Appendices:

Appendices for Executive Summary

Appendix ES-1 Spelling of Hawaiian Names

Appendix ES-2 Operating the Army Propagation Database

Appendix ES-3 Annual Report for University of Hawaii Tree Snail Conservation Lab to Oahu Army Natural Resources Program.

Appendix ES-4-a Stabilization Plan for *Drosophila substenoptera*

Appendix ES-4-b Stabilization Plan for *Drosophila montgomeryi*

Appendix ES-5 Assessment of Effects of Rodent Removal on Arthropods, and Development of Arthropod Monitoring Protocols on Conservation Lands Under US Army Management.

Appendices for Chapter 1

Appendix 1-1 Environmental Outreach 2011

Appendix 1-2-a *Chromolaena odorata* Management Summary and Control Plan

Appendix 1-2-b *Chromolaena odorata* Flier

Appendix 1-2-c *Chromolaena odorata* Habitat and ID Photos

Appendix 1-3 Vegetation Monitoring Trend Analysis for the Palikea MU

Appendix 1-4 CALIBRE Gap Analysis Report

Appendix 1-5 CALIBRE Integrated Vegetation Management Plan OANRP Discussion

Appendix 1-6 Vegetation Monitoring Checklists for Kaluaa

Appendix 1-7 Hapapa Bench/Land of 10,000 Snails Restoration/Re-vegetation Plan

Appendix 1-8 Vegetation Monitoring Checklists for Manuwai

Appendix for Chapter 4

Appendix 4-1 Memo to Report a Take of a Single Oahu Elepaio Territory

Appendix ES-1 Spelling of Hawaiian Names

Place name	Hawaiian spelling		Place name	Hawaiian spelling
Alaiheihe	Alaiheihe		Nuuanu	Nuʻuanu
Ekahanui	ʻĒkahanui		Oahu	Oʻahu
Haleauau	Haleʻauʻau		Ohikilolo	ʻŌhikilolo
Halona	Hālona		Opaeula	ʻŌpaeʻula
Hawaii	Hawaiʻi		Pahole	Pahole
Honolulu	Honolulu		Palawai	Pālāwai
Honouliuli	Honouliuli		Palehua	Pālehua
Huliwai	Huliwai		Palikea	Palikea
Kaaikukai	Kaʻaikūkaʻi		Pohakea	Pōhākea
Kaala	Kaʻala		Pualii	Pualiʻi
Kaawa	Kaʻawa		Puhawai	Pūhāwai
Kaena	Kaʻena		Pulee	Puleʻē
Kahanahaiki	Kahanahāiki		Punapohaku	Punapōhaku
Kaimuhole	Kaimuhole		Puu Hapapa	Puʻu Hāpapa
Kaluaa	Kaluaʻā		Puu Kailio	Puʻu Kaʻīlio
Kaluakauila	Kaluakauila		Puu Kanehoa	Puʻu Kānehoa
Kamaileunu	Kamaileʻunu		Puu Kaua	Puʻu Kaua
Kapuna	Kapuna		Puu Kawiwi	Puʻu Kawiwi
Kauai	Kauaʻi		Puu Kumakalii	Puʻu Kūmakaliʻi
Kauhiuhi	Kauhiuhi		Puu Pane	Puʻu Pane
Kaumoku Nui	Kaumoku Nui		Waialua	Waialua
Kawaihapai	Kawaihāpai		Waianae Kai	Waiʻanae Kai
Kawaiu	Kawaiū		Waiawa	Waiawa
Keaau	Keaʻau		Waieli	Waiʻeli
Kealia	Keālia		Waihee	Waiheʻe
Keawapilau	Keawapilau		Waimea	Waimea
Keawaula	Keawaʻula			
Kihakapu	Kihakapu			
Koiahi	Koʻiahi		Halawa	
Koolau	Koʻolau		Aimuu	
Kuaokala	Kuaokalā		Aihualama	
Lanai	Lānaʻi		Puulu	Pūʻulu
Lualualei	Lualualei		Peahinaia	Peʻahināʻa
Maakua	Maʻakua			
Makaha	Mākaha		Puaakanoa	
Makaleha	Makaleha		Mokuleia	
Makaua	Makaua		Punapohaku	
Makua	Mākua		Alau	
Manini	Manini		Papali	
Manoa	Mānoa		Kamaili	Kamāʻili
Manuwai	Manuwai		Kaiwikoele	
Maui	Maui		Kaipapau	
Mikilua	Mikilua		Waikane	
Mohiakea	Mohiākea		Hawaii loa	
Molokai	Molokaʻi		Kahaluu	
Nanakuli	Nānākuli		Kahana	
Niu	Niu		Kalena	

Aihualama	ʻAihualama		Keawaula	Keawaʻula
Aimuu	Aimuu		Kihakapu	Kihakapu
Aiea	ʻAiea		Kipapa	Kīpapa
Ekahanui	ʻĒkahanui		Koloa	Koloa
Halawa	Hālawa		Konahuanui	Kōnāhuanui
Haleauau	Haleʻauʻau		Koolau	Koʻolau
Halona	Hālona		Kuaokala	Kuaokalā
Hawaii	Hawaiʻi		Laie	Lāʻie
Hawaii loa	Hawaiʻiloa		Lualualei	Lualualei
Helemano/Halemano	Helemano/Halemano		Lulumahu	Lulumahu
Honolulu	Honolulu		Maakua	Maʻakua
Honouliuli	Honouliuli		Makaha	Mākaha
Huliwai	Huliwai		Makaleha	Makaleha
Kaala	Kaʻala		Makaua	Makaua
Kaawa	Kaʻawa		Makua	Mākua
Kaena	Kaʻena		Malaekahana	Mālaekahana
Kahaluu	Kahaluʻu		Manana	Mānana
Kahana	Kahana		Manoa	Mānoa
Kahanahaiki	Kahanahāiki		Manuka	Manukā
Kaimuhole	Kaimuhole		Manuwai	Manuwai
Kaiwikoele	Kaiwikōʻele		Maunawili	Maunawili
Kalena	Kalena		Maunauna	Maunauna
Kaluaa	Kaluaʻā		Maui	Maui
Kalauao	Kalauao		Mikilua	Mikilua
Kaleleliki	Kaleleiki		Moanalua	Moanalua
Kaluakauila	Kaluakauila		Mohiakea	Mohiākea
Kaluanui	Kaluanui		Molokai	Molokaʻi
Kamaileunu	Kamaileʻunu		Nanakuli	Nānākuli
Kamananui	Kamananui		Niu	Niu
Kaipapau	Kaipāpaʻu		Nuuanu	Nuʻuanu
Kapakahi	Kapakahi		Oahu	Oʻahu
Kapuna	Kapuna		Ohikilolo	ʻŌhikilolo
Kauai	Kauaʻi		Ohiaai	ʻŌhiʻaʻai
Kaukonahua	Kaukonahua		Oio	ʻŌʻio
Kaunala	Kaunala		Opaeula	ʻŌpaeʻula
Kawaihapai	Kawaihāpai		Paalaa Uka	Paʻalaʻa Uka
Kawailoa	Kawailoa		Pahipahialua	Pahipahiʻālua
Kawaiiki	Kawai Iki		Pahoa	Pāhoa
Kawainui	Kawai Nui		Pahole	Pahole
Kawaipapa	Kawaipapa		Palawai	Pālāwai
Keaau	Keaʻau		Palehua	Pālehua
Kealia	Keālia			
Pohakea	Pōhākea			
Pualii	Pualiʻi			
Puhawai	Pūhāwai			
Pukele	Pūkele			
Pulee	Puleʻē			
Puuhapapa	Puʻu Hāpapa			
Puukailio	Puʻu Kaʻīlio			
Puukaaumakua	Puʻukaʻaumakua			
Puukainapuaa	Puʻukaʻinapuaʻa			
Puukaua	Puʻukaua			
Puukawiwi	Puʻukawiwi			

Puukumakalii	Puʻukūmakaliʻi			
Puupane	Puʻupane			
Puukanehoa	Puʻukānehoa			
Puuokona	PuʻuoKona			
Puukeahiakahoe	PuʻukeahiaKahoe			
Puulu	Puulu			
Waahila	Waʻahila			
Wahiawa	Wahiawā			
Waialae Nui	Waiʻalae Nui			
Waialua	Waialua			
Waiawa	Waiawa			
Waimalu	Waimalu			
Waianae Kai	Waiʻanae Kai			
Waieli	Waiʻeli			
Waihee	Waiheʻe			
Waikane	Waikāne			
Wailupe	Wailupe			
Waimano	Waimano			
Waimea	Waimea			
Wiliwilinui	Wiliwilinui			

Appendix ES-2 Operating the Army Propagation Database

Tutorial: Operating the Army Propagation Database

Overview
The Army Propagation Database (APD) 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 or 2010 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 APD 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 10 year effort in developing and coordinating the collection, propagation, management, and tracking of rare species.

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

Several database reports may take a several minutes to compile within the database, thus pdf versions of the three major database reports (Population Unit Status, Threat Control Summary, and Genetic Storage Summary) have been created and may be found in the database reports subdirectory. Therefore, running the database may not be necessary unless more information is needed beyond the pdf version of the reports provided. Data provided is as of September 30, 2011.

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

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

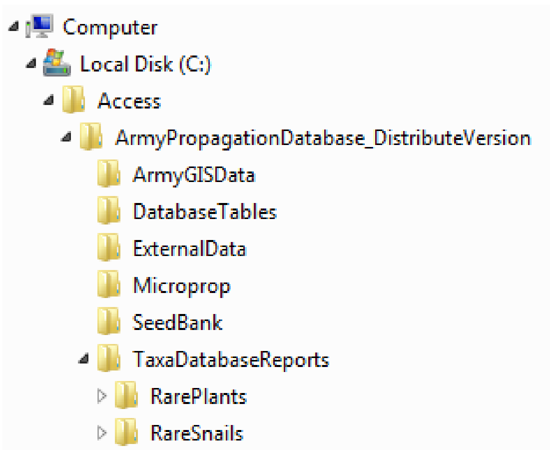
Krista Winger
Natural Resources Database/GIS Manager
Oahu Army Natural Resources Program
Email: krista.l.winger.ctr@mail.mil

I. Database Settings

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\ArmyPropagationDatabase_DistributVersion:

ArmyPropagationDatabase_DV.mdb

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

C:\Access\ArmyPropagationDatabase\ArmyGISData\

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

C:\Access\ArmyPropagationDatabase\DatabaseTables
ArmyPropagationDataTables_DV.mdb

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

C:\Access\ArmyPropagationDatabase\Microprop
Microprop.mdb

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

C:\Access\ArmyPropagationDatabase\SeedBank
SeedBankDatabase.mdb

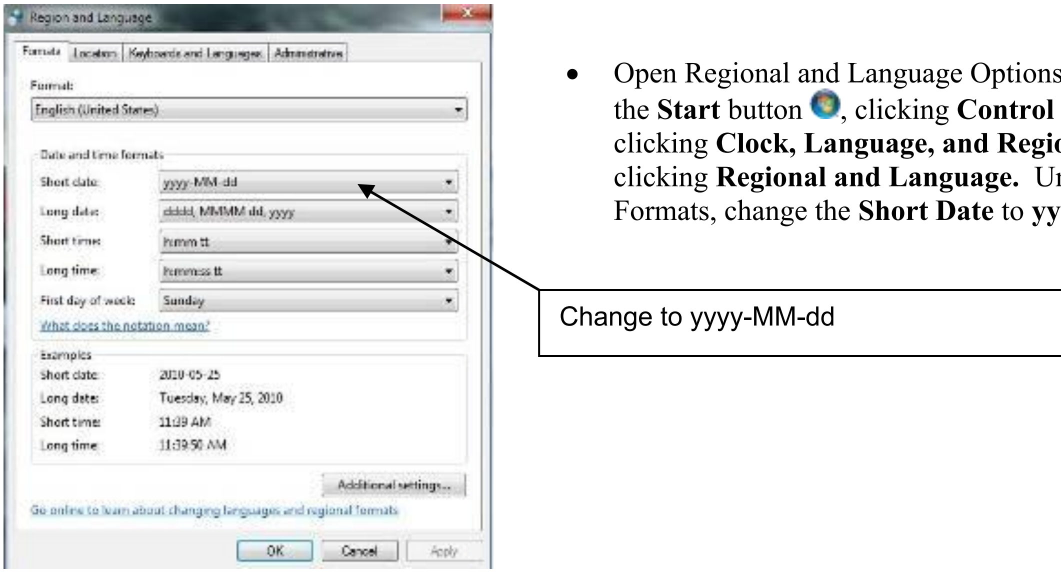
Army SeedLab Database. Contact Lauren Weisenberger for more information.

C:\Access\ArmyPropagationDatabase\TaxaDatabaseReports

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.

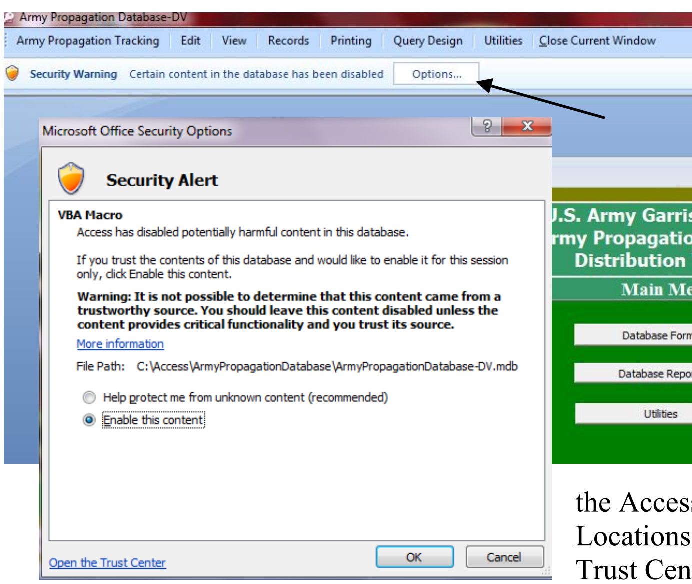


- Open Regional and Language Options by clicking the **Start** button, clicking **Control Panel**, clicking **Clock, Language, and Region**, and then clicking **Regional and Language.** Under the Formats, change the **Short Date** to **yyyy-MM-dd.**

Security Warning

Security features in Microsoft Access 2007 and 2010 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 2007/2010 database content must be enabled when the Security Warning appears..



