensis		I	*Paspalum conjugatum*[2]		A
Conyza canadensis var. *pusilla*		A	*Passiflora suberosa*[2]	I	A
Coprosma foliosa	I	I	***Pipturus albidus***		I
Cordyline fruticosa	I		***Planchonella sandwicensis*[1]**		I
Crassocephalum crepidioides	A	I	*Psidium cattleianum*[2]	I	A
Cyclosorus parasiticus	A	A	***Psychotria mariniana***	I	A
***Dianella sandwicensis*[1]**		A	***Psydrax odorata***	I	I
Digitaria violascens[2]		A	*Rubus rosifolius*	A	A
Diospyros sandwicensis	I	I	***Scaevola gaudichaudiana***	A	I
***Dodonaea viscosa*[1]**		I	*Schinus terebinthifolius*	I	A
Doodia kunthiana	A	A	*Sonchus oleraceus*	I	I
Emilia fosbergii		A	*Stachytarpheta australis*	A	A
Euphorbia hirta		A	***Wikstroemia oahuensis* var. *oahuensis***	A	
Gamochaeta purpurea		I	*Youngia japonica*	A	I

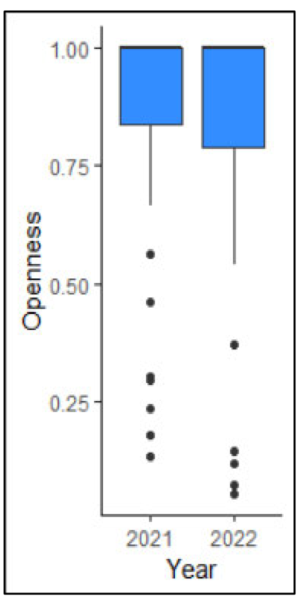

Figure 2: Boxplots for canopy openness over time at the new Kahanahaiki snail enclosure. The openness scale ranges from 0 (completely closed canopy) to 1 (completely open canopy). *Note: Boxplots depict the range of values for variables. The box depicts the interquartile range (the middle 50% of the data values), and the horizontal line inside the box (appears as a bold line when it occurs at one end of the box) represents the median value. The lines extending from the box represent the range of the remaining data, excluding outliers, which are represented individually as dots.*

Figure 3: UAV imagery of the new Kahanahaiki snail enclosure during baseline (March 9, 2021) and Year 1 (April 4, 2022) monitoring. Baseline imagery was taken following removal of the vast majority of weeds and wall construction completion, and prior to restoration outplanting efforts and baseline vegetation monitoring. Remnant native vegetation and extensive open areas are visible. Expansion of existing vegetation, natural recruitment, and outplants are visible in Year 1 imagery, along with the completed stairway crossover and shelter. The release site for translocated snails is indicated by the dashed line.

Figure 4: Photopoint 1 images over time with views in each cardinal direction in the first three quarters following the initiation of outplanting.

Figure 5: Photopoint 2 images over time with views in each cardinal direction in the first three quarters following the initiation of outplanting.

Figure 6: Photopoint 3 images over time with views in each cardinal direction in the first three quarters following the initiation of outplanting.

Figure 7: Photopoint 4 images over time with views in each cardinal direction in the first three quarters following the initiation of outplanting.

Figure 8: Photopoint 5 images over time with views in each cardinal direction in the first three quarters following the initiation of outplanting.

DISCUSSION

Good progress was made towards the native understory goal at the new Kahanahaiki snail enclosure. The lack of change in the canopy was expected, as cover expansion will take longer in that stratum. Nearly two-thirds of the enclosure remains non-vegetated, and will require more time to reach restoration goals. Additional restoration is planned for next season. As most of the outplants to date consisted of tree taxa, the majority of restoration inputs will include understory outplants (*Carex wahuensis*, *Coprosma foliosa*, *Microlepia strigosa*) and seed sows (*Cyperus polystachyos*). To further enhance snail host tree diversity, outplants will also include host tree taxa that are either absent (*Rockia sandwicensis*) or not well established yet (*Antidesma platyphyllum*, *Myrsine lessertiana*). *Nestegis sandwicensis*, an important host tree, has been challenging to propagate, but may be considered for outplanting pending improved propagation methods. Taxa with high calcium content (*Urera*, *Pipturus*) may be beneficial for snails (D. Sischo, pers. comm), and could be considered for future restoration efforts. Though the non-native cover goal was not met yet, most of the weedy cover was comprised of herbaceous taxa that are not expected to pose major threats to restoration efforts, and will likely decline over time with the expansion of native vegetation and reduced light levels. The zero-tolerance weeds present included taxa for which ingress was expected, and the minimal cover for those taxa is of limited concern. Spread should be mitigated by the ongoing quarterly weed control efforts.

Translocations of *A. mustelina* into the new enclosure were not planned to begin until it became more vegetated, however deteriorating conditions in the older enclosure led to rat and *Euglandina rosea* incursions, and prompted the decision to move snails into the new enclosure beginning in March 2022, as it was determined that they would be more successfully managed and protected at the new, predator-free enclosure (Appendix 5-1). Snails were released into the northwest corner of the new enclosure with more intact canopy and understory cover (Figure 3). As of vegetation monitoring in April 2022, 223 snails had been translocated into the new enclosure, and none found dead in ground shell monitoring.

Though dense multi-layered host vegetation is presumed ideal, partially restored vegetation may be sufficient for releasing snails. Stable or increasing *A. mustelina* populations may also be used as a measure of vegetation rehabilitation success. Successful releases of *A. mustelina* in partially restored habitat have occurred at the Palikea North (Appendix 5-5) and 3 Points (ANRPO 2021c) enclosures. The preliminary success of the initial snail releases suggests habitat readiness, such as the early stages of vegetation restoration as characterized here, are similarly sufficient for snail releases.

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ARMY NATURAL RESOURCES PROGRAM ON OAHU
MONITORING PROGRAM

VEGETATION MONITORING RESULTS FOR THE KAALA SNAIL ENCLOSURE, 2021

INTRODUCTION

The Army Natural Resources Program on Oahu (ANRPO) documents vegetation cover at the Kaala *Achatinella mustelina* ESU-C predator resistant enclosure at Kaala (Figure 1) in association with the management plan for the enclosure (ANRPO 2021a). The enclosure site is in an area with native dominated canopy and understory. Weed control was conducted during construction, along with removal of the native fern *Dicranopteris linearis* to facilitate searches for the predatory snail *Euglandina rosea*. Construction was completed in March 2021. Following this, a small amount of additional canopy clearing occurred in association with the installation of a crossover. This was followed by several months of repeated sweeps for *E. rosea*. Translocations of *A. mustelina* into the enclosure began in early November 2021 after the enclosure was determined to be predator-free.

Image Redacted
Sensitive Information
Available Upon Request

Figure 1: Location of the Kaala snail enclosure.

The primary objective of monitoring is to assess if vegetation cover goals from the enclosure's restoration plan are met (ANRPO 2021b). In the plan, it was assumed that the existing vegetation prior to construction, clearing, and sweeps contained appropriate habitat for *A. mustelina*. It was anticipated that native vegetation clearing associated with predatory snail search efforts as well as disturbance during searches would result in a reduction of native cover. The goal of the restoration plan is to restore (as needed) and maintain a native plant dominated community favorable for *A. mustelina*. Native vegetation cover goals, based on preliminary pre-clearing monitoring data, include:

- **Vascular plants**
  - 0 – 1 m above ground level (AGL): > 45% by 3 years
  - 1 – 2 m AGL: > 45% by 5 years
  - > 2 m AGL: > 85% by 10 years
  - Total AGL cover: > 90% by 5 years

- **Bryophytes** (natural recovery anticipated, no finite timeline for goals)
    - 0 – 1 m: > 70%, with progress towards goal by 3 years
    - 1 – 2 m AGL: > 5%

A secondary objective is to assess if weed cover goals in the plan are met. Goals include maintaining < 10% weed cover, and having zero tolerance for a number of species (*Hedychium gardnerianum*, *Psidium cattleianum*, *Rubus argutus*, *Crocosmia* x *crocosmiiflora*, *Diplazium esculentum*, and alien grasses).

METHODS

Monitoring schedule: Three monitoring events occurred within the first year: 1) in November 2020, after line clearing for the enclosure wall was completed and before any vegetation clearing in the interior; 2) in March 2021, following construction completion (which necessitated a small amount of additional line clearing to the inside of the line), non-native vegetation removal, and native vegetation simplification in association with *E. rosea* removal; and 3) in July 2021, after the enclosure was determined to be free of *E. rosea* (these monitoring events hereafter referred to as "pre-clearing," "post-clearing," and "post-sweeps," respectively, in this document). Future monitoring will occur after three years, then every five years.

Percent cover: Point intercept monitoring was used 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 (though bryophytes were categorized collectively rather than by species). A 5 millimeter diameter pole was used to determine "hits" in the understory (live vegetation that touched the pole, including leaves, branches and trunks) along an outstretched measuring tape at regular intervals. Vegetation "hits" in the understory were recorded from 0 – 1 and 1 - 2 m above ground level (AGL). A laser pointer held against the pole was used to determine laser "hits" in the canopy (above 2 m AGL) at these same intercept points, where the point fell within the perimeter of a tree's canopy. Bryophytes were not documented for the canopy. Locations where no vegetation was intercepted were recorded as non-vegetated, and further categorized by substrate type. During baseline monitoring, point intercepts were located every 0.5 m along transects spaced 3 m apart with a goal of achieving approximately 400 points (pre-clearing: n = 387, post-clearing: n = 462, and post-sweeps: n = 421). Locations of the sampled points were not permanent.

Canopy openness: Hemispherical photography was used to monitor changes in canopy openness. Photographs were taken at 2 m AGL, aimed 180° from the forest floor along the point intercept transects every 10 m during pre-clearing monitoring, and every 5 m during post-clearing and post-sweeps monitoring (pre-clearing: n = 16, post-clearing: n = 41, and post-sweeps: n = 39).

Supplemental data: Unmanned aerial vehicle (UAV) imagery was taken in conjunction with pre- and post-clearing vegetation monitoring to compare imagery over time. Five permanent photopoints were established post-clearing for visual documentation of sub-canopy change in each cardinal direction at each point. During the course of vegetation monitoring, a species diversity list was created documenting all species that happened to be observed, but not intercepted. The list will help document change in the presence or absence of species that have low cover, or are uncommon, and therefore less likely to be documented during point intercept monitoring. Efforts are underway for researcher collaboration with John DeLay to establish a weather station at the enclosure to document environmental conditions over time.

Analysis: Approximations of percent cover were obtained from the proportion of "hits" among all point intercepts. Analysis included Pearson's chi-square tests and Fisher's Exact tests (when the minimum expected count was less than 5) for cover change, and ANOVA tests for differences in canopy openness. Only species with 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. Canopy openness was estimated from hemispheric photographs using Gap Light Analyzer (GLA), Version 2.0. All analyses were performed using the software R, Version 4.1.1 (R Core Team 2020).

RESULTS

Pre-clearing vegetation was native dominated and densely covered the enclosure site. The 0 – 1 m stratum contained 74% native bryophyte cover, and 46% native vascular plant cover, dominated by ferns/fern allies, predominantly *D. linearis*, *Palhinhaea cernua*, and *Hymenophyllum* sp. (Tables 1 – 4). Non-vegetated substrate in the 0 – 1 m stratum was 13%, primarily comprised of leaf litter. The 1 – 2 m stratum had 10% native bryophyte cover, and 52% native vascular plant cover, mainly ferns and trees, dominated by *D. linearis*, *Cibotium glaucum*, and *Metrosideros polymorpha*. The > 2 m stratum had 87% native vascular cover, and was dominated by trees, predominantly *M. polymorpha* and *Melicope clusiifolia*. Total native AGL cover was 98%, while total non-native AGL cover was < 1%.

Post-sweeps vegetation remained dense and native dominated, though native over was reduced for some strata, and non-vegetated area increased in all strata. Most notable was a 38% decline in bryophyte cover in the 0 – 1 m stratum (percentage changes referenced are absolute, referring to differences in the total number of percentage points). This was paralleled by a 38% increase in non-vegetated substrate in the 0 – 1 m stratum, attributable mostly to increased leaf litter, but also gravel (added to the perimeter post-clearing), and exposed soil to a lesser extent. Native vascular plant cover also declined by 18% in the 0 – 1 m stratum, and by 9% in the > 2 m stratum as well as for total AGL cover. Total non-native AGL cover remained < 1%. *Dicranopteris linearis* total AGL cover was reduced from 22% to < 1% (chi square: $p = 0.000$, $X^2 = 96.911$), and was most heavily reduced (by 13%) in the 1 – 2 m stratum. Canopy openness remained unchanged (ANOVA: $p = 0.093$, $F = 2.888$).