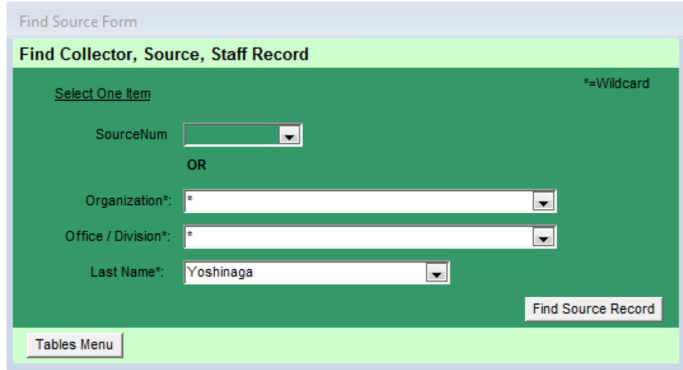
After opening the ArmyPropagationDatabase_DV.mdb file in Microsoft Access, click on Options when it appears at the top of your screen.

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.

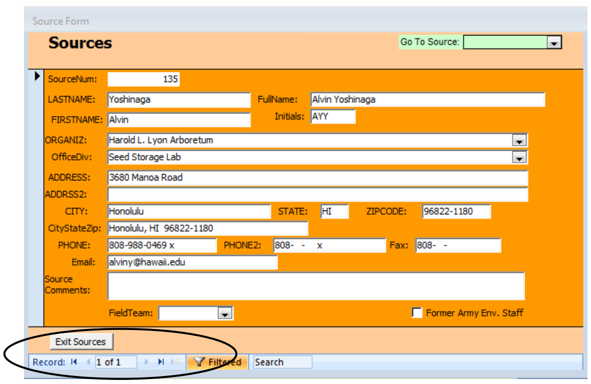
Enabling content will have to be done every time the database file is opened. You may avoid having this Security Warning appear if the Access subdirectory is added to the Trust Center Locations. Contact Roy Kam if you need to establish a Trust Center Location.

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.

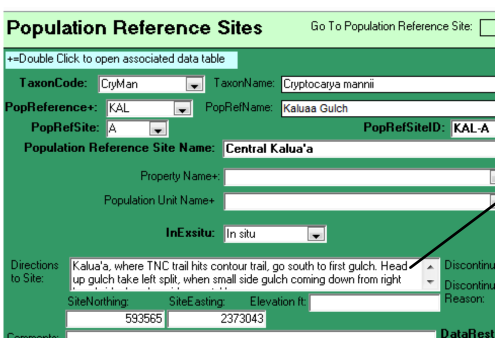


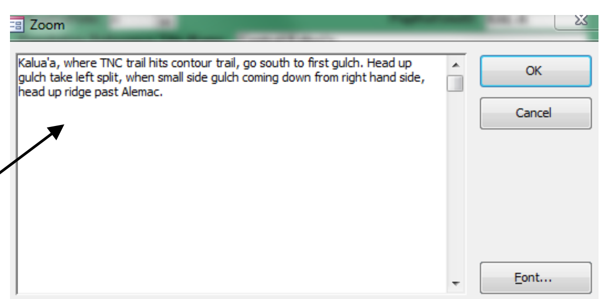
Using the * (asterisk), in a Find Form represents a wild card. Such as Organization *= Search for all Sources with any Organization. In this case, we will just search for the Last Name = Yoshinaga.



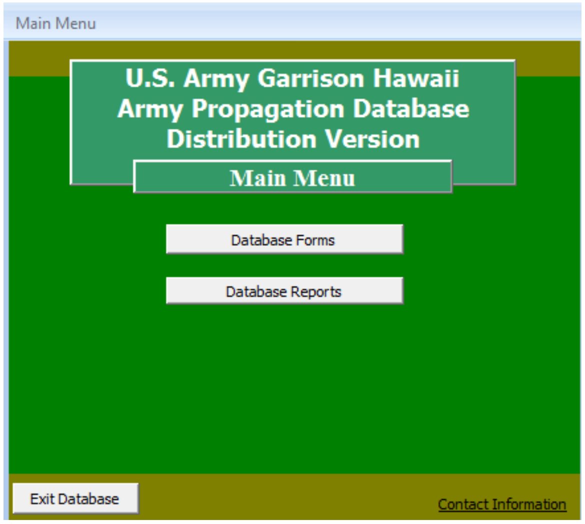
On the bottom of each Data entry form (such as the Sources Form), there are a set of Navigation buttons. These buttons allow you to go to the previous or next record. Pressing the tab or enter keys moves from one data field to another.

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 **ArmyPropagationDatabase_DV.mdb** 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.

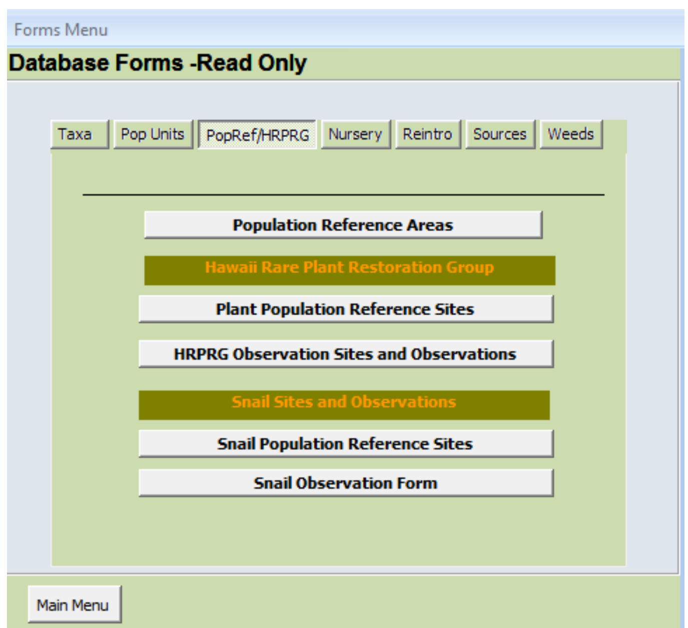
The database is broken up into 2 parts, Database Forms and Database Reports. We will primarily cover the Database reports. Database Forms are self-explanatory and is only for viewing purposes. The forms are provided for detailed review of individual observations. Only pertinent data fields will be discussed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

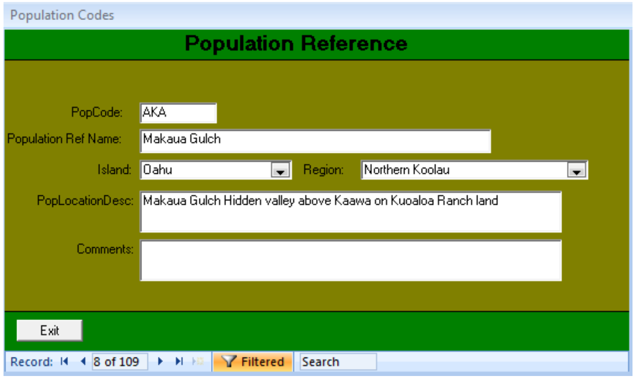
For the purpose of this tutorial, we will discuss forms of the PopRef/HRPRG tab with comprise of the Population Reference and Population Reference Sites. All other sections, are supplemental and self-explanatory.



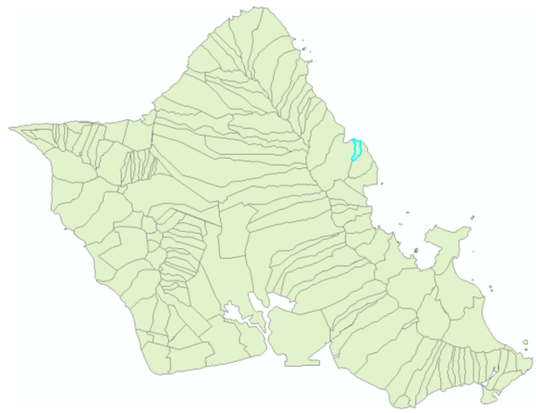
PopRef, Sites, and Observations

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

Population Reference Areas(PopRef)



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

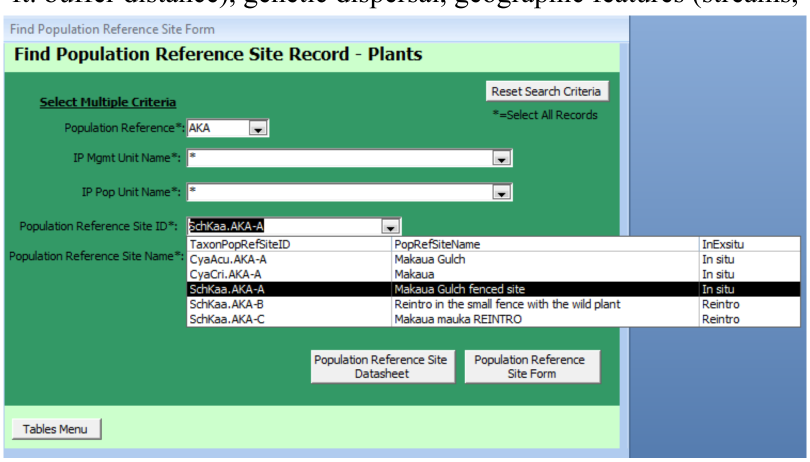


It should be noted that the Population Reference is not necessarily the name for any given population. It is only used as an identifier to compile different plant or animal populations within a given area. For example: Makaua on the Windward Koolau of Oahu (highlighted in blue). The GIS boundary is based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

Population Reference Site (PopRefSite)

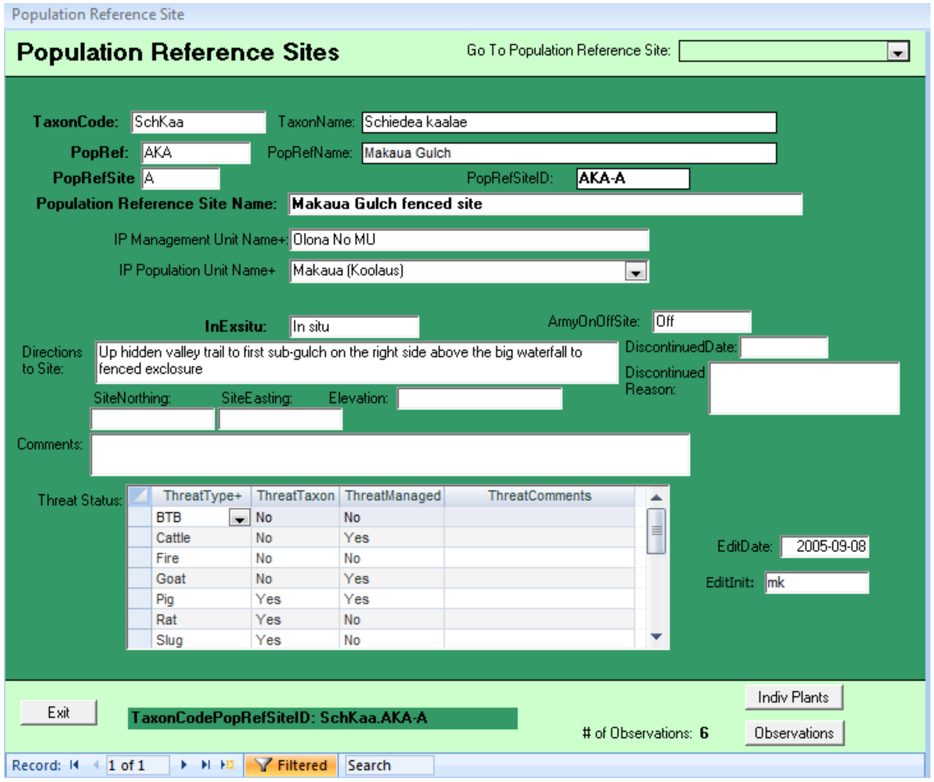
The Population Reference Site (PopRefSite) is the primary data table in establishing plant or animal population sites. The PopRefSite identifies the Population Name, whether it is In situ, Ex situ or Reintro, and provides directions to the site, etc. The PopRefSite is only site information; observation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

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



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

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



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

IP Management Unit Name: Management Unit commonly known from.

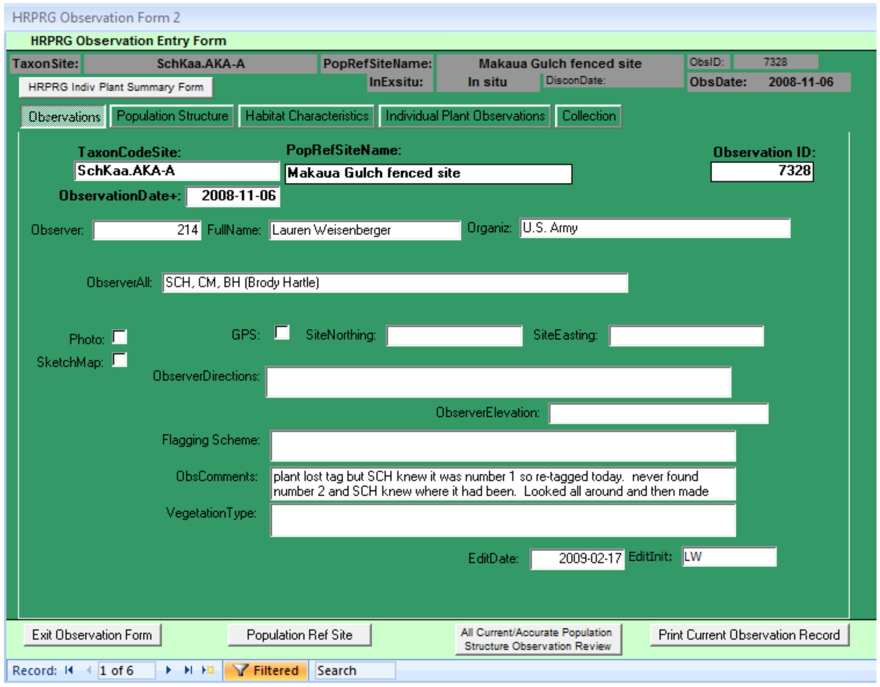
IP Population Unit Name (PopUnit): The PopUnit is used when several PopRefSites need to be tracked together. Such as a taxon with several sites throughout the Northern Waianae Mountains, Northern Waianae could be used as a PopUnit Name.

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

Directions to Site: Detailed directions to locate the population.

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

Observations

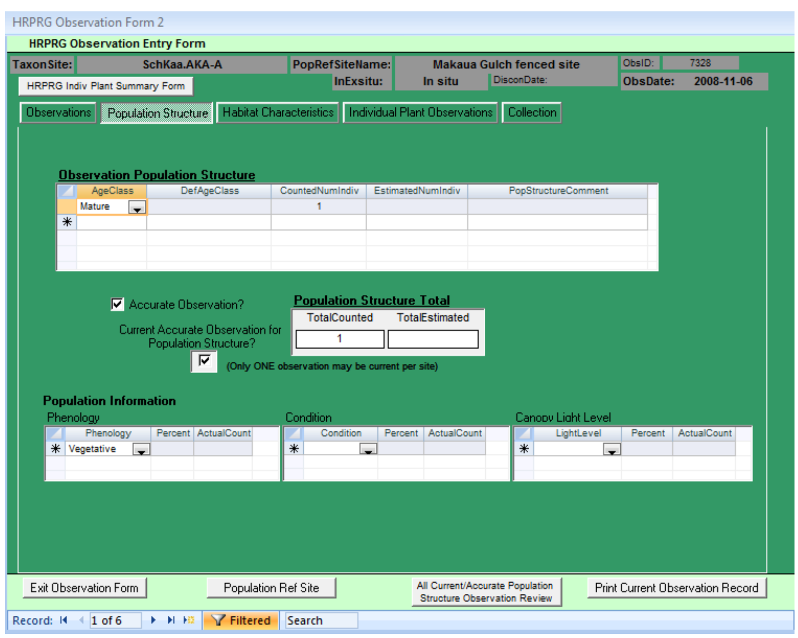


Clicking the Observations button on the bottom of the PopRefSite Form will open up the corresponding Observations.

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

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

Population Structure

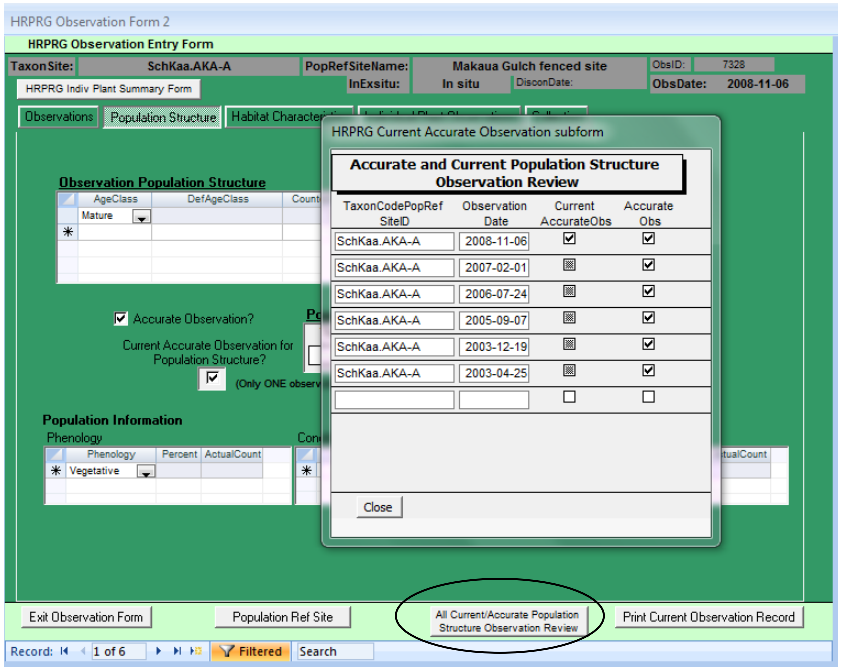


The Population Structure should are always entered for any observations, even if the number of plants observed are incomplete (not all plants observed).

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

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

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

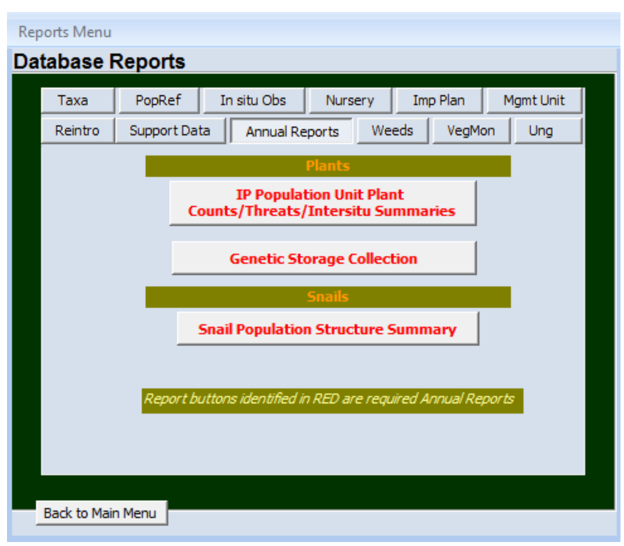


As op-posed to the Accurate Observation check box, the **Current Accurate Observation** check off box may only have one observation checked. The Current Accurate represents the population structure that is considered both current and accurate. The most recent observation may not always be the Current 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.

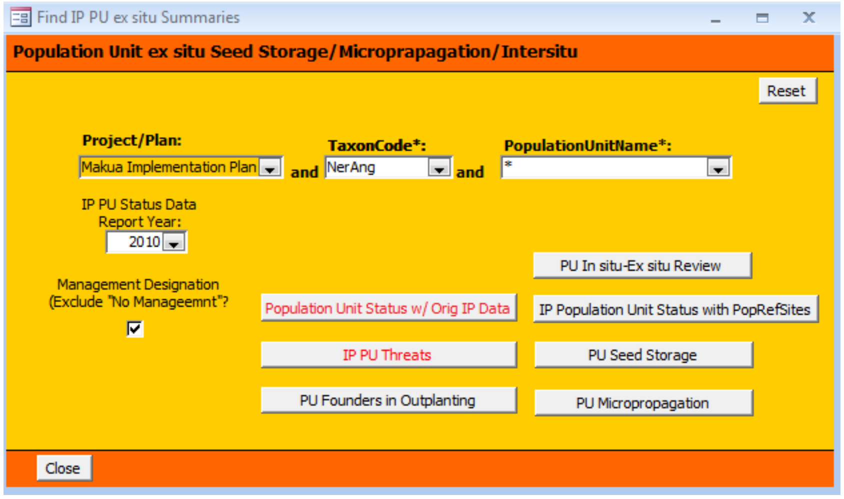


Similar to the Database Entries, clicking on a button within the Database Reports will open a Find Form that will assist in selecting data records for the report.

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 two reports (in red) 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. Select 2010 for the report year. Report Year is defined below.

Taxon Status Summary

Makua Implementation Plan - Population Unit Status

Action Area: In

TaxonName: Neraudia angulata **TaxonCode: NerAng**

Population Unit Name	Management Designation	Original IP Total Mature	Original IP Total Imm	Original IP Total Seedling	Current Mature (Wild)	Current Immature (Wild)	Current Seedling (Wild)	Current Outplanted Mature	Current Outplanted Immature	Current Outplanted Seedling	Total Mature 2010	Total Immature 2010	Total Seedling 2010	Total Current Mature	Total Current Immature	Total Current Seedling	PU LastObs Date	Population Trend Notes
Kaluakauila	Manage reintroduction for stability				0	0	0	118	0	0	125	3	0	**118**	**0**	**0**	2011-08-16	
Kapuna	Genetic Storage	1	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	2009-10-27	
Makua	Manage for stability	29	0	22	43	0	1	30	1	0	48	38	5	**73**	**1**	**1**	2011-07-26	
Punapohaku	Genetic Storage				1	0	0	0	0	0	1	0	0	**1**	**0**	**0**	2010-07-28	
	Total for Taxon:	30	0	22	44	0	1	148	1	0	174	41	5	**192**	**1**	**1**		

Action Area: Out

TaxonName: Neraudia angulata **TaxonCode: NerAng**

Population Unit Name	Management Designation	Original IP Total Mature	Original IP Total Imm	Original IP Total Seedling	Current Mature (Wild)	Current Immature (Wild)	Current Seedling (Wild)	Current Outplanted Mature	Current Outplanted Immature	Current Outplanted Seedling	Total Mature 2010	Total Immature 2010	Total Seedling 2010	Total Current Mature	Total Current Immature	Total Current Seedling	PU LastObs Date	Population Trend Notes
Halona	Genetic Storage	15	0	0	30	4	0	0	0	0	30	4	0	**30**	**4**	**0**	2006-05-22	
Leeward Puu Kaua	Genetic Storage	3	0	0	9	0	0	0	0	0	9	0	0	**9**	**0**	**0**	2006-11-21	
Makaha	Genetic Storage	56	14	0	6	7	0	0	0	0	12	0	0	**6**	**7**	**0**	2011-04-27	
Manuwai	Manage for stability	12	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	2010-08-04	
Waianae Kai Makai	Genetic Storage	4	0	0	45	35	25	0	0	0	45	35	25	**45**	**35**	**25**	2006-01-23	
Waianae Kai Mauka	Manage for stability	21	25	0	16	4	0	0	0	0	16	4	0	**16**	**4**	**0**	2010-06-08	
	Total for Taxon:	111	39	0	106	50	25	0	0	0	112	43	25	**106**	**50**	**25**		

The Taxon 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".

Original IP Total 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

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

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

Total Mature, Immature and Seedling 2010: 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 last three columns can be compared with the NRS 2010 estimates to see the change observed over the last year.

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

Action Area: In

TaxonName: Cenchrus agrimonioides var. agrimonioides

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	BTB Managed	Slugs Managed	Fire Managed
Kahanahaiki and Pahole	Manage for stability	348	Partial 99.43%	Partial 95.40%	Partial 31.03%	No	No	No

Action Area: Out

TaxonName: Cenchrus agrimonioides var. agrimonioides

PopulationUnitName	ManagementDesignation	# Mature Plants	Ungulates Managed	Weeds Managed	Rats Managed	BTB Managed	Slugs Managed	Fire Managed
Central Ekahanui	Manage for stability	125	Partial 98.40%	Yes	Yes	No	No	No
Makaha and Waianae Kai	Manage for stability	13	Partial 61.54%	Partial 61.54%	No	No	No	No
South Huliwai	Genetic Storage	17	No	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

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.

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. OANRP will develop this threat table in the next year to account for other potential threats such as arthropods other than the BTB, the fungal rust (*Puccinia psidii*) and other plant pathogens as they are identified and the threat evaluated.

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

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

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

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

BTB: BTB stands for the Coffee Black Twig Borer (*Xylosandrus compactus*). This threat is indicated for any PUs where damage from BTB has been confirmed by OANRP staff. This is known to be a threat for all *Alectryon macrococcus* var. *macrococcus* and *Flueggea neowawraea*. Other MIP/OIP taxa may be affected and will be monitored for damage. Effective control methods do not exist at this time.

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

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

Genetic Storage Summary

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

Genetic Storage Summary

Population Unit Name	# of Potential Founders			Partial Storage Status				Storage Goals				Storage Goals Met
	Current Mature	Current Imm.	NumWild Dead	# 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
Neraudia angulata												
Halona	30	4	0	0	0	0	7	0	0	0	5	5
Kapuna	0	0	2	1	1	0	2	0	0	0	1	1
Leeward Puu Kaua	9	0	0	0	0	0	1	0	0	0	1	1
Lower Kahanahaiki	0	0	0	0	0	0	0	0	0	0	0	0
Makaha	6	7	12	2	1	0	10	1	0	0	6	6
Makua	43	0	65	2	2	0	20	1	0	0	6	6
Manuwai	0	0	7	0	0	0	2	0	0	0	2	2
Punapohaku	1	0	0	0	0	0	1	0	0	0	0	0
Waianae Kai Makai	45	35	0	0	0	0	0	0	0	0	0	0
Waianae Kai Mauka	16	4	2	0	0	0	7	0	0	0	1	1
				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
				5	4	0	50	2	0	0	22	22

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: 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.

Storage Goals Met: 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.

Snail Population Status Summary
Number of Snails Counted

Population Reference Site	Management Designation	Total Snails	Date of Survey	Size Classes: Large	Medium	Small	Unk	Threat Control: Ungulate	Weed	Rat	Euglandina
Achatinella mustelina											
ESU: A — Pahole to Kahanahaiki											
MMR-A Kahanahaiki Exclosure	Manage for stability	15	2011-09-13	11	3	1	0	Yes	Yes	Yes	Yes
MMR-C Maile Flats	Manage for stability	250	2009-09-16	185	31	34	0	Yes	Yes	Yes	No
PAH-B Pahole Exclosure	Manage for stability	55	2011-09-27	0	0	0	55	Yes	Yes	Yes	Yes
	ESU Total:	320		196	34	35	55				

Size Class Definitions

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

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

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

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.

Annual Report for University of Hawaii Tree Snail Conservation Lab, to Oahu Army Natural Resources Program

Date: November 2011
Address: 337 Henke Hall
Telephone: (808) 956-6176
Project Name: Captive Propagation of Endangered Tree Snails, Threat Assessment of Invasive Jackson's Chameleons on Oahu, and *Euglandina rosea* predator trials
Location: UH Manoa, Center for Conservation Research & Training
Principal Investigator: Brenden Holland (bholland@hawaii.edu)

Current status of captive endangered tree snail populations:

As of our latest count, we currently are caring for 1171 Hawaiian tree snails, the majority of which are members of the genus *Achatinella*, from Oahu, and are listed as Federally endangered by the USFWS Endangered Species Act. For summaries of all captive species of tree snails, please see Tables 1-5 at the end of this report.

At current tree snail population levels, we are operating 6 environmental chambers (Figure 1), and we culture 50 potato dextrose agar plates of tree fungus per 2-week cage changing cycle. We currently have a crew of 7 technicians who are directly involved with leaf collection and care and maintenance of the captive tree snails.

Figure 1. Captive breeding entails constant care and documentation of mortality, births, and population status. Feeding and cage changing is conducted daily on a rotating schedule, by exchanging native foliage collected in the field and laboratory cultured leaf fungus.