Among the zero tolerance taxa, three (*H. gardnerianum*, *P. cattleianum*, and *R. argutus*) were observed during each monitoring event, and one new taxon (*C.* x *crocosmiiflora*) was newly observed post-sweeps. The limited areas of exposed soil inside the enclosure post-sweeps (mainly along the perimeter, associated with wall construction) were observed to have a small degree of weedy influx, while exposed soil areas outside the enclosure were anecdotally observed as densely flushed with weeds.

Slight changes in vegetation cover are visible following clearing in the UAV imagery (for total vegetation cover) (Figure 2), and following sweeps in photopoint images (for visual representation of sub-canopy vegetation) (Figures 3-7).

Table 1: Vegetation cover by stratum during pre-clearing (November 2020), post-clearing (March 2021), and post-sweeps (July 2021) monitoring. Bryophytes, though present, were not documented for the canopy. Pearson's chi-square tests were used for cover change between pre-clearing and post-sweeps ([a]Fisher's Exact test used when the minimum expected count was < 5). Statistically significant results are in boldface. Arrows indicate increase (↑) or decrease (↓) in cover. Cover goals are highlighted in blue when met, and in orange when unmet.

	Pre-clearing	Post-clearing	Post-sweeps	P	X^2
0-1 m					
Native Vascular	45.7	38.3	27.8	**0.000↓**	28.055
Native Bryophytes	74.2	66.9	36.8	**0.000↓**	113.48
Non-native Vascular	0.0	0.4	0.2	1.000[a]	
Non-vegetated	12.7	26.0	50.1	**0.000↑**	129.64
Dead Wood	*0.0*	*0.0*	*0.5*	*0.500[a]*	
Gravel	*0.0*	*0.4*	*8.8*	***0.000↑***	*35.644*
Leaf Litter	*11.9*	*14.1*	*32.5*	***0.000↑***	*49.106*
Rock	*0.0*	*0.0*	*0.2*	*1.000[a]*	
Root	*0.3*	*0.0*	*1.2*	*0.220[a]*	
Soil	*0.5*	*11.5*	*6.7*	***0.000↑***	*21.222*
1-2 m					
Native Vascular	51.9	43.5	46.3	0.110[a]	
Native Bryophytes	9.8	14.1	7.6	0.263	1.2538
Non-native Vascular	0.8	0.0	0.0	0.109	
Non-vegetated	42.9	55.0	51.3	**0.017↑**	5.7249
>2 m					
Native Vascular	87.3	85.5	78.1	**0.001↓**	11.825
Non-native Vascular	0.8	0.0	0.0	0.109[a]	
Non-vegetated	12.7	14.5	21.9	**0.001↑**	11.825
Total vegetation AGL					
Native Vascular	98.4	92.6	89.3	**0.003↓**	8.9501
Non-native Vascular	0.8	0.4	0.2	0.354[a]	

Table 2: Vegetation percent cover by growth form within stratum pre-clearing (November 2020), post-clearing (March 2021), and post-sweeps (July 2021).

	Native			*Non-native*		
	Pre-clearing	Post-clearing	Post-sweeps	Pre-clearing	Post-clearing	Post-sweeps
0-1 m						
Fern*	37.7	27.1	21.6	0.0	0.0	0.0
Herb	1.3	1.3	0.7	0.0	0.0	0.0
Moss	74.2	66.9	36.8	0.0	0.0	0.0
Sedge	0.5	0.9	0.7	0.0	0.0	0.2
Shrub	3.6	5.2	2.1	0.0	0.4	0.0
Tree	7.5	8.4	4.5	0.0	0.0	0.0
1-2 m						
Fern*	34.9	23.8	22.6	0.0	0.0	0.0
Herb	0.0	0.0	0.2	0.0	0.0	0.0
Moss	9.8	14.1	7.6	0.0	0.0	0.0
Sedge	0.0	0.6	0.0	0.0	0.0	0.0
Shrub	5.9	5.8	7.4	0.0	0.0	0.0
Tree	20.7	20.6	22.8	0.8	0.0	0.0
>2 m						
Fern	31.3	22.5	15.4	0.0	0.0	0.0
Shrub	8.8	8.2	8.6	0.0	0.0	0.0
Tree	80.9	81.4	73.2	0.8	0.0	0.0

*Includes fern allies.

Table 3: Vascular plant species percent cover by stratum pre-clearing (November 2020), post-clearing (March 2021), and post-sweeps (July 2021). Pearson's chi-square tests were used for cover change between pre-clearing and post-sweeps for taxa with > 10% absolute cover change. Native taxa are in boldface. Arrows indicate increase (↑) or decrease (↓) in cover. [1]Zero tolerance taxon.

Species	Pre-clearing	Post-clearing	Post-sweeps	p	X^2
0-1 m					
Adenophorus tamariscinus	2.3	1.3	1.4		
Asplenium contiguum	0.0	0.0	0.2		
Athyrium microphyllum	0.5	0.0	0.2		
Cheirodendron platyphyllum	0.0	0.2	0.0		
Cheirodendron trigynum	0.0	0.2	0.2		
Cibotium glaucum	5.7	6.9	5.9		
Cibotium menziesii	3.1	3.0	2.4		
Dianella sandwicensis	0.3	0.4	0.5		
Dicranopteris linearis	9.6	0.9	0.5		
Dryopteris glabra	0.3	0.0	1.0		
Dubautia laxa	0.0	0.0	0.2		
Freycinetia arborea	2.1	1.5	1.9		
Hedychium gardnerianum[1]	0.0	0.2	0.0		
Hydrangea arguta	1.3	0.2	1.2		
Hymenophyllum lanceolatum	NA	NA	2.4		
Hymenophyllum recurvum	NA	NA	4.0		
Hymenophyllum* sp.	8.0	8.0	NA		
Ilex anomala	1.8	0.2	0.2		
Juncus planifolius	0.0	0.0	0.2		
Leptecophylla tameiameiae	0.5	3.0	0.5		
Machaerina angustifolia	0.5	0.9	0.7		
Melicope christophersenii	0.0	0.2	0.0		
Melicope clusiifolia	0.3	0.9	0.2		
Metrosideros polymorpha	4.4	6.7	2.6		
Nertera granadensis	0.3	0.2	0.0		
Oreogrammitis hookeri	0.3	0.0	0.0		
Palhinhaea cernua	9.0	7.4	2.6		
Peperomia macraeana	0.8	0.6	0.2		
Polypodium pellucidum* var. *pellucidum	0.3	0.0	0.0		
Rubus argutus[1]	0.0	0.2	0.0		
Sadleria pallida	0.3	0.9	0.7		
Stenogrammitis saffordii	0.5	0.2	0.5		
Syzygium sandwicense	0.3	0.0	0.2		
Vaccinium calycinum	3.1	2.4	1.4		
1-2 m					
Adenophorus tamariscinus	1.0	2.2	1.9		
Cheirodendron platyphyllum	0.0	0.2	0.2		
Cibotium glaucum	10.9	7.4	7.8		
Cibotium menziesii	5.2	6.9	6.9		
Coprosma ochracea	0.8	0.0	0.2		
Dianella sandwicensis	0.0	0.0	0.2		
Dicranopteris linearis	12.7	0.2	0.0	0.000↓	56.746
Freycinetia arborea	4.4	3.9	4.3		
Hydrangea arguta	6.7	3.5	6.2		
Hymenophyllum lanceolatum	0.8	2.2	0.2		
Hymenophyllum recurvum	0.0	0.0	1.4		
Ilex anomala	2.3	1.9	5.2		
Leptecophylla tameiameiae	4.1	4.5	5.5		
Machaerina angustifolia	0.0	0.6	0.0		

Table 3 (continued).

Species	Pre-clearing	Post-clearing	Post-sweeps	p	X^2
1-2 m (continued)					
Melicope christophersenii	0.5	0.6	0.7		
Melicope clusiifolia	1.6	4.3	0.2		
Metrosideros polymorpha	9.6	10.8	11.2		
Myrsine sandwicensis	0.8	0.2	0.2		
Oreogrammitis hookeri	0.0	0.2	0.0		
Palhinhaea cernua	1.0	0.2	0.0		
Psidium cattleianum[1]	0.8	0.0	0.0		
Sadleria pallida	0.8	1.1	0.0		
Stenogrammitis saffordii	0.3	0.2	0.7		
Syzygium sandwicense	0.0	0.2	0.5		
Vaccinium calycinum	1.0	1.3	1.7		
> 2 m					
Adenophorus tamariscinus	1.3	0.2	0.5		
Cheirodendron platyphyllum	9.0	10.2	10.9		
Cheirodendron trigynum	0.0	0.0	0.2		
Cibotium glaucum	5.4	4.5	1.9		
Cibotium menziesii	6.2	7.8	4.5		
Coprosma ochracea	0.3	0.2	1.0		
Dicranopteris linearis	4.7	0.0	0.0		
Freycinetia arborea	15.0	11.3	8.3		
Hydrangea arguta	3.4	5.8	6.2		
Hymenophyllum recurvum	0.3	0.0	0.0		
Ilex anomala	14.7	12.6	15.0		
Leptecophylla tameiameiae	7.8	7.8	6.9		
Lepisorus thunbergianus	0.0	0.0	0.2		
Melicope christophersenii	1.0	1.3	2.1		
Melicope clusiifolia	27.4	24.7	22.3		
Metrosideros polymorpha	49.9	53.5	43.0		
Myrsine sandwicensis	0.0	0.6	0.0		
Oreogrammitis hookeri	0.0	0.2	0.0		
Psidium cattleianum[1]	0.8	0.0	0.0		
Syzygium sandwicense	2.3	2.8	3.3		
Vaccinium calycinum	1.0	0.2	0.7		

*Distinctions between *Hymenophyllum lanceolatum* and *H. recurvum* not definitive.

Table 4: All taxa intercepted (I) or anecdotally (A) observed during monitoring pre-clearing (November 2020), post-clearing (March 2021), and post-sweeps (July 2021) in any strata from 0 - 1 m, 1 -2 m, or >2 m above ground level. [1]Zero tolerance weed.

	Pre-clearing	Post-clearing	Post-sweeps
Native			
Adenophorus tamariscinus	I	I	I
Asplenium contiguum	A	A	I
Athyrium microphyllum	I	A	I
Bryophyte sp.	I	I	I
Cheirodendron platyphyllum	I	I	I
Cheirodendron trigynum		I	I
Cibotium glaucum	I	I	I
Cibotium menziesii	I	I	I
Coprosma ochracea	I	I	I

Table 4 (continued).

	Pre-clearing	Post-clearing	Post-sweeps
Native (continued)			
Coprosma longifolia	A		A
Dianella sandwicensis	I	I	I
Dicranopteris linearis	I	I	I
Dryopteris glabra	I	A	I
Dubautia laxa		A	I
Freycinetia arborea	I	I	I
Geniostoma waiolani			A
Hydrangea arguta	I	I	I
Hymenophyllum lanceolatum	I	I	I
Hymenophyllum recurvum	I	I	I
Ilex anomala	I	I	I
Lepisorus thunbergianus	A	A	I
Leptecophylla tameiameiae	I	I	I
Machaerina angustifolia	I	I	I
Melicope christophersenii	I	I	I
Melicope clusiifolia	I	I	I
Metrosideros polymorpha	I	I	I
Myrsine sandwicensis	I	I	I
*Nephrolepis exaltata**	A		A
Nertera granadensis	I	I	A
Oreogrammitis hookeri	I	I	A
Palhinhaea cernua	I	I	I
Peperomia macraeana	I	I	I
Phyllostegia grandiflora		A	A
Polypodium pellucidum var. *pellucidum*	I	A	A
Sadleria pallida	I	I	I
Stenogrammitis saffordii	I	I	I
Syzygium sandwicense	I	I	I
Vaccinium calycinum	I	I	I
Total native diversity	34	35	38
Non-native			
Ageratina adenophora	A		
Clidemia hirta	A		A
Coronopus didymus	A	A	A
Crassocephalum crepidioides			A
Crocosmia x *crocosmiifolia*[1]			A
Cyperus meyenianus			A
Hedychium gardnerianum[1]	A	I	A
Juncus planifolius	A	A	I
Psidium cattleianum[1]	I	A	A
Rubus argutus[1]	A	I	A
Rubus rosifolius			A
Verbena litoralis			A
Total non-native diversity	7	5	11

*Small individual plant, which could alternatively have been *N. brownii*.