Captive snail demographics

Evaluating long-term captive snail population demographics, particularly for the important Waianae species *Achatinella mustelina*, reveals a pattern where around 2006, most of the 12 small populations brought into the lab between 1995 and 2003, either slowed or ceased reproductive output. Examples include Peacock Flats (no birth since 8/06), Ohikilolo Mauka (no birth since 7/07) and Schofield Barracks West Range (no births since 7/07). The reasons underlying this pattern are difficult to pinpoint. Possible explanations are largely speculative, but may involve the artificial nature of the captive environment, including limited mate choice and quality of basic environmental conditions including water, airflow, and food sources. For example, it is clear from recent mycology studies, that surface growing leaf molds are complex communities with high species diversity, that vary widely among different host tree species. At present the lab protocol calls for provision of a single strain of cultured leaf fungus

Figure 2. Palikea Lunch cage (*Achatinella mustelina*) experienced its first birth in April 2011 since December 2005. This cage had an additional 2 births during July and August of this year (keiki and adult pictured). The first birth observed occurred about one month after we added the first set of *Pisonia* leaves to this cage.

as a supplement to several species of native tree snail host plants, including *Metrosideros polymorpha* (Ohia lehua) and *Freycinetia arborea* (‘Ie’ie) leaves and branches. However, it is likely that the captive snail diet differs greatly from the natural diet, in part due to the relative lack of diversity of nutritional options. During the Spring of 2011, we decided to begin to augment the diet in *A. mustelina* cages by adding *Pisonia* leaves to those that had ceased to reproduce. With the help of OANRP Rare Snail Specialist Vince Costello, we began this strategy in March, and began adding fresh

Pisonia leaves from Puu Hapapa to *A. mustelina* and *A fulgens* cages. Within one month, we began to see some promising results in several cages, continuing today. For example the cage Palikea Lunch had its first birth in April 2011 since December 2005. This cage had an additional 2 births during July and August of this year (Figure 2). Ekahanui Honouliuli has seen 7 births since April 2011, and we had not seen a birth in this cage since August 2004; Alaheihe Gulch had its first birth this June in 15 months. And interestingly, a single individual of *A. fulgens* in the Pia East cage gave birth in May 2011, and another in October 2011. This cage had not had a birth in five years, since October 2007, and most interesting, this single individual had been alone in the cage since November 2009.

Once again we should state clearly that we do not understand the detailed dynamics of what causes reproduction to stop, and then start up again, but we are encouraged by these preliminary results and feel that nutrition and variety of food sources may play a key role in long-term survival, condition and reproduction of captive tree snail populations. Thus we hope to continue to work closely with OANRP field crews, and will continue to strive to provide as much variety in host leaves and cultured fungus as possible.

Jackson's Chameleon Project

In a collaborative study by OANRP and UH tree snail lab biologists, endemic land snails and insects were discovered in the stomach contents of several invasive Jackson's chameleon *C. jacksonii* individuals collected from the Waianae Mountains on western Oahu (Figure 3 & 5). We have begun an OANRP-funded study this spring 2011 aimed at understanding the distribution, feeding ecology and movements of this predator in Hawaii.

Figure 3. Endemic Oahu snails discovered in the gut of a Jackson's chameleon collected on Oahu in 2010.

Figure 4. Radio frequency transmitters were epoxied to the flank of 5 Jackson's chameleons. Each transmitter has a unique frequency, and up to 164 days of battery life. Chameleons were captured, tagged (right) and released (left) in the Tantalus region of the Koolaus. We are conducting field monitoring and mapping of movement, as well as habitat utilization. For the second phase we plan to release tagged animals in more pristine areas, in consultation with OANRP. The goal of this work is to assess the threat posed by this invasive predator, and ultimately prioritize and devise control procedures.

We are interested in estimating digestion rates of tree snail shells. To this end, we fed empty *Achatinella mustelina* shells of standardized dimensions to live chameleons of standardized dimensions in the lab, and euthanized replicates of chameleons at various time intervals, until shells were completely digested. Our goal was to estimate how many snails a chameleon can consume in a given time period, as well as to provide us with an estimate of the time since consumption when field captured chameleons are found to have partially digested *Achatinella* shells in their gastrointenstinal tracts. Once we have an idea of how long digestion takes and how far chameleons tend to move, we will have an enhanced understanding of the potential impact and direct threat level posed by this species.

Digestion time trials

Objective: To estimate the amount of time required by Jackson's chameleons to digest *Achatinella mustelina* shells under a variety of feeding conditions.

Collection:

A total of forty-five adult specimens of *Chamaeleo jacksonii xantholophus*, have been collected by hand from the Tantalus Area and the Waianae Mountains (Figure 5) under DLNR permit ODF-092611R for the various aspects of this study. Live lizards were brought to the Hawaiian Tree Snail Conservation Lab (UH Manoa) and placed in individual plastic cages (210 x 120 x 120 mm) and kept according to IACUC Protocol Approval #11-1105. Each cage has a perforated lid and a rectangular portion of the floor (2 cm from each side) cut out and replaced by a 1 mm mesh, to facilitate air-flow. Chameleon body weight (*ChW*), snout-to-vent length (*SVL*) and sex (*S*) were recorded for each animal at the onset of laboratory trials.

Experimental design:

Laboratory experiments began with force-feeding each Jackson's chameleon one fresh empty *A. mustelina* shell, which were collected from Puu Hapapa (West Oahu). The ratio between shell weight (*ShW*) and *ChW* was maintained at 0.5% in all trials. Thus, smaller chameleons were fed smaller shells than larger chameleons and vice-versa, and shell sizes to chameleon ratio was determined based on chameleon esophagus diameter. Force-feeding was carried out by two people, with one person holding the mouth of the chameleon fully open, and the other one introducing the shell (apex down) into the mouth

(Figure 6)**.** The shell was gently pushed into the throat using a 5 mm-diameter wooden probe, once in the esophagus, water was used to facilitate swallowing of the shell. Once the shell was swallowed, time was recorded and used as time zero.

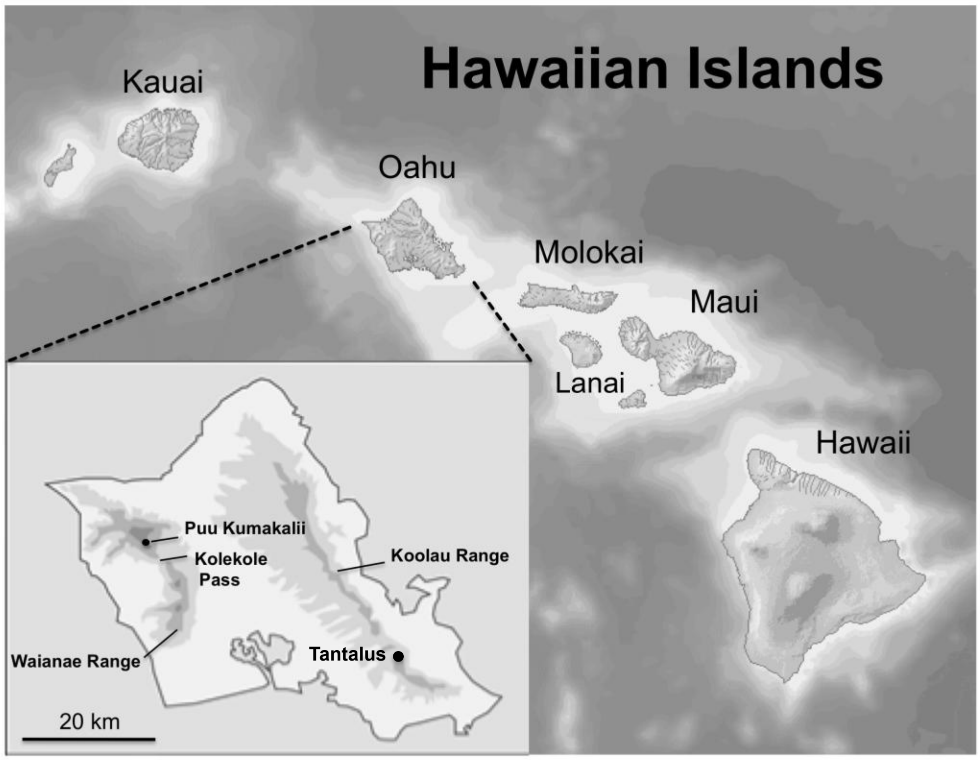


Figure 5. Sampling map for invasive Jackson's chameleons from Oahu. Chameleons used in his study were from Tantalus, 2 chameleons collected in 2010 from Kumakalii had endemic snails in their stomachs.

In order to create different feeding scenarios, chameleons were then split into two treatments: the first group was fed live cockroaches twice a day, while the second group was not fed. Water was provided twice a day in all groups. In order to assess the process of shell digestion, 3-7 chameleons from each group were euthanized at different time intervals: 3, 4, 5, 7, and 8 days. Experiments with well-fed chameleons lasted up to four days, since shells were passed in all cases after the fourth day (see results section). Individuals were then dissected and the condition of the shell (*ShC*), shell final weight (*FShW*), and position within the digestive system (*ShP*) were recorded. Six categories were defined in order to describe *ShC*: 0) fresh, intact shell, no evidence of digestion, 1) intact, with small holes scattered over the surface, 2) shell missing the apex, larger holes and pitting scattered over the shell surface, 3) only shell aperture and body whorl remaining, 4) shell in fragments, 5) shell completed digested (Figure 8 & 9). *ShP* was divided into four categories: 1) In stomach, 2) within first half portion of intestine, 3) within second, distal portion of intestine, 4) passed in feces. Following euthanasia, shells and shell fragments were cleaned thoroughly with 99% ethanol and dried before weighing to determine *FShW*. The percentage of shell mass digested (*DSh*) was determined by using the following formula: *DSh*: *(ShW- FShW)*100 / ShW.*

Statistical analysis:

Differences in shell condition (*ShC*) and undigested shell mass (*DShM*) between fed and starved chameleons, within a given time interval, were compared using a Mann-Whitney Test and a t-Test, respectively. *ShC* and *DSh* were compared among time intervals (i.e., days) using a Friedman ANOVA for non-parametric ordinal data and a regular ANOVA, respectively. Tukey tests were used for pairwise comparisons. Pearson correlations were used to assess the relationships between both *ShC* and *DSh* and time, using all chameleons from all experiments.

Figure 6. Force-feeding *Achatinella mustelina* shells to Jackson's chameleons.

Results:

A total of 34 Jackson's chameleons were used for the feeding trials in the laboratory: 15 females and 19 males. Sizes ranged from 9.7 g to 49.8 g in *ChW* and from 75.3 mm to 112.3 mm in *SVL*. The results of the laboratory experiments showed that the process of digestion of the shell is not affected by feeding treatments (i.e. fed daily versus starved). After three and four days, the percentage of the digested shell (*DSh*) and shell condition (*ShC*) did not vary significantly between fed and starved chameleons (t-Test: $t_{1,33} = 0.24$, $p > 0.05$' Mann-Whitney test, $U = 6$, $Z = 0.98$, $p > 0.05$) (respectively). However, feeding treatment significantly affected the time the shell remained in the stomach of the chameleon. Digestion ceases once the shell passes from the stomach into the intestine. Therefore shells in starved chameleons remained in the gut longer and continued digesting for the entire trial. Of fed chameleons, 65% had the shell located within the second lower portion of their intestines (1 cm from vent), 35% passed the shell after 4 days, while 100% of starved chameleons retained the

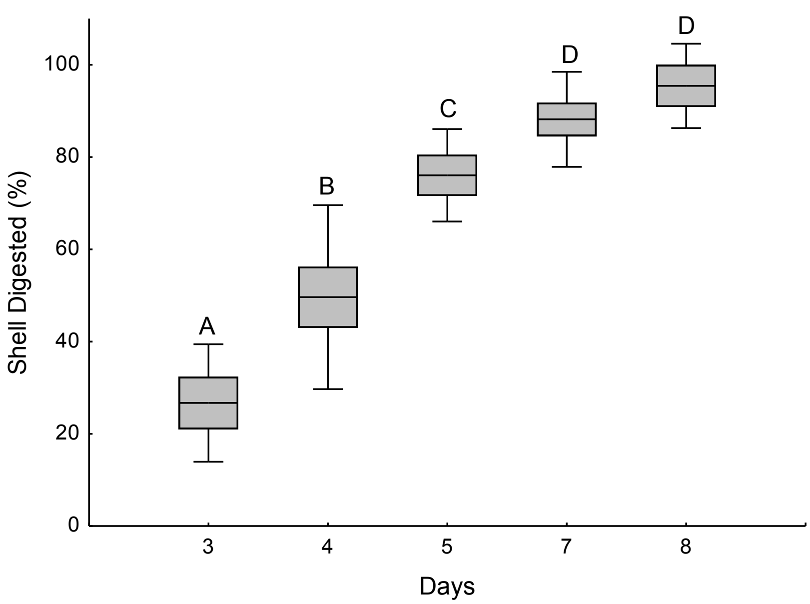


Figure 7. Percentage of shell mass digested over time. Box: mean and SD, Whiskers: SE. Different letters represent significant differences (Post-hoc ANOVA, Tukey test, $p < 0.01$)

shell in their stomachs for 8 days. This indicated that food items ingested after the shell "push" the shell out of the stomach into the intestine. Therefore, well-fed chameleons only retained the snail for 3 days or less, while digestion of the shell continued for 8 days in starved individuals.

There was a strong correlation between shell condition (*ShC*) and percentage of shell digested (*DSh*) ($r = 0.95$, $p < 0.001$), and both parameters positively correlated with time (*ShC*: $r = 0.82$, *DSh*: $r = 0.84$, $p < 0.001$ in both cases).

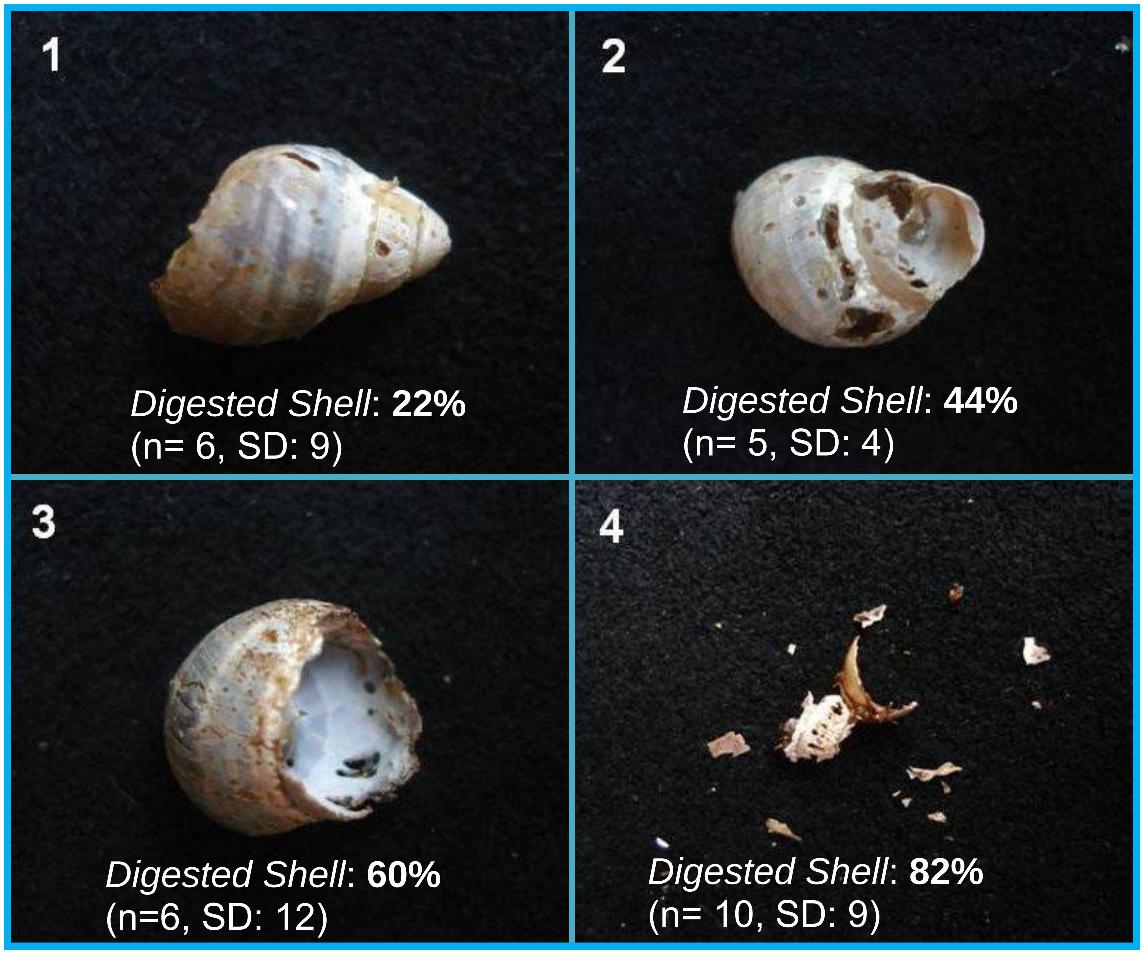


Figure 8. In this study we define categories of shell digestion, including: 0. Fresh undigested shell (not shown), 1. Intact shell with pitted periostracum. 2. Digested apex, extensive pitting, some holes pass thru the shell. 3. Late stage of digestion, where only the main body whorl remains. Internal shell digestion has progressed such that less than 50% of the shell mass remains. 4. Only shell fragments remain. 5. Shell completely digested (not shown).

Thus, Friedman ANOVA ($\chi^2 = 34.4$, $p < 0.001$) and regular ANOVA ($F_{1,33} = 22.43$, $p < 0.001$) revealed significant differences in *ShC* and *DSh* among days, respectively. *DSh* was significantly different among all days, with the exception of days 7 and 8 (Figure 7). Our results indicate that *DSh* occurred at a rate of ~20% per day after day 3.

Thus, in 8 days, 66% of shells, regardless of size, were totally digested (Category 5) and 34% were found in small pieces (Category 4) still in the stomach of starved chameleons.

Field study: Habitat utilization by Jackson's Chameleons

Objective: To assess habitat utilization and daily movement patterns of invasive Jackson's chameleons (*Chamaeleo jacksonii xantolophus*) using active radio transmitters.

Methods:

Specimens of *Chamaeleo jacksonii xantholophus* (Jackson's chameleons) were collected by hand at night (Collection permit: ODF-092611R), from the Tantalus Area and from the Waianae's Moutains (north of Puu Hapapa) (Figure 5). Chameleons were brought to the Hawaiian Tree Snail Conservation Lab, where they were placed in individual cages overnight. Three male (from Tantalus) and two female (one from Tantalus and one from the Waianaes) adult individuals were then selected to be fitted with ATS (Advance Telemetry Systems) R1640 two-stage radio transmitters (glue-on model), which weighed 2 g and were equipped with a 15 cm whipped antenna. Maximum transmitter duration was estimated to be 164 days. The weight of each transmitter was less than 6% of chameleon weight (mean weight: 39 g, SE: 2.1). Each transmitter was then attached to the animal using 5-min, non-toxic Epoxy glue (Figure 4). Individuals were then kept in the lab for 24 hrs to ensure transmitter adhesion. All capture, handling, attachment and removal of transmitters was done in accordance with protocols of the University of Hawaii Institutional Animal Care and Use Committee (IACUC).

An ATS R410 Scanning telemetry receiver, tuned to 148-152 MHz, was used to track signals from active transmitters. An ATS 13860 3-element folding Yagi antenna was attached to the receiver via a 5-foot long RG58 coaxial cable.

All five radio-tagged chameleons were released in the Tantalus region on June 23, 2011 (Figure 9, release point “R”). For the first week, tracking was carried out daily, then two times per week for the remaining period. During each survey, location of each radio tracked chameleon was recorded using a Garmin 60CSx GPS, with an average precision of ± 1.5 m. Radio-tagged Individuals will be retrieved from the field a week before the maximum estimated battery life, which will take place during the third week of November, 2011. Here we present data collected from June 23 to October 5.

The software MapSource© v15.11 was used to measure: 1) maximum straight-line distance from release site, for each chameleon, 2) daily distance covered by each individual, and 3) the two longest distances (perpendicular to each other, D_1 and D_2) of the distribution of each individual. Home range (i.e., area covered) by each individual was then estimated using the formula for the surface of an ellipse: pi x D_1/2 x D_2/2. Mean daily distances covered by each chameleon were calculated during the first three days, and then averaged for time after that initial period.

Results:

The results from this field study using active radio transmitting tags showed that Jackson’s chameleons in the Tantalus area do not move long linear distances per day. All five chameleons moved in an easterly direction, east or northeast, from the release site, and stayed within a 110 m radius (Figure 9). Each individual covered the longest distances during the first three days by moving following almost a straight line. After that period, their movements decreased considerably by covering much shorter distances (Table 1) and their movement pattern changed into an almost circular one, allowing them to remain within a relative small area for the more than three months (Figure 9). Male chameleons moved, on average, farther away from the release site (58.6 m, SE: 23.9) than did female individuals (34.5 m, SE: 13.6). Interestingly, male chameleons moved farther away from other male counterparts (72.3 m, SE: 10.9) than females did from one another (29.9 m), and home ranges of each individual (i.e., area covered) did not overlap with any of the other counterparts regardless of sex (Figure 9).

ID	Origin	Max. distance from release site	Daily distance first 3 days	Daily distance Overall (90 days)	Home range
Male 1	Tantalus	107.6	11.34 m (SE: 1.1)	3.07 m (SE: 0.31)	311.8 m^2
Male 2	Tantalus	40.4	12.6 m (SE: 1.5)	3.2 m (SE: 0.51)	222.5 m^2
Male 3	Tantalus	29.5	34.2 m (SE: 7.0)	6.5 m (SE: 0.53)	383.3 m^2
Female 1	Tantalus	46.7	13.62 m (SE: 2.0)	3.2 m (SE: 0.48)	220.3 m^2
Female 2	Waianaes	21.3	9.01 m (SE: 1.31)	3.6 (SE: 0.61)	216.1 m^2

Table 1. Regional origin, maximum distance traveled from release site, mean daily distance covered during the first three days, mean daily distance traveled after the first three days (ensuing 90 days), and home range size of each radio-tagged chameleon released at Tantalus. Mean home range for males was larger than for females.

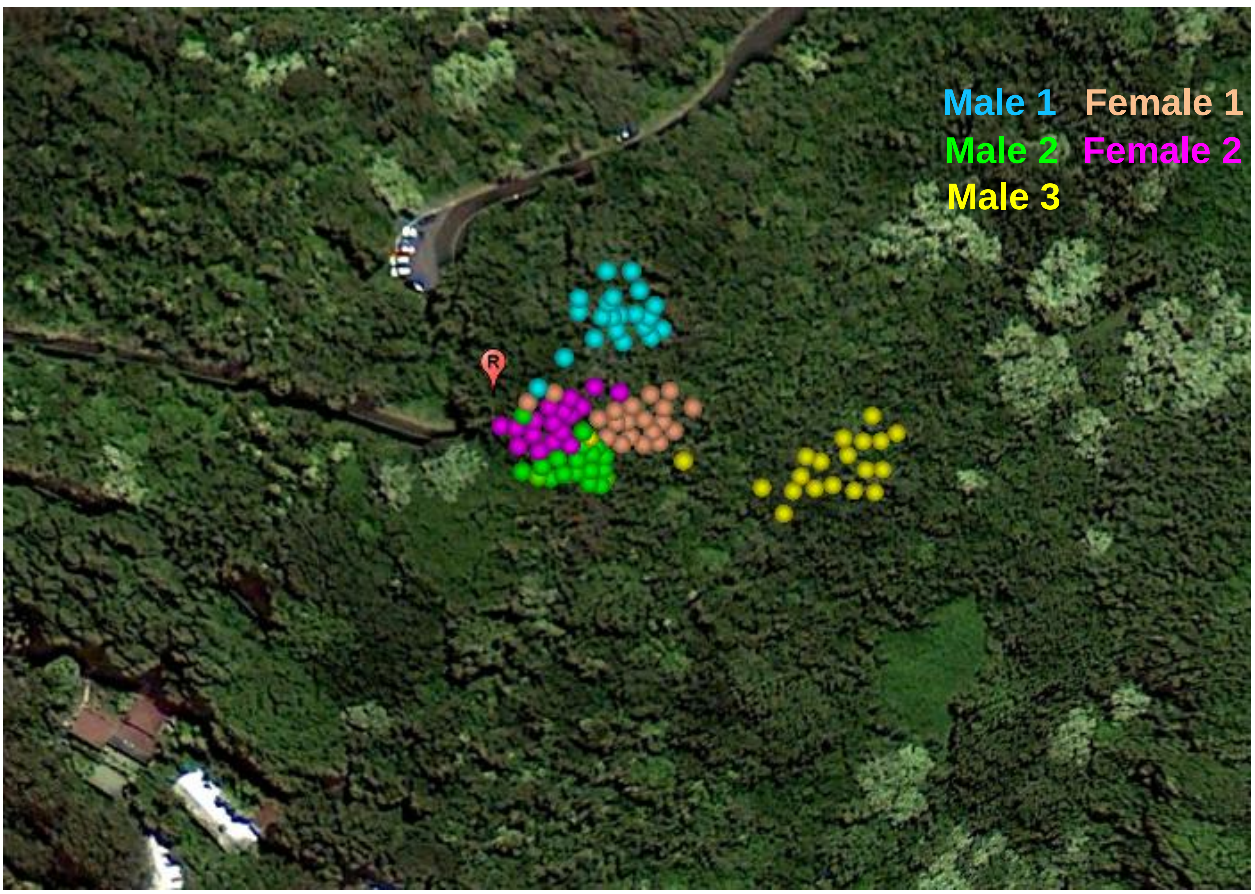


Figure 9. Satellite image showing the release site (R) in the Tantalus area on Oahu (inside map) and the position of each radio-tagged chameleon (different colors) recorded from June 23 to October 5, 2011. Note that home ranges do not overlap, and male chameleons are separated more than female home ranges.

Our plans for the second and possibly third releases will be discussed with OANRP personnel. The eastward movement observed for all 5 tagged animals may reflect behavioral avoidance of the road itself, perhaps due to the open canopy above it. We could test this by releasing chameleons on the west side of the road in the same area, then observing whether they head east and cross the road, or move in a westerly direction, away from the road. Alternatively, eastward movement might represent an inherent directional behavior, as has been observed in certain species that utilize either solar position or use iron ions to sense direction. In addition to a second Tantalus release, we are interested in a Waianae trial. This will entail a bit more logistics and coordination since the location is more remote than Tantalus, and daily tracking will only be possible providing we can have personnel staying in the area for multiple consecutive days. It is possible that home range size will vary dramatically depending on ecological conditions.

***Euglandina* Prey Preference and Tracking Studies**:

The primary threat to Hawaii's native land snail fauna currently comes from predation by the invasive molluscivore *Euglandina rosea*. Current trials have focused specifically on the situation at Puu Hapapa, where the *E. rosea* population has exploded within recent years. At roughly the same time, the population of the invasive slug *Limax* appeared to have undergone expansion in the area. We therefore conducted laboratory tracking and feeding trials with *Limax* and *E. rosea*.

We conducted a series of trials with adult *Euglandina* and all size classes of *Limax*, and the overall result showed that *Euglandina* tracks and attempts to kill and eat all sizes of the slug. When the largest of the adult slugs were presented in the open on a sheet of glass, *Euglandina* generally was not able to catch the slugs. Usually what occurred was *Euglandina* immediate showed interest, and pursued the prey, crawling onto the dorsal surface, and everting the mouth and biting. Slugs generally then accelerated their pace, and even exhibited a shaking behavior, where the distal end of the foot was actively swung from side to side effectively knocking off the predators. However, when placed in a confined space such as cup or cage, *Euglandina* were able to apprehend, bite and kill the slugs (Figure 10).

Figure 10. *Euglandina rosea* chasing, attacking, killing and feeding on a live leopard slug *Limax* from Puu Hapapa, Oahu.

It is unclear which lab setting best mimics the situation in the field, therefore it might be worthwhile to conduct field trials at Puu Hapapa with *Euglandina* and *Limax*. However, based on the strong interest expressed by *Euglandina* in feeding on *Limax*, we feel that it would be prudent to make efforts to eliminate slugs from the area surrounding the new tree snail exclosure, as it is likely that the high biomass of *Limax* in the area is at least in part, sustaining the large population of *Euglandina*, and removing this food source could help in decreasing the presence of *Euglandina* in the area.