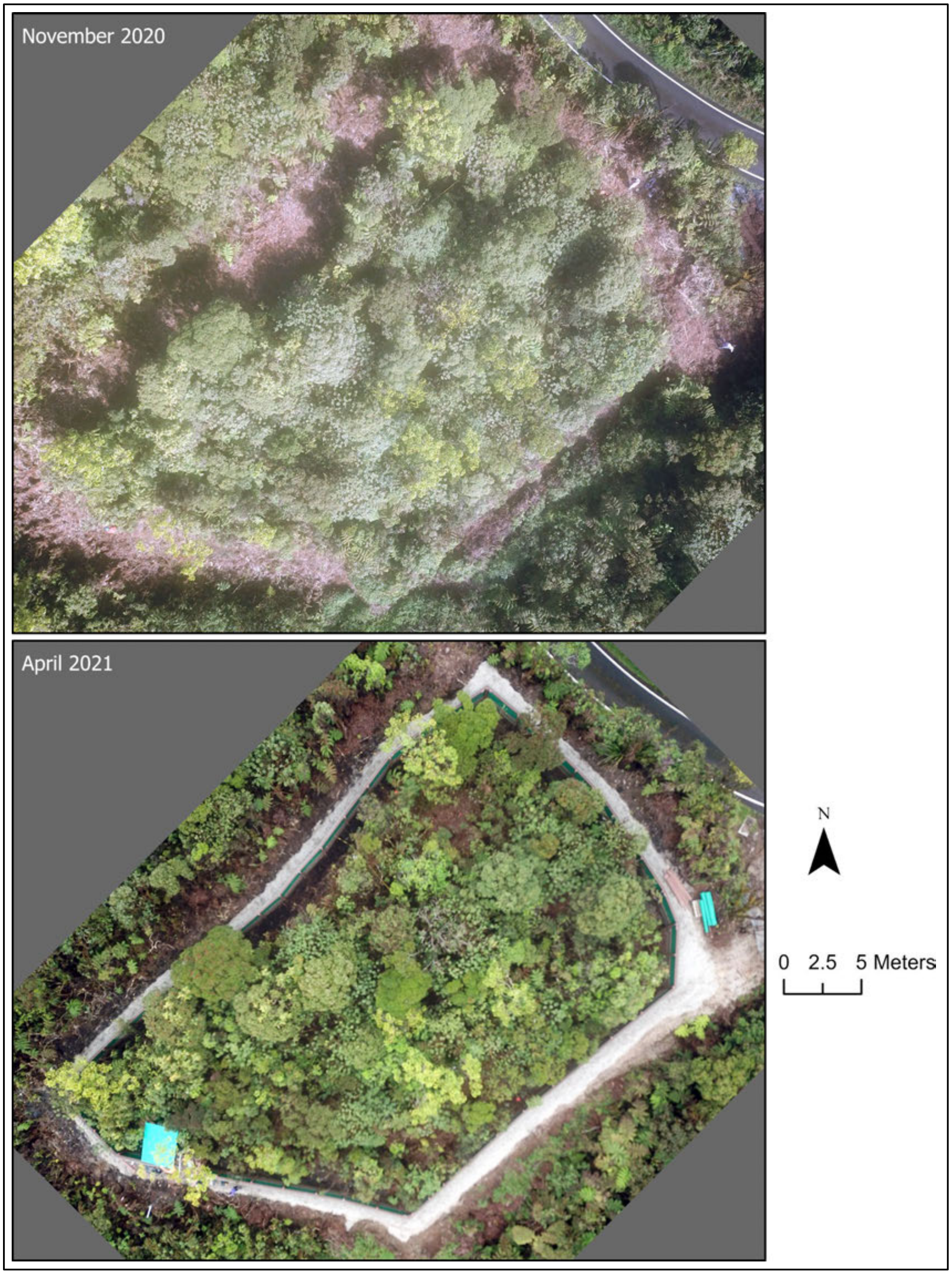

Figure 2: UAV imagery of the enclosure pre-clearing (November 2020) and post-clearing (April 2021).

Figure 3: Photopoint 1 images with views in each cardinal direction (from top to bottom: north, east, south, west) post-clearing and during construction (February 2021, left column), and post-sweeps for *Euglandina rosea* (November 2021, right column). Minimal vegetation change evident aside from impact to *Palhinhaea cernua* visible in bottom pair of images. Full-sized images may be viewed upon request.

Figure 4: Photopoint 2 images with views in each cardinal direction (from top to bottom: north, east, south, west) post-clearing and during construction (February 2021, left column), and post-sweeps for *Euglandina rosea* (November 2021, right column). Minimal vegetation change evident aside from impact to *Palhinhaea cernua* visible in third pair of images. Full-sized images may be viewed upon request.

Figure 5: Photopoint 3 images with views in each cardinal direction (from top to bottom: north, east, south, west) post-clearing and during construction (February 2021, left column), and post-sweeps for *Euglandina rosea* (November 2021, right column). Minimal vegetation change evident between images. Full-sized images may be viewed upon request.

Figure 6: Photopoint 4 images with views in each cardinal direction (from top to bottom: north, east, south, west) post-clearing and during construction (February 2021, left column), and post-sweeps for *Euglandina rosea* (November 2021, right column). Minimal vegetation change evident between images. Full-sized images may be viewed upon request.

↓Inside↓

↓Inside↓ ↓Outside↓

↓Outside↓

↓Outside↓ ↓Inside↓

Figure 7: Photopoint 5 images from 2021-10-06 with views in each cardinal direction (from top to bottom) post-sweeps for *Euglandina rosea*. Photopoint 5 images are taken from atop the crossover, which had not yet been built when Photopoints 1-4 were initiated, and includes views both inside and outside of the enclosure. Weedy ingress in disturbed areas adjacent to the outer perimeter is visible in the second and fourth images. Full-sized images may be viewed upon request.

DISCUSSION

Overall, negative impacts to native vascular vegetation cover at the Kaala snail enclosure resulting from management actions associated with threat management prior to initial translocations were relatively small. Native vascular plant taxa most impacted in the 0 – 1 m stratum were *D. linearis* and *P. cernua*, and it is unknown how quickly they will fill back in naturally. Upon recovery, future removal of *D. linearis* may be necessary if it limits staff maneuverability. *Palhinhaea cernua* stems are fairly fragile, and much of it was disturbed in the process of clearing and *E. rosea* sweeps. Owing to its creeping habit, perhaps it will recover on its own. As expected, a fair amount of moss on the ground surface was trampled during the *E. rosea* sweeps, resulting in a loss of roughly half the moss ground cover. It is expected to recover naturally now that there is less disturbance. Though disturbance adjacent to the wall associated with its construction resulted in mucky exposed soil along much of the perimeter (subsequently overlain with a layer of gravel after post-clearing monitoring), the ground surface in the interior remained minimally disturbed, with leaf litter and remnant moss substrate atop an intact humus layer. Despite *D. linearis* removal having its greatest reduction in cover in the 1 – 2 m stratum, overall native cover for that stratum remained intact. The reduced canopy and total AGL cover was slight (likely influenced by the *D. linearis* clearing, the small amount of additional line clearing that occurred to the inside of the line during construction, and the canopy trimming associated with the crossover construction, but ultimately falling within the range of sampling error), and post-sweeps cover was only slightly below the cover goals.

It was very fortunate that the enclosure was apparently devoid of *E. rosea* (none were found), as sweeps would otherwise have likely continued over a much longer period of time, potentially causing more disturbance to the vegetation and ground surface. Their confirmed presence also would likely have required additional clearing of moss and ferns to facilitate detection and eradication (ANRPO 2021a).

The addition of gravel to cover exposed soil along the interior perimeter, along with the largely intact interior ground surface, kept weedy ingress into the enclosure at a minimum. The use of gravel along the outside perimeter of the enclosure, used as a walkway to access the enclosure, also helped to prevent weeds from being tracked inside. The majority of weedy ingress associated with the construction occurred outside the wall and exterior gravel. However, the small amount of exposed soil within the enclosure remains a potential risk for weed incursion.

RECOMMENDATIONS AND MANAGEMENT RESPONSE

Restoration

The largest impact to vegetation from clearing and sweeps was to bryophyte cover on the ground surface. However, as per the restoration plan, no active bryophyte restoration will occur so long as natural recovery results in progress towards cover goals by three years. As overall native vascular plant cover was not heavily impacted, restoration efforts, if deemed necessary, may remain on a relatively small scale, with efforts focused on filling in open interior areas. Any restoration actions should be careful to avoid disturbance to the ground surface as much as possible, as this may enhance weedy ingress. Perhaps outplants should be limited to the use of small plants in dibbles, and rather than excavating holes for planting, the ground may simply be cut into with a single incision using a trowel, and outplant roots slipped into the small opening in the ground along the backside of the trowel. If larger plants are used, the hole should not be much larger than the pot size, and a generous layer of leaf litter applied to exposed soil. No restoration actions are currently planned.

Weed management

Weed management for the enclosure includes quarterly scheduled weeding, which may be amended to occur less frequently if weed levels remain low, to mitigate unnecessary trampling. Exposed soil and gravel substrate along the perimeter remain high risk areas for weedy ingress. Considerations should be made for managing the weedy ingress that occurred in areas of exposed soil outside of the enclosure, and for preventing similar ingress inside the enclosure. Perhaps weed mat and common native groundcover outplantings may be used to contain the large patches of weeds occurring outside the enclosure, to mitigate the potential for the area becoming a weed seed source. Efforts should be made to eliminate the zero tolerance taxa in the enclosure. There is a large patch of *C.* x *crocosmiifolia* along the road adjacent to the enclosure, and considerations should be made for mitigating further spread of this zero tolerance weed into the enclosure. Given the presence of *Juncus planifolius* and *Cyperus meyenianaus* in the interior of the enclosure, and alien mosses elsewhere at Kaala, the zero tolerance weed target list should be amended to include all non-native rushes, sedges, and mosses.

Habitat suitability

Measures of habitat suitability for the enclosure include low mortality rates as measured by ground shell plots, and stable or increasing snail counts over time. Over the first month following the initial release of snails, no ground shells were found and snail counts remained stable with a night-time detection rate of roughly 20-30%, even as snails were observed to migrate away from the release site and move further up into the trees (ANRPO 2021c). This detection rate was much higher than expected, as detection rates in dense, wet forest environments elsewhere have been very low (David Sischo, pers. comm.). Snail counts remained stable through to the end of the reporting year, with < 10% mortality observed (Chapter 5). The success to date for the initial release is a promising indication of the suitability of the site for this ESU.

REFERENCES

ANRPO. 2021a. Appendix 5-2 Kaala Snail Enclosure Special Use Permit Addendum *in* 2021 Status Report for the Makua and Oahu Implementation Plans.

ANRPO. 2021b. Appendix 5-4 Kaala Enclosure Restoration Plan *in* 2021 Status Report for the Makua and Oahu Implementation Plans.

ANRPO. 2021c. ANRPO Database. Accessed June, 2022.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Best Practices for Application of Molluscicide in Hawaiian Forests

For control of non-native slugs and snails via listed, approved molluscicide application in forests, on offshore islands, and in other natural areas to protect threatened and endangered Hawaiian plants. Only Ferroxx AQ® Slug and Snail Bait is approved for use in forest areas in Hawaii. Area must be thoroughly searched by experienced malacologists prior to application of Ferroxx AQ® granules to ensure that non-target native Hawaiian snail species are not impacted. Do not apply in areas where it may come into contact with known populations of endemic Hawaiian snail species from the following rare families or subfamilies: Amastridae, Achatinellinae and Endodontidae. Bait cannot be applied within 20 m of any tree known to harbor endangered Hawaiian tree snails (*Achatinella* spp.).

Pre-application Survey Protocol:

1. Conduct thorough Day survey of proposed treatment area to include searching trees and all understory vegetation. The ground and rock talus areas will also be searched. An effort to identify other snails found and their rarity will be made prior to Ferroxx use.
2. If proposed treatment area is known *Achatinella* spp. site or if *Achatinella* spp. is observed during Day survey, then must conduct night survey and remove all *Achatinella* spp. to a snail enclosure/protected area prior to bait use.
3. Area will continue to be surveyed and *Achatinella* spp. translocated to enclosures until all *Achatinella* spp. are removed from the area and at least one survey is conducted where 0 snails are found within area.
4. If *Achatinella* spp. is abundant in large numbers or is found on multiple trips, use of Ferroxx will not be allowed in area.
5. If *Achatinella* spp. are located in the area in the course of other field work, then surveys and relocated efforts will resume.
6. An effort to identify other snails found and determine their rarity will be made prior to Ferroxx use.