Status of Tree Snail Captive Breeding Program

Table 1. Captive *Achatinella* Propagation Data for Koolau Taxa 2007-2011

	August 2007	August 2008	August 2009	August 2010	August 2011
Species	**juv/sub/adult total**	**juv/sub/adult total**	**juv/sub/adult total**	**juv/sub/adult total**	**juv/sub/adult total**
A. lila	215/246/8 470	151/372/21 544	175/363/118 656	129/287/0 416	212/102/141 455
A. sowerbyana	4/14/3 21	8/14/3 25	7/13/5 25	2/10/4 16	2/5/2 9
A. livida	50/66/6 122	28/75/5 108	17/51/17 85	2/44/8 54	14/29/19 62
A. byronii	5/14/9 28	6/17/7 30	--	--	--
A. apexfulva	3/4/1 8	2/0/0 2	0/2/0 2	0/2/0 2	0/1/0 1
A. bulimoides	21/4/9 34	24/15/4 43	18/22/3 43	4/19/9 32	1/5/1 7
A. fulgens	-	-	3/24/1 28	2/8/4 15	0/6/6 12
A. decipiens	-	-	3/17/5 25	1/5/0 6	0/3/1 4
A. fuscobasis	-	-	69/66/210 345	29/63/57 149	18/73/47 138

Table 2. Captive Snail Propagation Summary for *Achatinella mustelina* by ESU.

Population	ESU	Date	# juv	# sub	# adult	# Individuals
Peacock Flats	A	1995	0	0	6	**6**
		2003	--	--	--	**21**
		4/2004	8	11	4	**23**
		9/2005	3	15	2	**20**
		8/2006	1	12	3	**16**
		7/2007	0	9	2	**11**
		8/2008	0	3	3	**6**
		8/2009	0	2	0	**2**
		8/2010	0	0	2	**2**
		9/2011	0	0	2	**2**
ʻŌhikilolo – Makai	B1	2003	0	0	10	**10**
		4/2004	27	0	4	**31**
		9/2005	15	8	0	**23**
		8/2006	3	9	0	**12**
		7/2007	1	9	1	**11**
		8/2008	0	9	0	**9**
		8/2009	0	8	0	**8**
		8/2010	0	6	1	**7**
		9/2011	0	2	1	**3**
ʻŌhikilolo – Mauka	B1	2003	0	0	8	**8**
		4/2004	20	5	0	**25**
		9/2005	18	7	0	**25**
		8/2006	0	21	2	**23**
		7/2007	0	12	1	**13**
		8/2008	0	11	1	**12**
		8/2009	0	10	0	**10**
		8/2010	0	4	0	**4**
		9/2011	0	3	0	**3**
Kaʻala S-ridge	B2	2003	0	0	10	**10**
		4/2004	23	0	6	**29**
		9/2005	19	5	0	**24**
		8/2006	4	11	0	**15**
		7/2007	0	4	1	**5**
		8/2008	0	3	1	**4**
		8/2009	0	2	1	**3**
		8/2010	0	1	0	**1**
		9/2011	0	1	0	**1**

Alaiheihe Gulch	C	2003	0	0	10	**10**
		4/2004	14	4	4	**22**
		9/2005	17	5	0	**22**
		8/2006	2	20	0	**22**
		7/2007	2	21	0	**23**
		8/2008	1	20	0	**21**
		8/2009	0	17	0	**17**
		8/2010	0	0	11	**11**
		9/2011	1	4	4	**9**
Palikea Gulch	C	2003	0	0	10	**10**
		4/2004	20	1	8	**29**
		9/2005	22	3	2	**27**
		8/2006	12	13	0	**25**
		7/2007	0	22	2	**24**
		8/2008	0	20	1	**21**
		8/2009	0	17	1	**18**
		8/2010	0	8	1	**9**
		8/2011	0	5	1	**6**

Schofield Barracks West Range	C	2003	0	0	10	**10**
		4/2004	15	1	9	**25**
		9/2005	27	1	2	**30**
		8/2006	8	22	0	**30**
		7/2007	2	28	0	**30**
		8/2008	0	26	1	**27**
		8/2009	0	23	1	**24**
		8/2010	0	17	2	**19**
		9/2011	0	10	1	**11**
10,000 snails	D1	2001	0	0	9	**9**
		2003	--	--	--	**29**
		4/2004	8	22	0	**30**
		9/2005	3	24	3	**30**
		8/2006	1	24	3	**28**
		7/2007	7	14	4	**25**
		8/2008	8	13	0	**21**
		8/2009	9	2	0	**11**
		8/2010	0	8	2	**10**
		9/2011	3	5	2	**9**
Schofield South Range	D1	2003	0	0	10	**10**
		4/2004	18	7	3	**28**
		9/2005	24	2	0	**26**
		8/2006	11	12	0	**23**
		7/2007	0	21	0	**21**
		8/2008	0	15	3	**18**

		8/2009	0	11	2	**13**
		8/2010	0	7	4	**11**
		9/2011	0	1	9	**10**
Mākaha	D2	2003	0	0	10	**10**
		4/2004	16	0	8	**24**
		9/2005	23	0	3	**26**
		8/2006	10	14	0	**24**
		7/2007	5	17	0	**22**
		8/2008	0	20	0	**20**
		8/2009	0	10	0	**10**
		8/2010	0	2	6	**8**
		9/2011	0	0	5	**5**
ʻĒkahanui - Honoʻuliʻuli	E	2003	0	0	10	**10**
		4/2004	24	2	3	**29**
		9/2005	22	2	0	**24**
		8/2006	7	9	0	**16**
		7/2007	2	9	1	**12**
		8/2008	0	8	0	**8**
		8/2009	0	6	0	**6**
		8/2010	0	0	5	**5**
		9/2011	2	0	5	**7**
Palikea Lunch / former Pālehua	F	1997	1	0	0	**1**
		4/2004	4	0	4	**8**
		9/2005	20	0	2	**22**
		8/2006	5	14	0	**19**
		7/2007	1	15	0	**16**
		8/2008	0	13	0	**13**
		8/2009	0	3	0	**3**
		8/2010	0	3	0	**3**
		9/2011	3	1	2	**6**
TOTAL		2003	**--**	**--**	**--**	**138**
TOTAL		4/2004	**--**	**--**	**--**	**303**
TOTAL		9/2005	**--**	**--**	**--**	**299**
TOTAL		8/2006	**--**	**--**	**--**	**255**
TOTAL		7/2007	**--**	**--**	**--**	**213**
TOTAL		8/2008	**--**	**--**	**--**	**180**
TOTAL		8/2009	**--**	**--**	**--**	**127**
TOTAL		8/2010	**0**	**56**	**34**	**90**
TOTAL		9/2011	**9**	**32**	**32**	**73**

Juvenile=<10mm, Subadult=>10mm no thickened lip, Adult=thickened lip

Table 3a. *Achatinella mustelina* Laboratory Population Deaths 2004-2006.

ARMY POPULATION DEATHS 2004-2009	jan-jun04	jul-dec04	jan-jun05	jul-dec05	jan-jun06	jul-sept06
Cage and location	**j/s/a**	**j/s/a**	**j/s/a**	**j/s/a**	**j/s/a**	**j/s/a**
Ka'ala S-ridge chamber 4 bottom	0/1/2	1/0/4	3/1/2	6/2/0	2/1/0	2/2/0
Ala'ihe'ihe Gulch chamber 5 top	1/0/3	2/0/3	1/0/1	0/0/0	0/0/0	0/0/0
Palikea Gulch chamber 5 top	0/0/2	2/0/4	6/0/3	1/0/1	0/0/1	0/0/0
'Ōhikilolo Mauka chamber 5 top	0/0/3	0/0/0	0/0/0	0/0/0	0/1/0	0/0/1
Schofield West chamber 5 top	1/0/1	1/0/3	1/0/2	2/1/2	0/0/2	0/0/0
Mākaha chamber 5 top	1/0/3	2/0/2	2/0/1	1/0/2	1/0/1	0/1/1
'Ēkahanui Gulch chamber 5 bottom	3/0/4	1/0/2	0/0/0	1/2/0	0/4/0	0/2/0
'Ōhikilolo Makai chamber 5 bottom	3/0/2	3/1/4	4/0/0	8/4/0	0/0/0	0/0/0
Schofield South chamber 5 bottom	1/0/0	6/0/1	4/0/6	1/0/1	0/0/2	0/0/0
Schofield chamber 5 bottom	2/0/0	0/0/0	0/0/1	4/0/1	5/0/1	0/0/0
Palehua chamber 1	1/0/0	1/0/0	1/0/1	3/0/2	1/0/0	0/0/0
Peacock Flats chamber 1	1/0/1	1/0/0	2/0/2	0/0/0	0/3/1	0/0/1
10,000 snails chamber 1	1/0/0	0/0/0	0/0/0	0/1/0	1/1/1	0/0/0
Total mortality	37	44	44	46	29	10
Mortality by age class Totals	15/1/21	20/1/23	24/1/19	27/10/9	10/10/9	2/5/3
Births during period	72	50	33	10	8	2
Total live *A. mustelina* at end of period	321	327	316	280	259	251
Population totals at beginning of period by age	188/57/41 286	192/72/57 321	213/75/39 327	220/71/25 316	189/73/18 280	121/124/14 259
Percent mortality by age class	8/1.8/51.2	10.4/1.4/40	11/1.3/48.7	12.3/14/36	5.2/13.7/50	1.7/4/21

Table 3b. *Achatinella mustelina* Laboratory Population Deaths 2007-2011.

ARMY POPULATION DEATHS 2007-2011	**oct06-jul07**	**aug-dec07**	**jan-jun08**	**jul-aug09**	**sept09-feb10**	**mar-aug10**	**sept10-feb11**	**mar-sept11**
Cage and location	**j/s/a**	**j/s/a**	**j/s/a**	**j/s/a**	**j/s/a**	**j/s/a**	**j/s/a**	**j/s/a**
Ka'ala S-ridge chamber 4 bottom	2/6/0	0/0/0	0/0/0	0/1/0	0/0/0	0/0/2	0/0/0	0/0/0
Ala'ihe'ihe Gulch chamber 5 top	0/0/0	0/0/0	0/3/0	0/2/0	0/2/2	1/0/2	0/0/0	0/3/0
Palikea Gulch chamber 5 top	0/2/1	0/1/0	0/0/0	0/3/0	0/5/1	0/2/1	0/3/0	0/0/0
ʻŌhikilolo Mauka chamber 5 top	0/9/1	0/0/0	0/0/0	0/2/1	0/3/0	0/3/0	0/1/0	0/0/0
Schofield West chamber 5 top	0/0/0	0/1/0	0/1/0	0/2/2	0/3/1	0/1/0	1/7/1	1/0/0
Mākaha chamber 5 top	0/2/0	0/0/0	0/2/0	0/11/0	0/1/0	0/0/1	0/1/1	0/0/0
ʻĒkahanui Gulch chamber 5 bottom	1/3/0	0/1/0	0/2/0	0/3/0	0/1/0	0/0/0	0/0/0	1/0/0
ʻŌhikilolo Makai chamber 5 bottom	0/1/0	0/1/1	0/0/0	0/1/0	0/1/0	0/0/0	0/4/0	0/0/0
Schofield South chamber 5 bottom	0/2/0	0/1/0	0/0/0	0/5/1	0/1/0	0/1/0	0/0/1	0/0/0
Schofield chamber 5 bottom	1/0/2	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Palehua chamber 1	0/3/0	0/0/0	0/7/0	0/8/0	0/0/0	0/0/0	0/0/0	0/0/0
Peacock Flats chamber 1	0/5/1	0/1/0	0/2/1	0/0/4	0/0/0	0/0/0	0/0/0	0/0/0
10,000 snails chamber 1	9/8/1	4/2/0	1/2/4	1/11/0	0/1/0	0/0/0	1/0/0	0/1/2
Total mortality	60	13	25	58	22	14	21	8
Mortality by age class Totals	13/41/6	4/8/1	1/19/5	1/49/8	0/18/4	1/7/6	2/15/4	2/4/2
Births during period	15	7	4	2	0	2	2	11
Total live *A. mustelina* at end of period	206	200	179	127	104	92	73	72
Population totals at beginning of period by age	55/183/13 251	19/176/11 206	10/180/10 200	8/163/13 184	9/112/7 126	0/60/44 104	1/55/35 91	2/41/29 72
Percent mortality by age class	23.6/22.4/46	21/4.5/9	10/10.6/50	12.5/30.5/61.5	0/16.1/57.1	0/11.7/13.6	200/27.3/11.4	100/9.8/6.9

Table 4a. *Achatinella mustelina* Pu'u Hapapa Laboratory Population 2010.

Population numbers by month	February	March	April	May	June	July	August	September	October	November	December
	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a
'Ie'Ie	8/1/9	17/13/16	21/13/16	22/13/16	21/13/16	25/13/16	25/13/16	30/13/13	36/13/12	35/18/11	35/18/11
Outplant 1	12/10/19	16/13/15	21/13/14	26/12/14	28/12/14	27/12/14	27/12/14	39/12/14	39/12/13	47/7/15	49/7/15
Outplant 2	11/11/18	17/12/15	16/12/15	20/12/15	22/12/14	21/12/13	21/12/13	27/12/12	31/12/12	35/15/5	35/15/5
Shelter	11/0/10	18/14/15	23/14/15	26/14/15	27/14/15	30/14/14	30/14/14	35/14/12	36/14/12	41/12/14	40/12/13
Pu'u Hapapa 5	--	--	--	--	8/26/14	13/26/14	13/26/14	23/26/14	21/26/14	39/11/11	26/23/13
Total live at end of period	120	181	193	205	256	264	264	299	306	316	317
Deaths by size	0/0/0	3/0/1	4/0/1	4/1/0	6/1/1	4/0/2	0/0/0	5/0/2	10/0/4	8/1/6	8/0/3
Total Deaths	0	4	5	5	8	6	0	7	14	15	11
Total Births	0	18	17	17	16	14	0	23	19	19	16

Table 4b. *Achatinella mustelina* Pu'u Hapapa Laboratory Population 2011.

Population numbers by month	January	February	March	April	May	June	July	August	September
	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a	j/s/a
'Ie'Ie	34/18/10	36/13/9	45/13/8	40/13/7	39/13/6	40/13/5	38/13/4	38/13/4	38/13/4
Outplant 1	51/7/15	51/1/19	53/2/17	54/2/17	56/2/16	58/2/12	34/21/3	34/21/3	35/21/2

Outplant 2	36/15/5	34/19/6	33/18/4	38/18/4	39/18/2	40/18/2	38/13/8	40/13/8	43/13/8
Shelter	39/12/13	39/12/13	44/12/12	45/15/11	45/15/11	45/15/10	34/5/13	34/5/13	34/3/9
Pu'u Hapapa 5	28/19/16	37/19/16	35/19/16	39/19/15	45/18/15	53/18/14	41/9/8	41/9/8	48/9/8
Pu'u Hapapa 6	--	--	--	--	--	--	56	44/10/3	47/10/3
Total live at end of period	316	322	329	337	340	345	338	341	350
Deaths by size	4/0/6	2/3/3	1/3/8	7/0/3	3/0/4	4/0/3	6/0/7	3/2/5	2/0/2
Total Deaths	10	8	12	10	7	11	13	0	14
Total Births	10	14	20	18	10	16	7	3	23

Table 5. This table shows geographic origins, time of original collections, and numbers of *Achartinella sowerbyana* snails initially brought in to the UH tree snail facility. These two populations have been maintained in separate cages since inception.