ARMY NATURAL RESOURCES PROGRAM ON OAHU
MONITORING PROGRAM

VEGETATION MONITORING RESULTS FOR THE PALIKEA NORTH SNAIL ENCLOSURE, 2021

INTRODUCTION

The Army Natural Resources Program on Oahu (ANRPO) documents vegetation cover change at the "Palikea North" *Achatinella mustelina* ESU-E predator resistant enclosure at Palikea Management Unit (MU) (Figure 1 and 2) as a measure of vegetation rehabilitation success in association with the enclosure's restoration plan (ANRPO 2017). The goal of restoration was to achieve a native plant dominated community favorable for *A. mustelina* as well as *Drosophila substenoptera*, *Drosophila montgomeryi*, and *Chasiempis ibidis*. The primary objective of monitoring is to assess if native vegetation cover goals are met. Despite highly intensive and ongoing restoration efforts, by Year 3, native cover goals continued to fall short of the anticipated goal timeline established in the original restoration plan, and it was apparent that the goals were overly optimistic. Recommendations were made to revise the goals for strata that had not yet been met (ANRPO 2021a). Native vegetation cover goals in the restoration plan were revised in 2021 (ANRPO 2021b) to reflect a more realistically attainable outcome as follows:

> 50% for 0 – 1 m above ground level (AGL) by Year 1
> 50% for 1 – 2 m AGL by Years 5 – 6*
> 50% for > 2 m AGL by Year 10*, > 75% by Year 15*
> 75% for total AGL cover by Year 2

*revised goals

A secondary objective is to assess if weed cover goals in the plan are met. Goals include maintaining < 10% weed cover, and having zero tolerance for a number of species (*Blechnum appendiculatum*, *Ehrharta stipoides*, *Nephrolepis brownii*, *Paspalum conjugatum*, and *Drymaria cordata*). Other taxa are specified as control targets (*Christella dentata*, *Christella parasitica*, *Clidemia hirta*, *Passiflora edulis*, *Passiflora suberosa*, *Phytolacca octandra*, *Psidium cattleianum*, *Rubus rosifolius*, and *Schinus terebinthifolius*, as well as non-native grasses and Asteraceae).

Vegetation monitoring occurred in April 2016 prior to non-native vegetation removal and enclosure wall construction, in September 2017 following completion of the enclosure wall, and annually thereafter in September 2018, October 2019, October 2020, and September 2021 (referred to in this report as pre-clearing, baseline, Year 1, Year 2, Year 3, and Year 4). Prior to initial non-native vegetation clearing, in 2016 the enclosure area contained dense vegetation with nearly continuous non-native cover and a smaller amount of scattered native vegetation. Non-native vegetation primarily consisted of *P. cattleianum*, *S. terebinthifolius*, and *C. hirta*. Native vegetation was mainly *Metrosideros polymorpha*, *Freycinetia arborea*, and *Nephrolepis exaltata*. After removal of non-native vegetation and enclosure wall completion in 2017, canopy openness increased dramatically, and native cover was somewhat reduced, primarily consisting of the remaining *M. polymorpha* trees. Considerable vegetation cover change occurred in the first three years after the completion of enclosure construction, following the expansion of native vegetation from natural regrowth and recruitment, as well as the addition of large numbers of outplants, sown seeds, and transplants. The native cover goal for the 0 – 1 m AGL stratum was met by Year 2. By Year 3 the goal of > 75% total AGL native cover was nearly met. Weed cover goals were

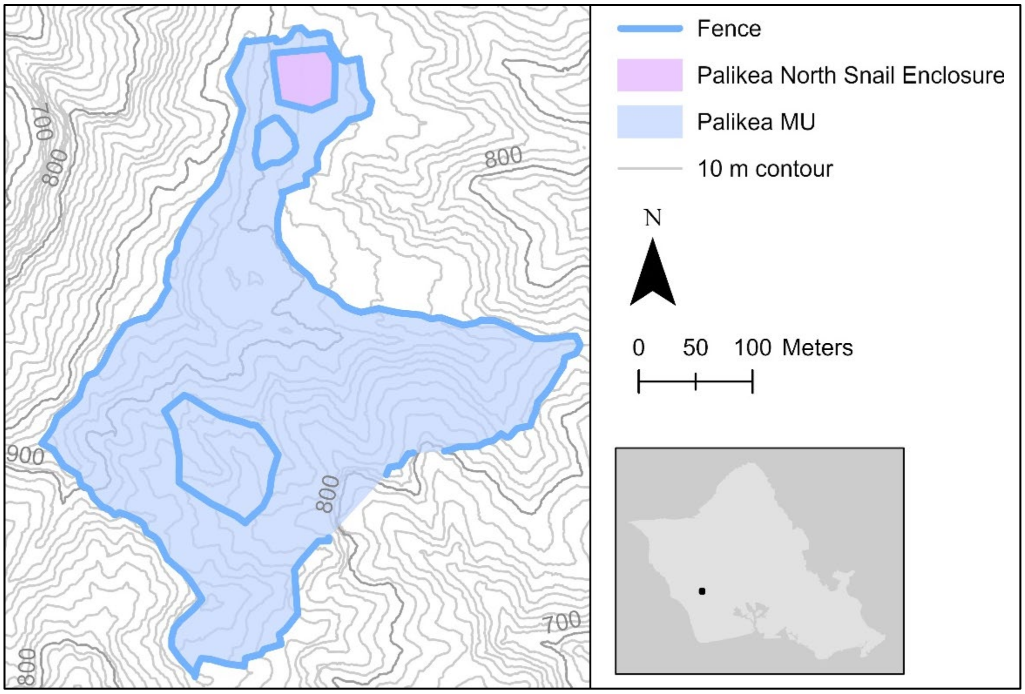

Figure 1: Location of the Palikea North snail enclosure at Palikea MU.


Figure 2: View of the Palikea North snail enclosure (April 2022).

maintained in the first year, but not thereafter, following aggressive colonization by weeds, particularly by grasses in Year 3. Four zero tolerance taxa were present within the first three years, with *E. stipoides* and *P. conjugatum* presenting the greatest challenges for control. A number of new control targets were present in conjunction with an increase in non-native species diversity. Canopy openness remained high through Year 3. Results were described and discussed in more detail in prior ANRPO Implementation Plan status reports (ANRPO 2016, 2019, 2020, and 2021a), and are reiterated in tables and figures presented in this report.

Vegetation monitoring occurred in April 2016 prior to non-native vegetation removal and enclosure wall construction, in September 2017 following completion of the enclosure wall, and annually thereafter in September 2018, October 2019, October 2020, and September 2021 (referred to in this report as pre-clearing, baseline, Year 1, Year 2, Year 3, and Year 4). Prior to initial non-native vegetation clearing, in 2016 the enclosure area contained dense vegetation with nearly continuous non-native cover and a smaller amount of scattered native vegetation. Non-native vegetation primarily consisted of *P. cattleianum*, *S. terebinthifolius*, and *C. hirta*. Native vegetation was mainly *Metrosideros polymorpha*, *Freycinetia arborea*, and *Nephrolepis exaltata*. After removal of non-native vegetation and enclosure wall completion in 2017, canopy openness increased dramatically, and native cover was somewhat reduced, primarily consisting of the remaining *M. polymorpha* trees. Considerable vegetation cover change occurred in the first three years after the completion of enclosure construction, following the expansion of native vegetation from natural regrowth and recruitment, as well as the addition of large numbers of outplants, sown seeds, and transplants. The native cover goal for the 0 – 1 m AGL stratum was met by Year 2. By Year 3 the goal of > 75% total AGL native cover was nearly met. Weed cover goals were maintained in the first year, but not thereafter, following aggressive colonization by weeds, particularly by grasses in Year 3. Four zero tolerance taxa were present within the first three years, with *E. stipoides* and *P. conjugatum* presenting the greatest challenges for control. A number of new control targets were present in conjunction with an increase in non-native species diversity. Canopy openness remained high through Year 3. Results were described and discussed in more detail in prior ANRPO Implementation Plan status reports (ANRPO 2016, 2019, 2020, and 2021a), and are reiterated in tables and figures presented in this report.

METHODS

Percent cover: Point intercept monitoring was used 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 pole was used to determine "hits" in the understory (live vegetation that touches the pole, including leaves, branches and trunks) along an outstretched measuring tape at regular intervals. Vegetation "hits" in the understory were recorded from 0 – 1 m AGL and 1 – 2 m AGL. A laser pointer was used to determine laser "hits" in the canopy (above 2 m AGL) at these same intercept points, where the point fell within the perimeter of a tree's canopy. Locations where no vegetation was intercepted were recorded as non-vegetated. Approximately 500 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. Locations of the sampled points are not permanent. Points were along 11 transects pre-clearing, and along 10 transects thereafter. Transects were spaced 5 m apart and oriented east/west, with point intercepts located every 1 m along transects (pre-clearing: n = 542, baseline: n = 501, Year 1: n = 492, Year 2: n = 494, Year 3: n = 490, and Year 4: n = 491). Approximations of percent cover were obtained from the proportion of "hits" among all intercepts.

Canopy openness: Hemispherical photography was used to monitor changes in canopy openness. Fish-eye photographs were taken at 2 m AGL, aimed 180° from the forest floor every 10 m on alternating transects during pre-clearing monitoring, and every 5 m along all transects during baseline and Years 1 - 4 monitoring (pre-clearing: n = 22, baseline: n = 88, Year 1: n = 92, Year 2: n = 93, Year 3: n = 95, and Year 4: n = 98).

Supplemental data: Unmanned aerial vehicle (UAV) imagery was taken during the course of non-native vegetation clearing and in conjunction with vegetation monitoring following completion of the enclosure construction. Five permanent photopoints were established (marked with permanent galvanized pipe) for visual documentation of sub-canopy change in each cardinal direction at each point. During the course of vegetation monitoring, a species diversity list was created documenting all species that happened to be observed, but not intercepted. The list will help document change in the presence or absence of species that have low cover, or are uncommon, and therefore less likely to be documented during point intercept monitoring. A data logger (Onset HOBO U23-001) was installed on site in April 2018 to document hourly temperature and relative humidity (data not presented here). A soil moisture sensor (Onset S-SMD-M005) and data logger (Onset HOBO H21-USB) was installed in April 2018 to document hourly soil moisture (data to be presented at a later date).

Analysis: Analysis included Pearson's chi-square tests and Fisher's Exact tests (when the minimum expected count was less than 5) for cover change, and Mann-Whitney tests for differences in canopy openness. 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. Additional point intercepts were obtained during the 2016 monitoring (prior to wall construction) and were excluded from the analysis as they were located outside the enclosure wall. Exact wall placement had not been determined at that time. Canopy openness was estimated from hemispheric photographs using Gap Light Analyzer (GLA), Version 2.0. All analyses were performed using the software R, Version 4.1.1 (R Core Team 2020).

Monitoring schedule: Monitoring will continue annually through Year 5, after which it will occur in Year 7, Year 10, and Year 15. The monitoring interval will be re-evaluated after Year 15.

RESULTS

Upon further expansion of native vegetation (naturally occurring and restored, including over 3,100 outplants) (Table 1), by Year 4, there was a significant increase in native vegetation cover for all strata (Table 2). The rate of change in the 0 – 1 m stratum slowed somewhat in Years 3 and 4, while the rate of change in the 1 – 2 m stratum has remained steady since Year 1 (Figure 3). The native sedge *Cyperus polystachyos* (naturally recruiting and sown) continues to be the most prevalent taxon in the 0 – 1 m stratum, after its considerable expansion between Years 1 and 4 (Table 3). Most prevalent in the 0 – 1 stratum following *C. polystachyos* were *N. exaltata* (largely regeneration from *in situ* plants, and nearly reaching pre-clearing levels) and *Kadua affinis* (the taxon with the greatest number of outplants). Sedges remained the dominant native growth form in the 0 – 1 m stratum in Year 4, followed by ferns, shrubs, and trees (Table 4). The increased cover in the 1 – 2 m stratum was largely attributable to the vertical growth of *K. affinis, Cheirodendron trigynum, Coprosma longifolia*, *Cibotium chamissoi*, and *Scaevola gaudichaudiana* into this stratum. *Metrosideros polymorpha* remained the dominant canopy species, with increased cover in the > 2 m stratum largely attributable to increased cover of *C. trigynum* and *Pipturus albidus.* Canopy openness remained unchanged from Year 1 (Mann-Whitney: $p = 0.703$, $W = 4065$). Most outplanted, sown, and transplanted taxa were either intercepted during monitoring or otherwise anecdotally observed in Year 4 (Table 5). Fates of unobserved taxa were undetermined, as they are not individually tracked, and the density of the vegetation greatly hampered visibility and limited the ability to observe small plants and infrequent taxa and to make comprehensive lists of all species present.

Table 1: Species outplanted, sown, and/or transplanted in association with native vegetation restoration during the first four years following enclosure construction (Fall 2017 to Fall 2018 = Year 1, etc.). Total number of outplants, seeds, and transplants are listed by year post-construction. Seed and transplant numbers were not tracked for every restoration effort; these are listed as undetermined, or U.