Achatinella sowerbyana (Pulcherrima) 3/93- 3 snails (subadults)	*Lat. 21d 32m 32.1s N *Long. 157d 55m 35s W (these coordinates do not agree with the collection location note). Location is likely Army SHAKA.	Lab pop has not been combined with others pops. First notes on lab population March 1993. called “A. pulcherrima” until 9/96. Collection site is “N of Peahinaia” summit.
Achatinella sowerbyana (Peahinaia) 8/6/96 - 8 snails	UTM 608202.3599 2383700.9387 Lat. 21d 32m 10.3s N Long. 157d 57m 18.1s W	Lab pop has not been combined with others of species. First notes on lab population 8/13/96. Also noted as Frog Pond.

Stabilization Plan for *Drosophila substenoptera*

Long Term Goals:

- Manage extant populations units (PUs) and additional reintroductions, up to a total of three PUs to encompass the known geographical range of the species.
- Restore native host plants at three managed field site of at least five hectares.
- Monitor *D. substenoptera* presence and distribution over time to gauge management effectiveness.
- Control all threats at each managed field location.

Table 2.3.1 Taxon Summary

Population Unit	Population Reference code	Total Number of Individuals	Manage for stability	Management Unit	Notes
Inside AA					
Pu'u Kalena	SBW-A	#N/A	Manage for stability	Lihu'ē	Observed June 2009
Outside AA					
Pu'u Palikea	PAK-A	#N/A	Manage for stability	Pu'u Palikea MU	Observed Jan 2010
	Total	#N/A			

Taxon Specific Issues

Unfortunately, there is no technique currently available to uniquely mark individual flies and thereby quantify *D. substenoptera* numbers (Magnacca 2010 pers. comm.) Bait can be used to survey for Hawaiian *Drosophila* but only to indicate the presence or absence of taxa. Additionally, Hawaiian *Drosophila* life cycles, and thus presence, vary year to year based on rainfall patterns and other environmental variables, making survey results difficult to compare over time and across sites.

Two PUs have been found with recent survey efforts, thus more survey is required for this taxon. Mt Ka'ala Summit was resurveyed recently but none of this taxon was observed. Additional surveys should be undertaken at proposed or existing management units in the Wai'anae Mountains ('Ēkahanui, West and East Makaleha, Mākaha Subunit II, Manuwai). Because *D. substenoptera* was also collected in the Ko'olau Mountains, surveys should also be conducted in appropriate habitat in the Ko'olau Mountains at the Kawailoa Training Area and Schofield Barracks, East Range.

Discussion of Management Designations

All the point locations from the Pu'u Palikea MU are considered one PU because the habitat between them is continuous.

Threats in the Action Area

The only possible threat in the Action Area due to military training is habitat destruction from fire. The Army adopted a wildfire management plan for Schofield Barracks which substantially minimizes the possibility of fire. Thus the fire threat at the Pu'u Kalena PU is low.

Lab Rearing Information

Researchers have developed reliable techniques for rearing native Hawaiian *Drosophila* from natural substrates. Dr. Steven Montgomery, Dr. Kenneth Kaneshiro and Dr. Karl Magnacca have extensive experience in rearing picture-wing *Drosophila* from natural substrates. In addition, the Center for

Conservation Research & Training has established a Hawaiian *Drosophila* Research Stock Center (HDRSC) where laboratory colonies of several Hawaiian *Drosophila* species are being maintained for various experimentation and research. Currently, three endangered species of Hawaiian *Drosophila* are being maintained at the HDRSC. While long term maintenance in a laboratory setting could expose flies to unnatural selection pressures causing the taxa to diverge from natural lineages, use of captive breeding should be considered for reintroduction purposes.

Management Notes

Successful propagation techniques will be gathered for host plants to inform restoration plans. Monitoring strategies will be developed in order to document the expansion of population nodes and to demonstrate the presence of the target taxon across the target five hectare managed site. NRS will monitor regularly for *Vespula* and problematic alien ant species. If detected, NRW will apply control techniques. If control techniques do not exist, NRS will support threat control development research.

Table 2.2 Priority Management Actions for *Drosophila substenoptera*

Population Unit	Specific Management Actions	Timeline
Pu‘u Kalena	• Construct Līhu‘e MU fence • Monitor for alien predatory insects • Following fence construction begin habitat restoration • Conduct weed control • Establish baseline for target taxa	Begin Līhu‘e MU construction by January 2012/OIP Year 4
Pu‘u Palikea	• Maintain Pu‘u Palikea MU fence • Monitor for alien predatory insects • Begin habitat restoration • Conduct weed control • Establish baseline for target taxa	Begin new actions OIP Year 4
Ko‘olau Mountains	• Survey at sites within proposed or existing MUs to find 3rd PU to manage.	OIP Year 3 until complete
Wai‘anae Mountains	• Survey at sites within proposed or existing MUs to find 3rd PU to manage.	OIP Year 4 until complete

Relevant Research Projects

- For each of the of picture-wing flies, determine annual life history cycle and investigate impacts of nonnative insect predators, parasites, and competitors
- Pilot reintroduction of lab reared *Drosophila*
- Confirm suspected additional host *Urera glabra.*
- Track temperature and rainfall at current populations in an effort to predict favorable conditions for detection.
- Captive rearing genetic effects to guide lab population establishment for genetic backup and reintroduction.
- Develop abundance and population extent monitoring techniques.

Stabilization Plan for *Drosophila montgomeryi*

Long Term Goals:

- Manage extant populations units (PUs) and additional reintroductions, up to a total of three PUs to encompass the known geographical range of the species.
- Restore native host plants at three managed field site of at least 5 hectares.
- Monitor *D. montgomeryi* presence and distribution over time to gauge management effectiveness.
- Control all threats at each managed field location.

Table 2.3.1 Taxon Summary

Population Unit	Population Reference code	Total Number of Individuals	Manage for stability	Management Unit	Notes
Inside AA					
Pu‘u Kalena	SBW-A	#N/A	Manage for stability	Līhu‘e	Observed June 2009
Outside AA					
Kalua‘ā and Wai‘eli	KAL-A	#N/A	Manage for stability	Kalua‘ā and Wai‘eli MU	Observed Jan-Feb 2010
	Total	#N/A			

Taxon Specific Issues

Unfortunately, there is no technique currently available to uniquely mark individual flies and thereby quantify *D. montgomeryi* numbers (Magnacca 2010 pers. comm.) Bait can be used to survey for Hawaiian *Drosophila* but only to indicate the presence or absence of taxa. Additionally, Hawaiian *Drosophila* life cycles, and thus presence, vary year to year based on rainfall patterns and other environmental variables, making survey results difficult to compare over time and across sites.

Two PUs have been found with recent survey efforts, thus more survey is required for this taxon. Additional surveys should be undertaken at proposed or existing management units in the Wai‘anae Mountains (‘Ēkahanui, West and East Makaleha, Mākaha Subunit II, Manuwai). Unlike *D. substenoptera*, *D. montgomeryi* has not been collected in the Ko‘olau Mountains.

Discussion of Management Designations

The two point locations from the Kalua‘ā to Wai‘eli MU are considered one PU because the habitat between them is continuous and they are only 700 meters apart.

Threats in the Action Area

The only possible threat in the Action Area, due to Army training, is habitat destruction from fire. The Army adopted a wildfire management plan for Schofield Barracks which substantially minimizes the possibility of fire. Thus the fire threat at the Pu‘u Kalena PU is low.

Lab Rearing Information

Researchers have developed reliable techniques for rearing native Hawaiian *Drosophila* from natural substrates in a captive setting. Dr. Steven Montgomery, Dr. Kenneth Kaneshiro and Dr. Karl Magnacca have extensive experience in rearing picture-wing *Drosophila*. In addition, the Center for Conservation Research & Training has established a Hawaiian *Drosophila* Research Stock Center (HDRSC) where laboratory colonies of several Hawaiian *Drosophila* species are being maintained for various experiments and research. Currently, three endangered species of Hawaiian *Drosophila* are being maintained at the HDRSC. While long term maintenance in a laboratory setting could expose flies to unnatural selection pressures causing the taxa diverge from natural lineages, use of captive breeding should be considered for reintroduction purposes.

Management Notes

Successful propagation techniques will be gathered for host plants to inform restoration plans. Monitoring strategies will be developed in order to document the expansion of population nodes and to demonstrate the presence of the target taxon across the target five hectare managed site. NRS will monitor regularly for *Vespula* and problematic alien ant species. If detected, NRW will apply control techniques. If control techniques do not exist, NRS will support threat control development research.

Table 2.2 Priority Management Actions for *Drosophila montgomeryi*

Population Unit	Specific Management Actions	Timeline
Pu‘u Kalena	• Construct Līhu‘e MU fence and remove ungulates • Monitor for alien predatory insects • Following fence construction begin habitat restoration • Conduct weed control • Establish baseline for target taxa	Begin Līhu‘e MU construction by January 2011/OIP Year 3
Kalua‘ā and Wai‘eli	• Construct the Kalua‘ā and Wai‘eli subunit III fence • Maintain Kalua‘ā and Wai‘eli MU fence • Monitor for alien predatory insects • Maintain and expand habitat restoration already conducted by Nature Conservancy • Conduct weed control • Establish baseline for target taxa	OIP Year 3 Begin OIP Year 4
Wai‘anae Mountains	• Survey at sites within proposed or existing MUs to find 3rd PU to manage. • Map *Urera glabra* patches to guide surveys	OIP Year 3 until complete

Relevant Research Projects

- For each of the of picture-wing flies, determine annual life history cycle and investigate impacts of nonnative insect predators, parasites, and competitors.
- Pilot reintroduction of lab reared *Drosophila.*
- Confirm suspected additional host *Urera glabra.*
- Track temperature and rainfall at current populations in an effort to predict favorable conditions for detection.
- Captive rearing genetic effects to guide lab population establishment for genetic backup and reintroduction.
- Develop abundance and population extent monitoring techniques.

ASSESSMENT OF EFFECTS OF RODENT REMOVAL ON ARTHROPODS, AND DEVELOPMENT OF ARTHROPOD MONITORING PROTOCOLS, ON CONSERVATION LANDS UNDER US ARMY MANAGEMENT

Dr. Paul Krushelnycky
Dept. of Plant and Environmental Protection Sciences
University of Hawaii
3050 Maile Way, Gilmore 310
Honolulu, HI 96822
Phone: 808-956-8261
Fax: 808-956-2428
Email: pauldk@hawaii.edu

INTRODUCTION

Arthropods constitute a majority of the biodiversity in most terrestrial ecosystems. In addition, these animals typically play important roles in ecosystem processes such as decomposition, soil turnover and pollination, and form critical links in food webs. In short, native insects and their allies are not only important entities to conserve in their own right, but they are also important for the functioning of native ecosystems. Conversely, invasive arthropod species not only threaten native arthropods, but can also disrupt and alter entire biological communities. Obtaining basic measures of the status and trends of arthropod diversity should therefore be a fundamental component of any natural area management program. Moreover, understanding how arthropods are affected by other invasive species is central to their management and conservation. Because of their many roles throughout the larger biological community, this understanding is likely to have implications for the conservation of other endemic taxa, from plants that rely on arthropods for pollination to birds that use arthropods as prey.

Invasive black rats are believed to exert severe predatory pressure on native arthropod species, but the effects of this pressure on arthropod populations has not been quantified in the field. Because rats are now nearly ubiquitous in natural areas of Hawaii, the most effective way to assess their impacts on arthropod species and communities is to monitor the response of arthropods to rat removal. The Oahu Army Natural Resource Program is implementing or planning rat removal operations in three areas in the Waianae Mountains: Kahanahaiki, Palikea and Ekahanui. In conjunction with these efforts, I am conducting standardized, quantitative arthropod sampling before and after rat removal in two of these areas (Kahanahaiki and Palikea), as well as in adjacent control sites where rats will not be immediately removed, to measure arthropod responses and estimate the impacts of rats on native and introduced arthropod populations. This sampling will also serve as an arthropod inventory, providing important information on the biodiversity of these management areas. Thirdly, the sampling conducted in this project will be used to help develop broader arthropod monitoring protocols for the OANRP management units, as desired under the Makua and Oahu Implementation Plans.

METHODS

Kahanahaiki site: Arthropod sampling at this site is more limited than at the Palikea site because of very short lead time prior to initiation of rodent trapping. Pre-removal sampling was conducted in Kahanahaiki in May 2009, and post-removal sampling has been conducted in December 2009, May 2010, December 2010 and May 2011. Pahole NAR was selected for the untrapped control site, but because obtaining sampling permits took a little bit of time, the first sampling event did not occur until late June 2009, and subsequent summer sampling events were also offset from the Kahanahaiki sampling by about six weeks. Sampling at Pahole occurred in June 2009, December 2009, June 2010, December 2010 and June 2011. At both sites, sampling included pitfall trapping and vegetation beating on four shrub/tree species (*Charpentiera tomentosa, Pisonia umbellifera, Pipturus albidus, Psidium cattleianum*). At each site, 16 pitfall traps were established, one every 25 m, along the central gulch. Eight individuals of each of the four tree species were randomly chosen in the same general area as the pitfall traps. During each sampling event, each tree received five beats with a stick over a 1x1m beating sheet, and all arthropods dislodged were collected.