Species	Year 1	Year 2	Year 3	Year 4	**Total**
Outplants					
Acacia koa	24				**24**
Alyxia stellata	3		4		**7**
Antidesma platyphyllum		15	4		**19**
Bidens torta	146	1			**147**
Carex wahuensis			62		**62**
Cheirodendron trigynum	168	12	66	31	**277**
Clermontia oblongifolia		14		21	**35**
Coprosma longifolia	290	19	13	117	**439**
Cyrtandra waianaeensis				1	**1**
Dodonaea viscosa			12		**12**
Dianella sandwicense			40	28	**68**
Freycinetia arborea	3	20	10	11	**44**
Ilex anomala	12	13		1	**26**
Kadua affinis	412	20	57		**489**
Labordia kaalae		98	25		**123**
Luzula hawaiiensis		4			**4**
Metrosideros polymorpha var. *glaberrima*		41	24	8	**73**
Metrosideros polymorpha var. *polymorpha*		43	79		**122**
Microlepia speluncae		3		50	**53**
Microlepia strigosa		3		33	**36**
Myrsine lessertiana			35	4	**39**
Perrottetia sandwicensis	26	35	54	56	**171**
Pipturus albidus	12			27	**39**
Pisonia brunoniana	160			49	**209**
Pittosporum confertiflorum		11			**11**
Psychotria hathewayi		16	7	1	**24**
Psychotria mariniana	38	7	20	48	**113**
Pteris excelsa				64	**64**
Rumex albescens				30	**30**
Santalum freycinetianum var. *freycinetianum*	4				**4**
Scaevola gaudichaudiana	9		5	1	**15**
Urera glabra	131	100	57	68	**356**
Wikstroemia oahuensis var. *oahuensis*	33				**33**
Total outplants	**1471**	**475**	**574**	**649**	**3169**
Seed sows					
Bidens torta	ca. 10,000	19,000			**>29,000**
Cyperus polystachyos		>10,000			**>10,000**
Pipturus albidus	U	U			**U**
Scaevola gaudichaudiana	24	24			**>48**
Total seeds sown	**>10,024**	**>29,024**			**>39,048**
Transplants					
Cibotium chamissoi	65				**65**
Dianella sandwicense		U			**U**
Total transplants	**65**	**U**			**65**

Table 2: Vegetation cover by stratum during pre-clearing (2016), baseline (2017), and Years 1 - 4 (2018 - 2021) monitoring. Pearson's chi-square tests were used for cover change between baseline and Year 4 ([a]Fisher's Exact Test used when minimum expected count was less than 5). Statistically significant results are in boldface. Arrows indicate increase (↑) or decrease (↓) in cover. Cover values meeting management goals are highlighted in blue.

	Pre-clearing	Baseline	Year 1	Year 2	Year 3	Year 4	P	X^2
0-1 m								
Native	18.1	2.8	24.4	53.0	63.7	71.9	**0.000**↑	507.97
Non-native	37.3	0.0	6.1	18.8	27.6	50.1	**0.000**↑	333.78
Non-vegetated	49.8	97.2	71.1	37.9	25.7	9.8	**0.000**↓	762.92
1-2 m								
Native	6.1	1.4	2.2	9.3	25.7	36.5	**0.000**↑	200.07
Non-native	36.3	0.0	0.0	0.2	2.4	4.3	**0.000**↑	21.891
Non-vegetated	59.6	98.6	97.8	90.5	73.1	62.3	**0.000**↓	209.12
>2 m								
Native	16.8	6.8	6.9	7.1	10.8	16.1	**0.000**↑	21.263
Non-native	94.8	0.0	0.0	0.0	0.0	0.6	0.121[a]	
Non-vegetated	2.0	93.2	93.1	92.9	89.2	83.7	**0.000**↓	22.035
Total vegetation AGL								
Native	32.1	9.0	28.9	57.7	72.4	81.7	**0.000**↑	529.46
Non-native	98.2	0.0	6.1	18.8	28.8	51.1	**0.000**↑	342.87

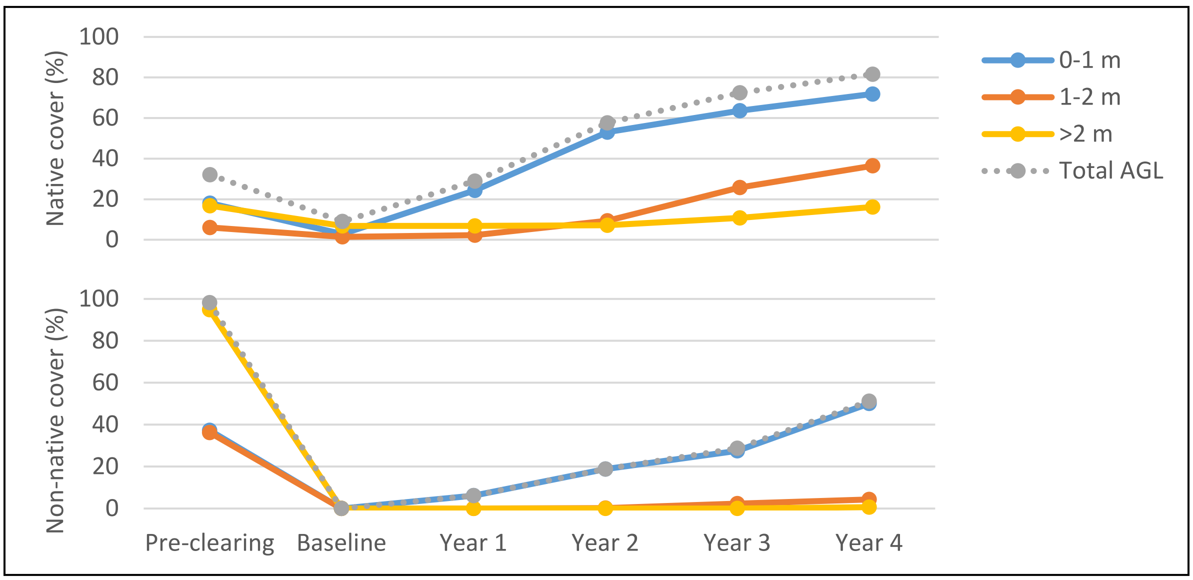

Figure 3: Native and non-native cover by stratum, and total cover above ground level (AGL), over time.

Table 3: Species percent cover by stratum and year: pre-clearing (2016), baseline (2017), and Years 1 - 4 (2018 - 2021). Pearson's chi-square tests were used for cover change between baseline and Year 4 for taxa with > 10% absolute cover change. Native taxa are in boldface. Arrows indicate increase (↑) or decrease (↓) in cover.

Species	Pre-clearing	Baseline	Year 1	Year 2	Year 3	Year 4	p	X^2
0-1 m								
Acacia koa	0.0	0.0	0.2	0.0	0.0	0.0		
Ageratum conyzoides	0.0	0.0	0.0	0.2	0.2	1.0		
Alyxia stellata	0.0	0.0	0.0	0.0	0.0	0.2		
Andropogon virginicus	0.0	0.0	0.0	0.2	0.4	2.6		
Asplenium contiguum	0.9	0.0	0.0	0.0	0.2	0.2		
Bidens torta	0.0	0.0	2.2	1.2	0.8	0.6		

Table 3 (continued).

Species	Pre-clearing	Baseline	Year 1	Year 2	Year 3	Year 4	p	X^2
0-1 m (continued)								
Blechnum appendiculatum[1]	0.6	0.0	0.0	0.0	0.0	0.0		
Buddleja asiatica	0.0	0.0	0.0	0.0	0.0	0.2		
Carex wahuensis	0.0	0.0	0.0	0.0	0.8	1.0		
Ceodes brunoniana	0.0	0.0	0.6	0.4	0.4	0.2		
Cheirodendron trigynum	0.0	0.2	0.8	1.8	0.4	1.6		
Christella parasitica	0.2	0.0	0.0	0.2	0.2	0.8		
Cibotium chamissoi	0.0	0.0	0.2	1.6	1.2	1.0		
Clermontia oblongifolia	0.0	0.0	0.0	0.0	0.2	0.2		
Clidemia hirta	13.1	0.0	0.6	2.4	4.9	12.2	0.000↑	65.163
Conyza bonariensis	0.0	0.0	0.0	0.6	0.6	0.4		
Conyza canadensis var. *pusilla*	0.0	0.0	0.0	0.6	1.2	1.0		
Coprosma foliosa	0.0	0.2	0.0	0.6	0.0	0.8		
Coprosma longifolia	0.0	0.2	3.3	7.9	11.8	9.2		
Crassocephalum crepidioides	0.0	0.0	0.0	5.9	0.4	0.0		
Cyperus polystachyos	0.0	0.0	1.6	22.3	21.4	32.2	0.000↑	191.760
Dianella sandwicensis	0.0	0.0	0.0	0.4	1.2	2.9		
Dodonaea viscosa	0.0	0.0	0.0	0.2	2.0	1.4		
Drymaria cordata var. *pacifica*[1]	0.0	0.0	0.0	0.2	0.0	0.2		
Ehrharta stipoides[1]	0.9	0.0	0.2	1.0	4.9	5.7		
Emilia sonchifolia	0.0	0.0	0.0	0.4	0.4	0.0		
Freycinetia arborea	0.6	1.0	1.8	2.4	3.3	3.7		
Kadua affinis	0.0	0.0	2.2	7.7	10.0	11.0	0.000↑	58.272
Melinis minutiflora	0.0	0.0	0.0	0.0	0.0	1.2		
Metrosideros polymorpha	0.4	0.2	0.0	0.2	1.2	1.0		
Microlepia strigosa	2.8	0.0	0.2	0.8	1.6	2.2		
Nephrolepis brownii[1]	0.0	0.0	0.0	0.0	0.2	0.4		
Nephrolepis exaltata	14.0	1.0	3.9	5.1	10.8	12.0	0.000↑	49.881
Oxalis corniculata	0.0	0.0	0.4	3.0	0.0	0.2		
Paspalum conjugatum[1]	4.4	0.0	4.1	4.0	15.9	30.3	0.000↑	178.910
Passiflora edulis	0.0	0.0	0.0	0.0	0.2	0.0		
Passiflora suberosa	0.2	0.0	0.0	0.0	0.2	0.8		
Perrottetia sandwicensis	0.0	0.0	0.6	0.2	0.0	0.0		
Phytolacca octandra	0.0	0.0	0.6	0.4	0.2	0.4		
Physalis peruviana	0.0	0.0	0.0	0.2	0.0	0.0		
Pipturus albidus	0.0	0.0	6.5	2.0	1.8	0.8		
Pluchea carolinensis	0.0	0.0	0.2	0.0	0.0	0.0		
Psidium cattleianum	20.3	0.0	0.4	0.6	0.8	0.2		
Psychotria mariniana	0.0	0.0	0.2	0.0	0.6	0.2		
Rubus rosifolius	2.4	0.0	0.2	0.2	0.4	0.0		
Scaevola gaudichaudiana	0.0	0.0	2.2	6.7	7.1	4.9		
Schinus terebinthifolius	0.4	0.0	0.0	0.2	0.0	0.8		
Setaria parviflora	0.0	0.0	0.0	0.0	0.2	0.4		
Smilax melastomifolia	0.0	0.0	0.0	0.2	0.2	0.2		
Solanum americanum	0.0	0.0	0.0	0.2	0.8	1.0		
Urera glabra	0.0	0.0	0.0	0.2	0.2	0.0		
Wikstroemia oahuensis* var. *oahuensis	0.0	0.0	0.2	0.4	1.2	0.8		
Youngia japonica	0.0	0.0	0.0	0.2	0.0	0.2		
1-2 m								
Ageratina adenophora	0.0	0.0	0.0	0.0	0.0	0.2		
Andropogon virginicus	0.0	0.0	0.0	0.0	0.4	0.2		
Antidesma platyphyllum	0.2	0.0	0.0	0.0	0.0	0.0		
Ceodes brunoniana	0.0	0.0	0.0	0.0	0.2	0.0		

Table 3 (continued).

Species	Pre-clearing	Baseline	Year 1	Year 2	Year 3	Year 4	p	X^2
1-2 m (continued)								
Cheirodendron trigynum	0.2	0.2	0.0	1.8	2.2	7.3		
Cibotium chamissoi	0.4	0.2	0.6	1.2	3.3	4.7		
Clermontia persicifolia	0.0	0.0	0.0	0.0	0.0	0.4		
Clidemia hirta	19.9	0.0	0.0	0.0	0.4	1.2		
Conyza bonariensis	0.0	0.0	0.0	0.0	0.2	0.2		
Conyza canadensis var. *pusilla*	0.0	0.0	0.0	0.0	0.0	0.2		
Coprosma foliosa	0.0	0.0	0.0	0.0	0.2	0.4		
Coprosma longifolia	0.0	0.6	0.2	0.2	4.9	6.9		
Crassocephalum crepidioides	0.0	0.0	0.0	0.2	0.0	0.0		
Dodonaea viscosa	0.0	0.0	0.0	0.0	1.2	2.6		
Freycinetia arborea	2.0	0.0	0.0	0.8	0.8	2.0		
Kadua affinis	0.6	0.2	0.4	0.6	4.7	7.7		
Melinis minutiflora	0.0	0.0	0.0	0.0	0.0	0.2		
Metrosideros polymorpha	0.9	0.2	0.0	0.2	0.4	0.0		
Microlepia strigosa	0.6	0.0	0.0	0.0	0.2	0.0		
Morella faya	0.2	0.0	0.0	0.0	0.0	0.0		
Nephrolepis exaltata	1.1	0.0	0.0	0.0	0.4	0.4		
Paspalum conjugatum	0.0	0.0	0.0	0.0	0.6	0.8		
Passiflora edulis	0.0	0.0	0.0	0.0	0.6	0.0		
Passiflora suberosa	0.0	0.0	0.0	0.0	0.0	0.2		
Pipturus albidus	0.0	0.0	1.0	3.2	3.1	3.3		
Psidium cattleianum	15.5	0.0	0.0	0.0	0.0	0.2		
Psychotria mariniana	0.2	0.0	0.0	0.0	0.0	0.0		
Rubus rosifolius	0.2	0.0	0.0	0.0	0.0	0.2		
Scaevola gaudichaudiana	0.0	0.0	0.0	1.2	5.1	4.5		
Schinus terebinthifolius	1.1	0.0	0.0	0.0	0.2	0.6		
Smilax melastomifolia	0.0	0.0	0.0	0.0	0.2	0.2		
Wikstroemia oahuensis* var. *oahuensis	0.2	0.0	0.0	0.0	0.0	0.0		
>2 m								
Acacia koa	0.0	0.0	0.0	0.0	0.2	0.0		
Cheirodendron trigynum	1.1	0.2	0.2	0.4	1.2	4.3		
Cibotium chamissoi	0.4	0.0	0.0	0.2	0.4	0.2		
Clidemia hirta	4.2	0.0	0.0	0.0	0.0	0.0		
Coprosma longifolia	0.2	1.0	0.4	0.0	0.2	0.0		
Dodonaea viscosa	0.0	0.0	0.0	0.0	0.0	0.4		
Freycinetia arborea	5.4	0.2	0.0	0.0	0.6	0.2		
Grevillea robusta	1.1	0.0	0.0	0.0	0.0	0.0		
Kadua affinis	0.6	0.0	0.4	0.0	0.0	0.6		
Metrosideros polymorpha	9.6	5.4	5.9	4.7	5.1	5.7		
Morella faya	4.4	0.0	0.0	0.0	0.0	0.0		
Passiflora edulis	0.6	0.0	0.0	0.0	0.0	0.0		
Passiflora suberosa	0.0	0.0	0.0	0.0	0.0	0.2		
Pipturus albidus	0.0	0.0	0.0	1.6	3.7	4.3		
Psidium cattleianum	77.7	0.0	0.0	0.0	0.0	0.0		
Psychotria mariniana	0.4	0.0	0.0	0.2	0.0	0.0		
Scaevola gaudichaudiana	0.4	0.0	0.0	0.0	0.2	1.6		
Schinus terebinthifolius	39.1	0.0	0.0	0.0	0.0	0.4		

[1]Zero tolerance weed

Table 4: Vegetation percent cover by growth form within stratum by year: pre-clearing (2016), baseline (2017), and Years 1 - 4 (2018 - 2021).

	Native						*Non-native*					
	Pre-clearing	Base-line	Year 1	Year 2	Year 3	Year 4	Pre-clearing	Base-line	Year 1	Year 2	Year 3	Year 4
0-1 m												
Fern	17.7	2.0	5.7	9.1	14.9	17.7	0.7	0.0	0.0	0.2	0.4	1.2
Grass	0.0	0.0	0.0	0.0	0.0	0.0	5.4	0.0	4.3	5.3	21.0	38.1
Herb	0.0	0.0	2.2	1.6	2.0	3.5	0.0	0.0	0.4	10.5	2.7	3.1
Sedge	0.0	0.0	1.6	22.3	22.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0
Shrub	0.0	0.4	5.7	16.0	21.0	17.3	15.1	0.0	1.6	3.0	5.3	12.8
Tree	0.4	0.4	11.0	12.6	16.5	15.9	20.7	0.0	0.4	0.8	0.8	1.0
Vine	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.8
1-2 m												
Fern	4.1	0.2	0.6	2.0	4.7	6.9	0.0	0.0	0.0	0.0	0.0	0.0
Grass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.2
Herb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.4
Shrub	0.2	0.6	0.2	1.4	10.4	12.0	20.1	0.0	0.0	0.0	0.4	1.6
Tree	2.0	0.6	1.4	5.9	11.6	19.8	16.6	0.0	0.0	0.0	0.2	0.8
Vine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2
>2 m												
Fern	5.7	0.2	0.0	0.2	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Shrub	0.6	1.0	0.4	0.0	0.4	1.6	4.2	0.0	0.0	0.0	0.0	0.0
Tree	11.6	5.6	6.5	6.9	10.0	14.7	94.1	0.0	0.0	0.0	0.0	0.4
Vine	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.2

Table 5: All taxa intercepted (I) or anecdotally (A) observed by year in any strata from 0 - 1 m, 1 -2 m, or >2 m above ground level. Note: The anecdotally observed area in 2016 (pre-clearing, prior to wall construction and final wall placement determination) included area outside the enclosure wall, and may include taxa not present within the bounds of the enclosure. New taxon observations for 2021 are highlighted in blue. [1]Taxon represented in restoration efforts (outplant, seed sow, and/or transplant). [2]Zero tolerance weed.

Species	Pre-clearing	Baseline	Year 1	Year 2	Year 3	Year 4
Native						
Acacia koa[1]			I	A	I	A
Alyxia stellata[1]			A	A	A	I
Antidesma platyphyllum[1]	I			A	A	A
Asplenium caudatum	A					
Asplenium contiguum	I	A	A	A	I	I
Athyrium microphyllum	A					
Bidens torta[1]			I	I	I	I
Carex wahuensis[1]					I	I
Ceodes brunoniana[1]			I	I	I	I
Cheirodendron trigynum[1]	I	I	I	I	I	I
Cibotium chamissoi[1]	I	I	I	I	I	I
Clermontia oblongifolia[1]				A	I	I
Coprosma foliosa	A	I		I	I	I
Coprosma longifolia[1]	I	I	I	I	I	I
Cyperus polystachyos[1]			I	I	I	I
Dianella sandwicensis[1]	A	A	A	I	I	I
Dodonaea viscosa[1]			A	I	I	I
Dryopteris fusco-atra		A	A			
Dryopteris glabra	A					

Table 5 (continued).

Species	Pre-clearing	Baseline	Year 1	Year 2	Year 3	Year 4
Native (continued)						
Freycinetia arborea[1]	I	I	I	I	I	I
Hydrangea arguta	A	A				
Ilex anomala[1]	A		A			
Kadua affinis[1]	I	I	I	I	I	I
Labordia kaalae[1]	A	A		A	A	
Lepisorus thunbergianus	A	A	A	A	A	A
Metrosideros polymorpha[1]	I	I	I	I	I	I
Microlepia strigosa[1]	I	A	I	I	I	I
Myrsine lessertiana[1]	A				A	
Nephrolepis exaltata subsp. *hawaiiensis*	I	I	I	I	I	I
Odontosoria chinensis				A	A	
Peperomia membranacea		A	A	A		
Peperomia tetraphylla	A	A	A			
Perrottetia sandwicensis[1]			I	I	A	
Pipturus albidus[1]			I	I	I	I
Pittosporum confertiflorum[1]				A	A	A
Psilotum nudum	A	A				
Psychotria hathewayi[1]	A	A		A		A
Psychotria mariniana[1]	I	A	I	I	I	I
Pteridium aquilinum			A	A	A	
Sadleria cyatheoides				A	A	A
Scaevola gaudichaudiana[1]	I	A	I	I	I	I
Sicyos pachycarpus				A		
Smilax melastomifolia	A	A	A	I	I	I
Solanum americanum				I	I	I
Streblus pendulinus	A	A	A			
Urera glabra[1]			A	I	I	A
Vandenboschia davallioides	A					
Waltheria indica		A				
Wikstroemia oahuensis var. *oahuensis*[1]	I	A	I	I	I	I
Total native diversity	29	25	30	36	35	31
Non-native						
Acacia confusa						A
Ageratina adenophora					A	I
Ageratina riparia					A	
Ageratum conyzoides			A	I	I	I
Andropogon virginicus			A	I	I	I
Blechnum appendiculatum[2]	I					
Buddleja asiatica			A	A		I
Casuarina equisetifolia			A			
Cheilanthes viridis					A	A
Christella parasitica	I	A	A	I	I	I
Clidemia hirta	I	A	I	I	I	I
Conyza bonariensis			A	I	I	I
Conyza canadensis var. *pusilla*				I	I	I
Crassocephalum crepidioides			A	I	I	

Table 5 (continued).

Species	Pre-clearing	Baseline	Year 1	Year 2	Year 3	Year 4
Non-native (continued)						
Cuphea carthagenensis					A	A
Cyperus meyenianus					A	
Drymaria cordata var. *pacifica*[2]				I	A	I
Epidendrum x obrienianum	A					
Ehrharta stipoides[2]	I	A	I	I	I	I
Emilia sonchifolia			A	I	I	A
Erechtites valerianifolia						A
Gamochaeta purpurea			A	A	A	
Grevillea robusta	I					A
Lantana camara						A
Leucaena leucocephala			A			
Macrothelypteris torresiana				A	A	
Melinis minutiflora			A		A	I
Mesosphaerum pectinatum					A	
Morella faya	I		A			
Nephrolepis brownii[2]					I	I
Oxalis corniculata			I	I	A	I
Paspalum conjugatum[2]	I	A	I	I	I	I
Passiflora edulis	I				I	
Passiflora suberosa	I	A		A	I	I
Phlebodium aureum			A			A
Physalis peruviana				I		A
Phytolacca octandra		A	I	I	I	I
Pityrogramma austroamericana			A			
Pluchea carolinensis			I		A	A
Polystachia concreta		A				
Psidium cattleianum	I	A	I	I	I	I
Rubus rosifolius	I		I	I	I	I
Schinus terebinthifolius	I	A	A	I	I	I
Setaria parviflora					I	I
Unknown			A			
Youngia japonica	*		A	I		I
Total non-native diversity	14	9	25	22	30	31

The goal of > 50% native cover was maintained for the 0 – 1 m stratum, and the goal of > 75% total native cover was finally met in Year 4. Progress was made towards meeting native cover goals in the 1 – 2 m and > 2 m strata. Unfortunately, the goal of maintaining weed cover of < 10% continues to not be met, and there was a substantial increase from the prior year in non-native cover in the 0 – 1 m stratum. This was primarily due to continued aggressive colonization by alien grasses and shrubs in Year 4 (grasses continued to be the dominant weedy growth form), largely attributable to increased cover of *P. conjugatum* and *C. hirta* from the prior year. Four zero tolerance species were present, with *P. conjugatum* continuing to be most problematic. Weed diversity in Year 4 was similar to that of the prior year.

The dramatic changes in vegetation cover following removal of non-native vegetation, and notable changes in the first four years following construction completion and initiation of both active and passive restoration, are quite apparent in the UAV imagery (for total vegetation cover) (Figure 4) as well as in photopoint images (for visual representation of sub-canopy vegetation) (Figures 5-9).

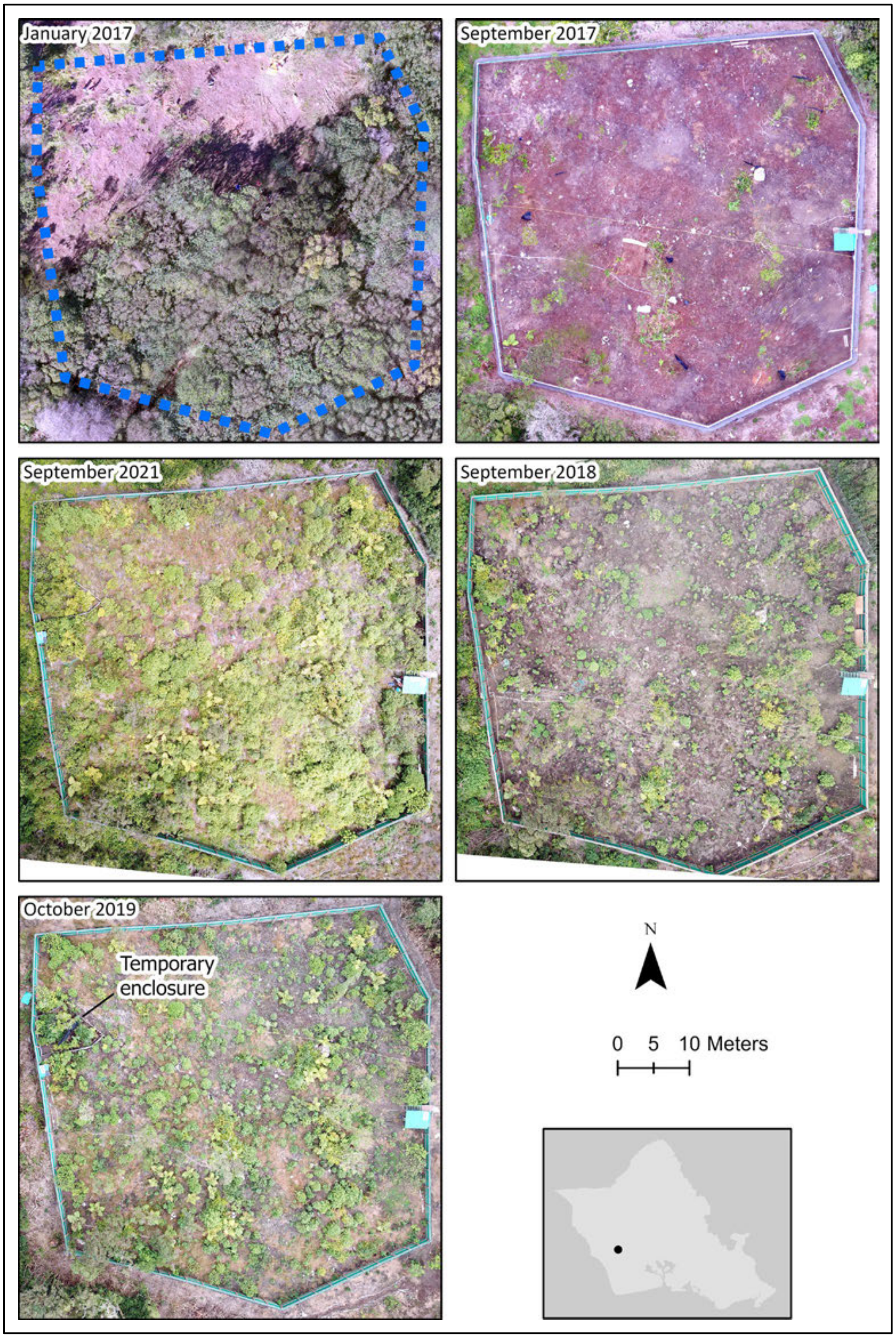

Figure 4: UAV imagery of the enclosure over time (clockwise from top left): during clearing (January 2017), post-completion (baseline, September 2017), and in Years 1, 2 and 4 (September 2018, October 2019, and September 2021) monitoring. The temporary enclosure is indicated when it first appeared in the imagery.

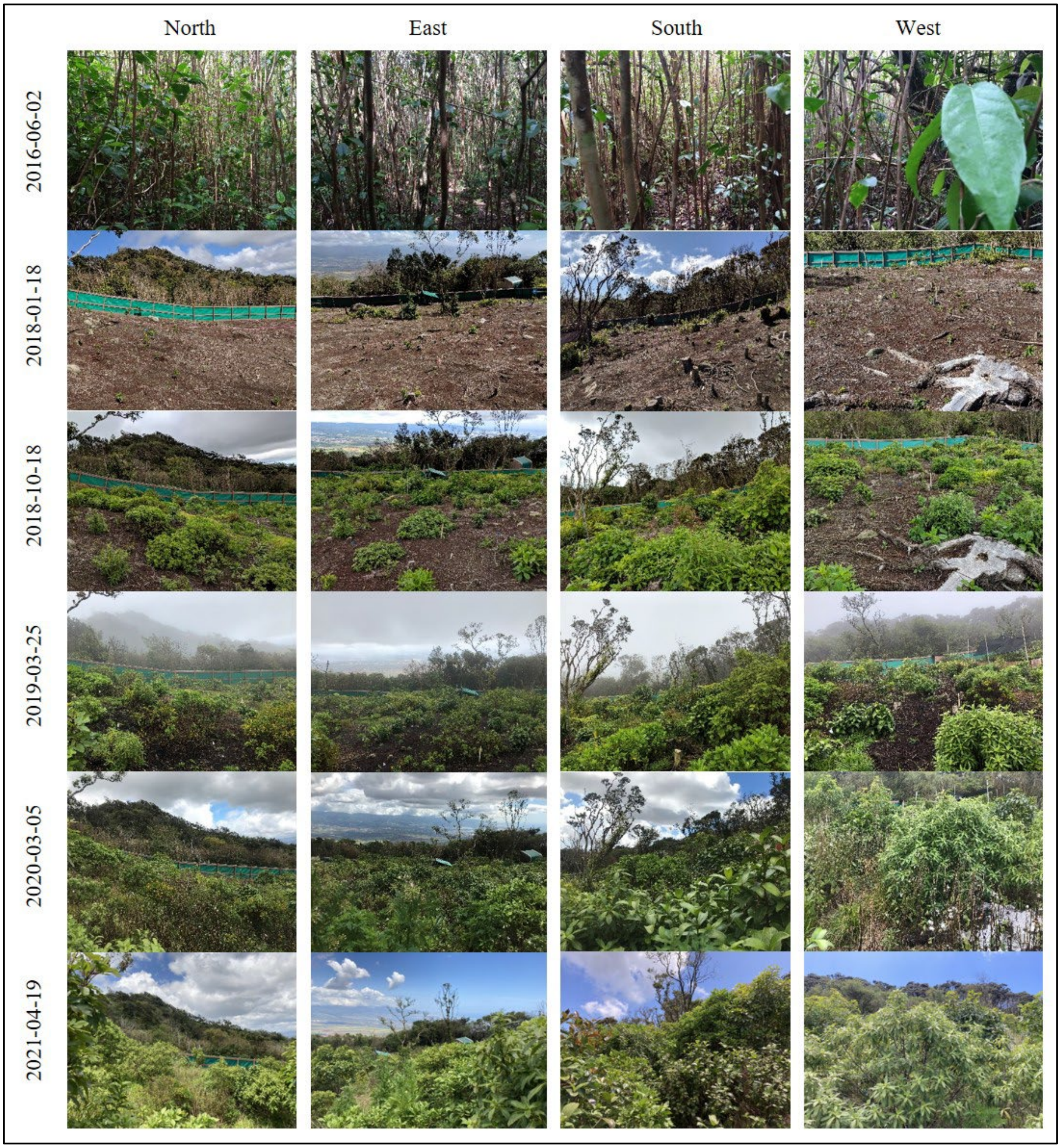

Figure 5: Photopoint 1 images over time with views in each cardinal direction pre-clearing (June 2016), post-clearing and after the initial outplantings (January 2018), and at one year (October 2018), 1.5 years (March 2019) 2.5 years (March 2020), and 3.5 years (April 2021) post-completion of the wall. Full-sized images may be viewed upon request.

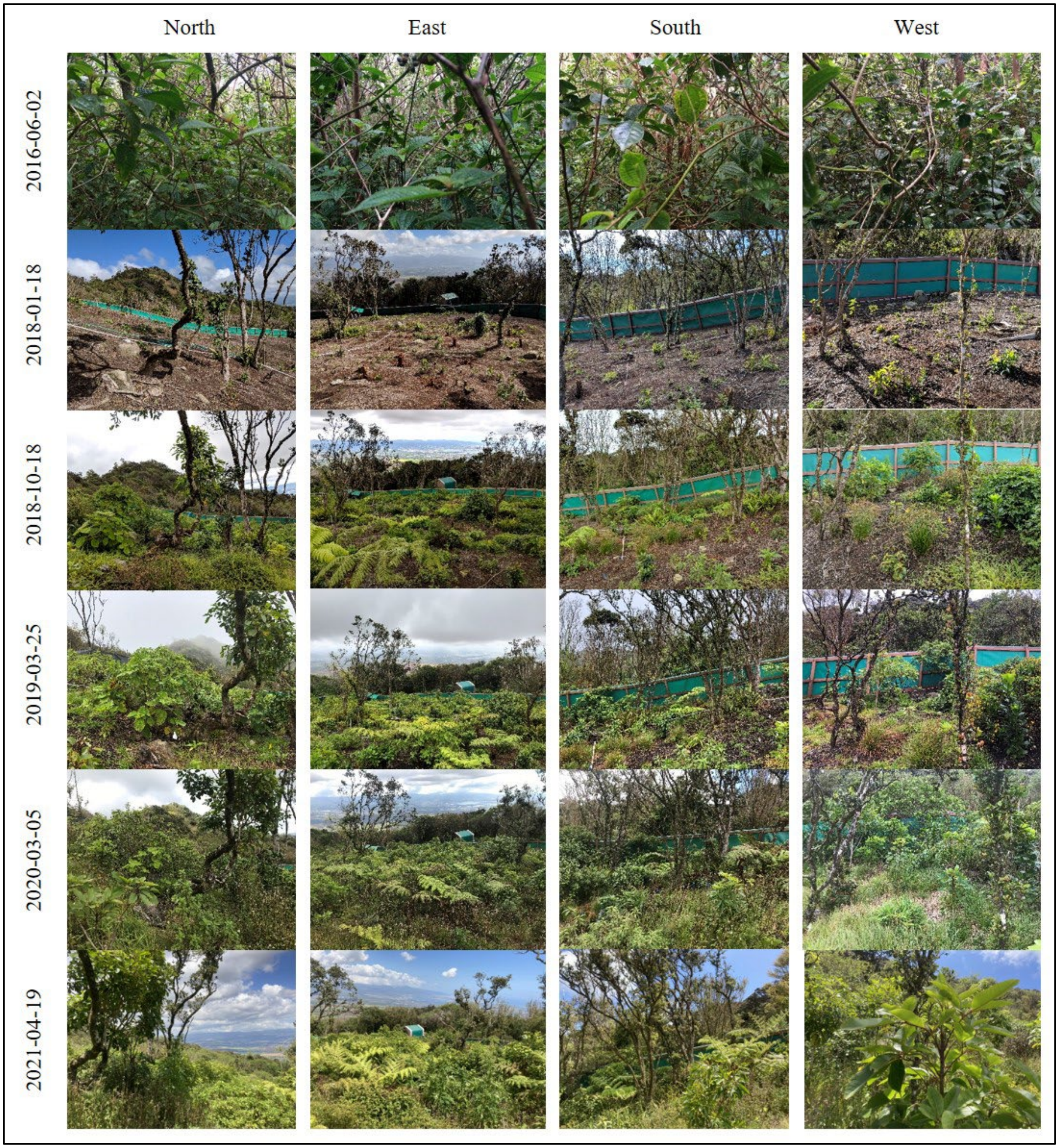

Figure 6: Photopoint 2 images over time with views in each cardinal direction pre-clearing (June 2016), post-clearing and after the initial outplantings (January 2018), and at one year (October 2018), 1.5 years (March 2019) 2.5 years (March 2020), and 3.5 years (April 2021) post-completion of the wall. Full-sized images may be viewed upon request.

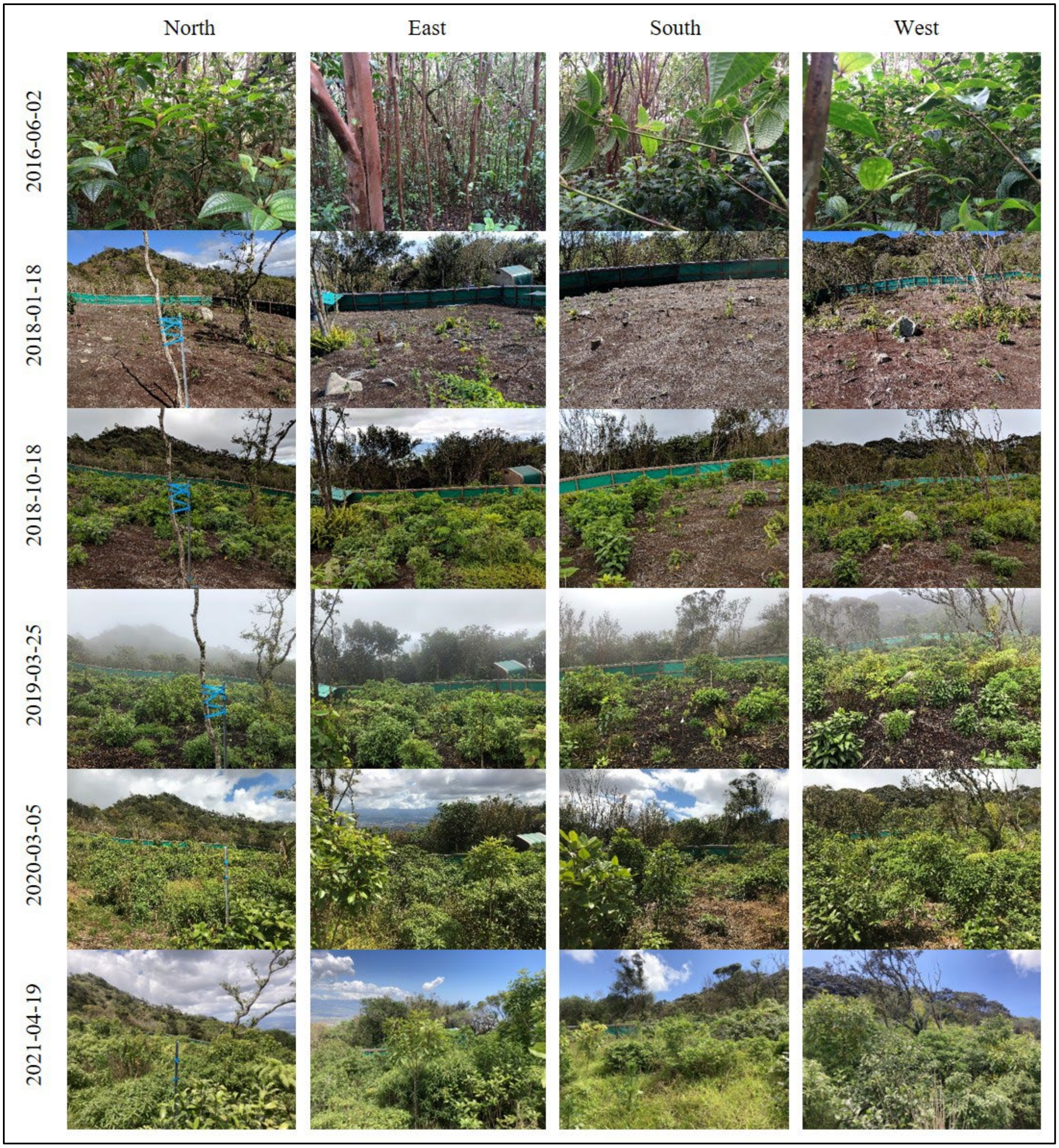

Figure 7: Photopoint 3 images over time with views in each cardinal direction pre-clearing (June 2016), post-clearing and after the initial outplantings (January 2018), and at one year (October 2018), 1.5 years (March 2019) 2.5 years (March 2020), and 3.5 years (April 2021) post-completion of the wall. Full-sized images may be viewed upon request.

Figure 8: Photopoint 4 images over time with views in each cardinal direction pre-clearing (June 2016), post-clearing and after the initial outplantings (January 2018), and at one year (October 2018), 1.5 years (March 2019) 2.5 years (March 2020), and 3.5 years (April 2021) post-completion of the wall. Full-sized images may be viewed upon request.

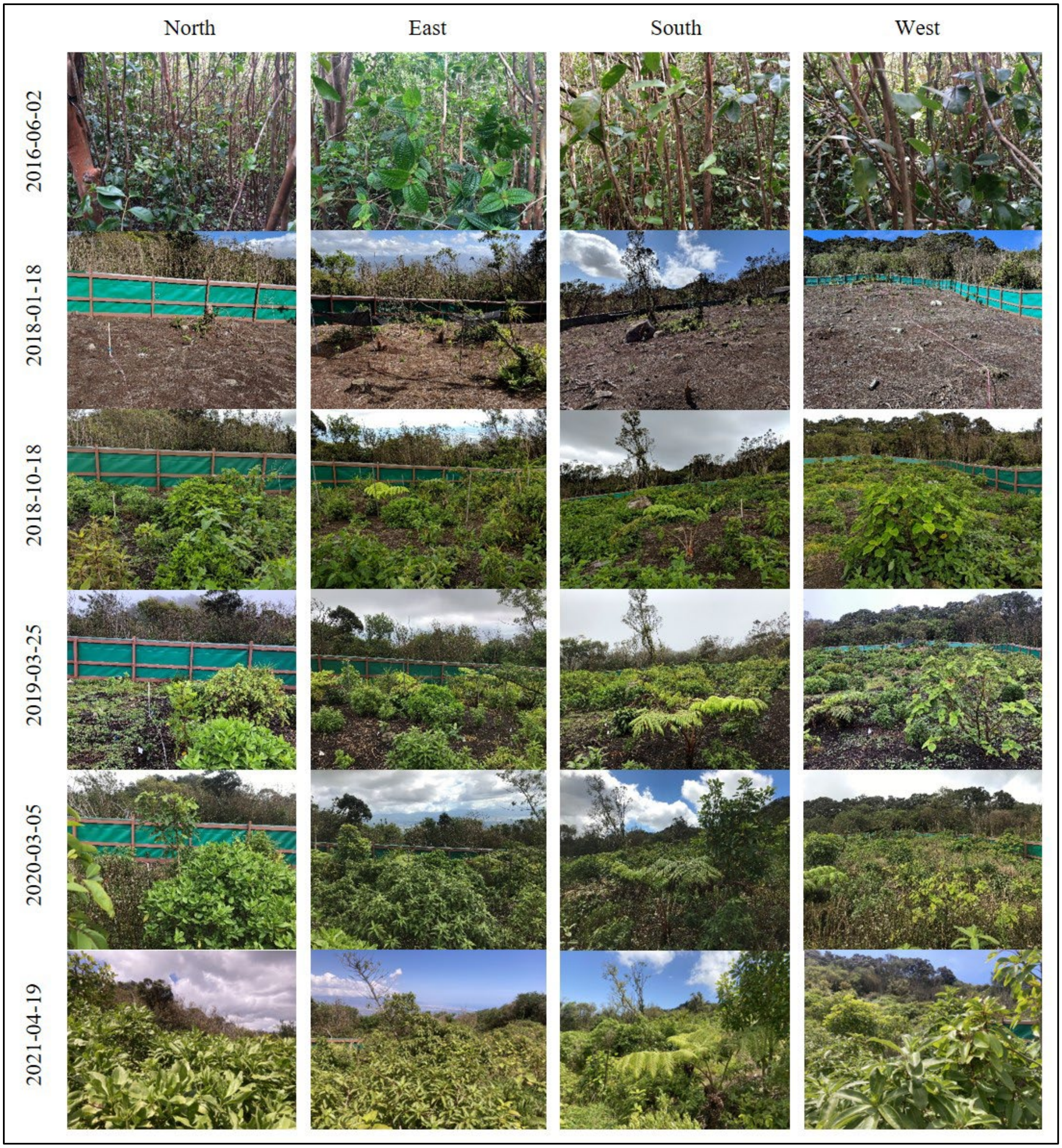

Figure 9: Photopoint 5 images over time with views in each cardinal direction pre-clearing (June 2016), post-clearing and after the initial outplantings (January 2018), and at one year (October 2018), 1.5 years (March 2019) 2.5 years (March 2020), and 3.5 years (April 2021) post-completion of the wall. Full-sized images may be viewed upon request.

DISCUSSION

Native cover restoration goals: Substantial understory cover increase occurred in the first four years as a successful result of the both active (outplantings, seed sows, and transplants) and passive (growth of in situ vegetation as well as natural recruitment) restoration of native vegetation. In Year 4, the native cover goal for the 0 – 1m stratum continued to be surpassed, and the goal of > 75% total AGL was finally met. Cover in the 1 – 2 m and > 2 m strata appear to be on track for meeting their goals in the coming years.

Weed control goals: The weed cover goal of < 10% continued to not be met in Year 4, as the trend of yearly weed cover increases continued with the further expansion of weedy grasses in particular, but also with a resurgence of *C. hirta*. The enclosure has been scheduled for weeding at least once per quarter, to maintain low cover given the continual influx of weeds, with particular emphasis on controlling target and zero tolerance taxa (ANRPO 2021c). However, weeding efforts were more limited and less thorough in Years 3 and 4, in part due to the COVID-19 pandemic, as well as concerns about foliar sprays around snails that escaped the release site. Alien grass has become increasingly challenging to control, and control efforts in recent years included the use of Ranger Pro, and were limited to more open areas to avoid negative impacts to native vegetation.

RECOMMENDATIONS AND MANAGEMENT RESPONSE

Specific goals for vegetation cover were constructed to guide restoration efforts and to trigger additional restoration actions if those goals were not met. This was particularly important in the early years of restoration as intensive efforts were needed to rapidly establish sufficient habitat for the release of *A. mustelina*. As the native cover goals for the 0 – 1 m stratum and total AGL have been met, and the 1 – 2 m and > 2 m strata are on track towards meeting their goals, additional restoration actions are not triggered. The last big push for restoration inputs occurred in Year 4, with efforts focused on filling in open areas adjacent to the snail release site to provide more cover and improve habitat in anticipation of snail migration into the surrounding area. No additional restoration inputs are planned at this time.

Considerations should be made for how to address the marked expansion of weedy cover, particularly for grasses. The goal of having < 10% weed cover may not be realistic at this point, given how widespread grasses became by Year 4. The methods, timing of, and the extent to which grass control should occur warrants discussion. Challenging issues for grass control include 1) the limited capacity for grass specific herbicides such as Fusilade to control *P. conjugatum* and *E. stipoides*, 2) non-target impacts using broad spectrum herbicides such as Ranger Pro on grass that is tightly intermixed with native vegetation, as it is often growing together with *C. polystachyos*, 3) hand pulling is not ideal for such widescale grass infestation, and, most concerning, 4) the potential threat to snails from foliar sprays, as snails primarily occur in the understory, given the limited amount of canopy present. Given these challenges, deliberations should be made whether it is worthwhile and feasible to control grass aggressively before snails become widespread, or to accept grass presence over the next several years if snails have already become too widespread, waiting to control grass until the canopy forms, native shrubs are not so intermixed with the grasses, and snails migrate to strata above the grass layer. If the Snail Extinction Prevention Program releases ground dwelling snails into the enclosure, that should also be a consideration with respect to grass control. Further discussion is recommended regarding additional restoration inputs, such as *C. polystachyos* seed sows, to create more ground cover in place of weedy grasses, and/or to fill any remaining open areas that could be colonized by weedy grasses. General ecosystem weeding should be prioritized to be thoroughly conducted across the entire enclosure, perhaps only twice a year, to minimize trampling of native vegetation. These efforts should have particular focus on specified control targets *C. hirta*, *P. suberosa*, *P. cattleianum*, *R. rosifolius*, and *S. terebinthifolius*. Zero target taxa *N. brownii* and *D. cordata* var. *pacifica* should also be comprehensively controlled before they become more widespread.

Restoration actions are not new for the program, however, this restoration site is the first to have specific aggressive goals within a narrow timeframe, given the pressing need for suitable protected habitat for *A. mustelina*. As such it continues to be an excellent learning opportunity for planning, execution, and practical timelines for fully restored habitat and habitat readiness for use by endangered animals.

Qualifications for the level of restoration suitable for the release of *A. mustelina* have not been studied. Though dense multi-layered host vegetation is presumed ideal, partially restored vegetation may be sufficient for releasing snails. Stable or increasing *A. mustelina* populations may also be used as a measure of vegetation rehabilitation success. Prior to vegetation monitoring in 2021, a total of 334 ESU-E snails (including wild snails from Ekahanui and snails from the Snail Extinction Prevention Program (SEPP) captive rearing facility) had been released in the enclosure since December 2018, and the population at the release site remained stable (ANRPO 2021d). While all ESU-E snails from the SEPP lab have been released, small numbers of the remaining wild snails may continue to be translocated in the future. The release area (approximately 40 m^2) was bounded by a low plywood wall with an internal electric barrier to prevent snails from traversing out into areas of sparse vegetation where they may encounter environmental stress, and to facilitate monitoring of survival and mortality within a confined area. Restricting snails to a smaller area also maximized the opportunity for snails to encounter one another and potentially reproduce. The electronic barrier further ensured that snails did not escape over the wall of the larger enclosure, where they would not be protected from predators, and could potentially intermix with ESU-F *A. mustelina*. Shade cloth and a drip irrigation system were installed to enhance shade and moisture levels. By Year 3, because the vegetation in the release site had become so dense, the shade cloth and irrigation were discontinued. As vegetation within and adjacent to the release area continued to expand towards and over the plywood wall, small numbers of snails began to make their way into the larger enclosure. Through Year 3, those found outside the plywood wall were moved back inside for added protection and to enhance fecundity. Following Year 3, there was less concern regarding snails encountering environmental stress in the larger enclosure, given the continued expansion of vegetation cover in the surrounding area; the temporary wall ceased to be maintained, vegetation growing over the wall was no longer trimmed, and staff stopped moving escaped snails back inside the temporary release site. Given the presence of *A. mustelina* outside the temporary barrier, staff walking around or applying herbicide in the areas adjacent to the release site should be careful and cognizant that snails are present (though not necessarily observed) in these areas, and foliar sprays should be limited or avoided altogether. The ongoing success of snail releases at the Palikea North snail enclosure continues to indicate an unexpected level of *A. mustelina* resilience within small confined islands of dense, short stature host vegetation, such that the early stages of vegetation restoration as characterized here are sufficient for snail releases.

While the Palikea North snail enclosure was constructed to house and protect *A. mustelina*, the goal of restoration efforts at the enclosure was to achieve a native plant dominated community favorable for *A. mustelina* as well as *D. substenoptera*, *D. montgomeryi*, and *C. ibidis*. Measures of vegetation rehabilitation success were specified to include increasing native vegetation as well as utilization of the enclosure by *A. mustelina*, *D. substenoptera*, *D. montgomeryi*, and *C. ibidis*. With the substantially increased native vegetation cover and successful use of the enclosure by *A. mustelina* by Year 4, the early stages of vegetation rehabilitation have clearly had positive results, with the restoration goal in essence being met for achieving a native dominated community favorable for *A. mustelina*. Additional headway is anticipated as restoration progresses, with further improved habitat for *A. mustelina*, and eventual establishment of habitat suitable for *D. substenoptera*, *D. montgomeryi*, and *C. ibidis*.

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