Palikea site: Arthropod sampling at Palikea has been conducted seasonally, occurring every four months. Three sampling events were completed, in November 2009, March 2010 and July 2010, before intensive rat trapping began in October 2010. Two post-trapping sampling events have been conducted so far, in March 2011 and July 2011. Sampling at Palikea occurs within a randomly chosen subset of the 5 by 10 m WCA vegetation plots, and includes pitfall trapping, leaf litter extraction, and timed vegetation sweeping at both day and night. Eighteen plots were chosen for arthropod sampling: 3-70, 3-90, 3-100, 3-110, 3-160, 3-170, 3-180, 3-190, 3-200; 4-100, 4-110, 4-140, 4-190, 4-200, 4-210, 4-240, 4-250, 4-260. An additional 18 plots were established at a nearby control site that is not undergoing intensive rodent management. Sampling at removal and control sites are conducted simultaneously. A sampling protocol was also established at each site to monitor *Rhyncogonus* beetles. *Rhyncogonus* is a genus of native weevils that are relatively large, rare and nocturnally active, and could therefore be predicted to be strongly impacted by invasive rodents. It also therefore serves as a good taxon with which to track potential recovery after rodent suppression. These beetles are not easily captured with standardized sampling methods, so potential host plants at each site were selected for targeted monitoring. At both sites, 12 trees or shrubs of two species (*Antidesma platyphyllum* and *Kadua terminalis*) were initially selected during the daytime (when adults are not active) and tagged for monitoring; each selected tree had at least some feeding damage on the leaves that was consistent with the damage caused by *Rhyncogonus* beetles. Numbers of monitored trees/shrubs were gradually increased with each monitoring event, until a total of 25 trees/shrubs were designated at each site by July 2011, including five *Psychotria* sp. individuals at each site. During each sampling event, each tagged plant was visited on one night, and lightly beat over a 1x1m beating sheet to dislodge any adult beetles.

RESULTS TO DATE

I. Potential effects of rodent trapping: Kahanahaiki and Pahole

A. Arboreal communities: vegetation beating sample trends

Changes in abundances of various taxa over time at Kahanahaiki, relative to Pahole, were calculated for each of two time periods: summer of 2009 to summer of 2010 (one year), and summer of 2009 to summer of 2011 (two years). Changes in abundances over time at the matched sites were compared with one another to derive a measure of the magnitude of relative abundance increases or decreases. Positive values indicate that the taxon increased more (or decreased less) over the specified time period at Kahanahaiki relative to Pahole, while negative values indicate the opposite: the taxon increased more (or decreased less) at Pahole relative to Kahanahaiki. A value of 0 indicates that the taxon fluctuated over the time period equally at both sites. The 32 sampling trees at each site were used as replicates, and mean relative changes for each taxon were compared to 0 with a one-sample t-test for taxa whose data were normally distributed, while medians were compared to 0 with a Wilcoxon Signed Rank Test for data that were not normally distributed.

Among spiders, all comparisons had mean positive values, suggesting increases at Kahanahaiki relative to Pahole, however only one comparison was close to being significantly different from zero (Figure 1). This was the comparison of changes in all Araneae from 2009 to 2011 ($t=1.96$, $p=0.059$). (For all Araneae from 2009-2010, $t=1.30$, $p=0.204$; native Araneae 2009-2010, $t=0.37$, $p=0.713$; native Araneae 2009-2011, $t=0.24$, $p=0.812$).

For beetles, patterns are difficult to discern. Most comparisons suggested increases in beetle numbers at Pahole relative to Kahanahaiki (Figure 2), although none of these were statistically significant (all Coleoptera 2009-2010, $t=-1.26$, $p=0.217$; native Coleoptera 2009-2010, $t=-0.84$, $p=0.409$; native Coleoptera 2009-2011, $t=-1.81$, $p=0.080$). The only comparison that was significantly different from zero suggests that all beetles increased at Kahanahaiki relative to Pahole over the two year period of 2009 to 2011 ($t=3.01$, $p=0.005$). The same trend did not occur among native beetles, indicating that the large increase at Kahanahaiki was comprised of adventive beetles.

Lepidoptera show the most consistent pattern of increasing abundances at Kahanahaiki relative to Pahole (Figure 3). Both all Lepidoptera and native Lepidoptera (exclusively caterpillars) had statistically significant relative increases at Kahanahaiki over both time periods (all Lepidoptera 2009-2010, $t=2.33$, $p=0.027$; all Lepidoptera 2009-2011, $t=3.09$, $p=0.004$; native Lepidoptera 2009-2010, $t=2.90$, $p=0.007$; native Lepidoptera 2009-2011, $t=3.18$, $p=0.003$). Native Lepidoptera caterpillars were represented by two groups, predatory *Eupithecia* and herbivorous *Hyposmocoma*, and both groups also showed significant relative increases at Kahanahaiki for most comparisons (*Eupithecia* 2009-2010, $W=71.0$, $p=0.013$; *Eupithecia* 2009-2011, $W=70.0$, $p=0.017$; *Hyposmocoma* 2009-2010, $W=123.5$, $p=0.102$; *Hyposmocoma* 2009-2011, $W=74.5$, $p=0.046$).

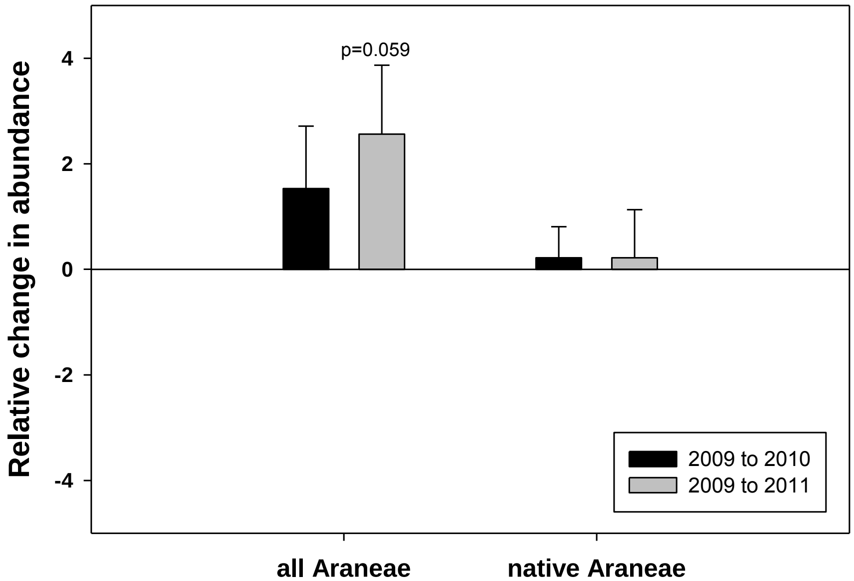


Figure 1. Mean changes in abundances of spiders at Kahanahaiki relative to Pahole, per vegetation beating sample, over one and two year periods. Positive values indicate increases at Kahanahaiki relative to Pahole, while negative values indicate increases at Pahole relative to Kahanahaiki. Only one comparison is marginally statistically significant, indicated with the associated p value.

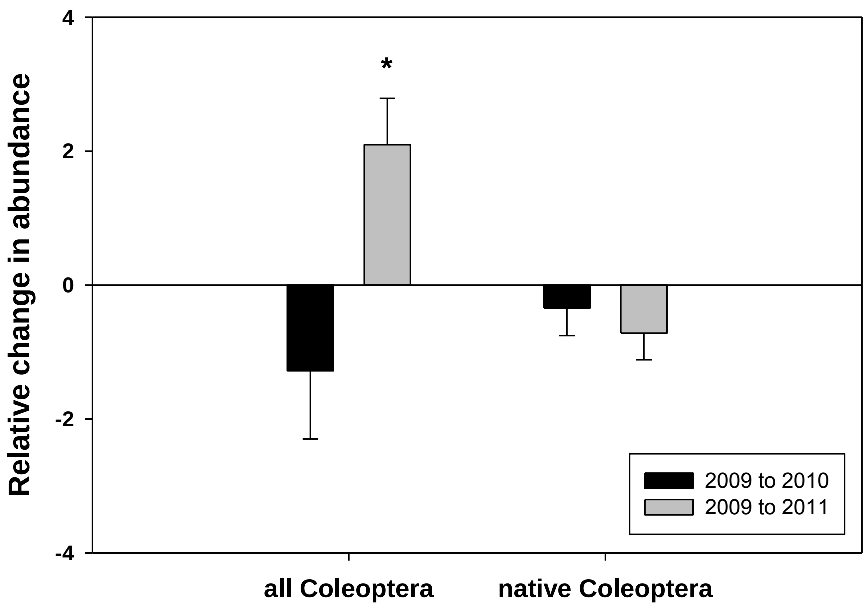


Figure 2. Mean changes in abundances of beetles at Kahanahaiki relative to Pahole, per vegetation beating sample, over one and two year periods. Positive values indicate increases at Kahanahaiki relative to Pahole, while negative values indicate increases at Pahole relative to Kahanahaiki. Comparisons that are significantly different from zero (at $p<0.05$) are indicated with an asterisk.

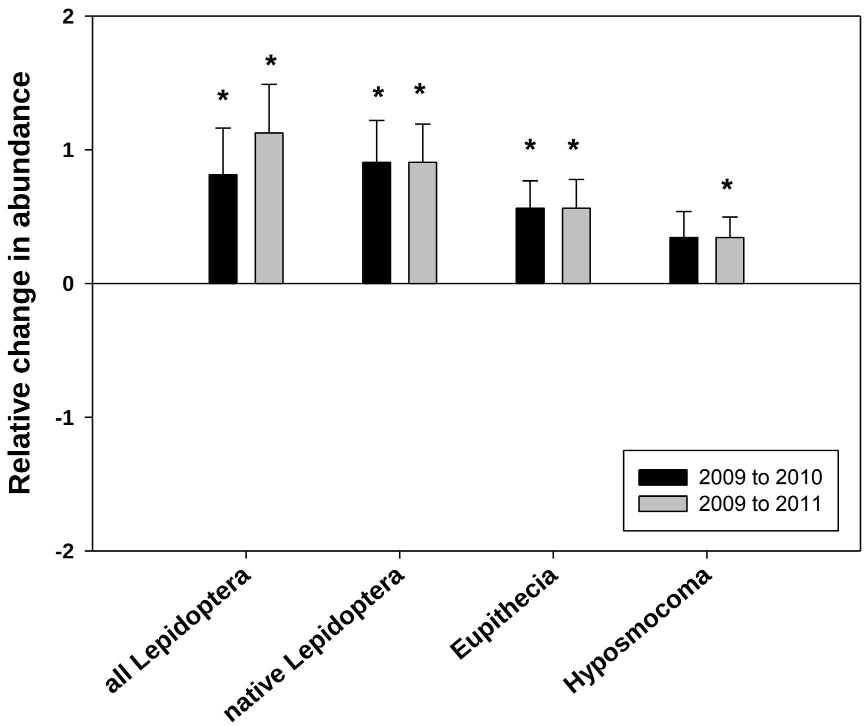


Figure 3. Mean changes in abundances of Lepidoptera at Kahanahaiki relative to Pahole, per vegetation beating sample, over one and two year periods. Positive values indicate increases at Kahanahaiki relative to Pahole, while negative values indicate increases at Pahole relative to Kahanahaiki. Comparisons that are significantly different from zero (at $p<0.05$) are indicated with an asterisk.

Other groups examined but found not to have significant patterns of relative increases or decreases among sites include Hemiptera (2009-2010, t=-0.76, p=0.450; 2009-2010 results for native Hemiptera were very similar, as most Hemiptera individuals were endemic; Hemiptera specimens not yet identified from 2011 samples) and crickets and katydids (all Orthoptera 2009-2010, W=50.0, p=0.410; all Orthoptera 2009-2011, W=9.0, p=0.787; native Orthoptera 2009-2010, W=10.5, p=0.612; native Orthoptera 2009-2011, W=4.0, p=0.855).

Other major groups remaining to be examined include Psocoptera (barklice), Blattodea (cockroaches), Collembola (springtails) and Thysanoptera (thrips).

B. Terrestrial communities: pitfall trap trends

The same procedure described above for vegetation beating samples was used to assess relative changes in abundances of arthropods captured in pitfall traps. The 16 traps at each site were used as replicates, and mean relative changes for each taxon were compared to 0 with a one-sample t-test for taxa whose data were normally distributed, while medians were compared to 0 with a Wilcoxon Signed Rank Test for data that were not normally distributed.

When grouping all Araneae, spiders were found to increase significantly more at Kahanahaiki relative to Pahole both from 2009 to 2010 (t=3.01, p = 0.009) and from 2009 to 2011 (t=3.91, p=0.001) (Figure 4). The trends were the same among native spiders, however relative changes were significantly different from zero over only the two year period (for 2009-2010, W=9.0, p=0.787; for 2009-2011, W=21.0, p=0.036).

All beetles, as a group, showed trends of increasing abundances at Kahanahaiki relative to Pahole over both time periods (Figure 5), but because of high variances among samples, these trends were not statistically significant (for 2009-2010, t=0.78, p-0.447; for 2009-2011, t=1.70, p=0.110). Conversely, trends for native beetles were in the opposite direction, but were much smaller and also not statistically significant (for 2009-2010, t=-0.86, p=0.403; for 2009-2011, t=-0.52, p=0.609).

Lepidoptera, as a group, tended to increase more at Pahole relative to Kahanahaiki (Figure 6), however this pattern was significant for only the first year (2009-2010, t=-2.82, p=0.013; 2009-2011, t=-0.19, p=0.855). The trends for *Hyposmocoma* were small (Figure 6) and not significantly different from zero (2009-2010, t=-1.23, p=0.236; 2009-2011, t=-0.55, p=0.590).

Native crickets in the *Laupala/Trigonidium* group were the only Orthoptera captured in pitfall traps. Species in this group are very difficult to differentiate morphologically, however as the specimens collected at Kahanahaiki and Pahole tend to resemble the genus *Laupala* more than *Trigonidium* according to Otte (1994), I refer to them as ?*Laupala* spp. These crickets tended to increase more at Kahanahaiki relative to Pahole (Figure 7), with this trend being significant over the two year period (2009-2010, W=9.0, p=0.201; 2009-2011, W=73.0, p=0.009). Furthermore, ?*Laupala* crickets were almost completely absent from pitfall samples at Pahole during all sampling events.

Earwig (Dermaptera) specimens have yet to be identified for the summer 2011 samples. From 2009 to 2010, neither all earwigs nor native earwigs only (represented by one species, *Euborellia eteronoma*) increased significantly more at one site relative to the other (all Dermaptera, t=1.06, p=0.308; native Dermaptera, W=19.0, p=0.415).

Hemiptera specimens have also not yet been identified for the summer 2011 samples. From 2009 to 2010, there was no significant difference in the relative change in Hemiptera abundances between sites (t=0.81, p=0.428). Hemiptera captured in pitfalls were represented mainly by the adventive burrowing bug (*Rhytidoporus indentatus*), plus nymphs of various other groups such as delphacid planthoppers.

Amphipods are abundant detritivores inhabiting the leaf litter at Kahanahaiki and Pahole. All specimens captured appear to belong to the adventive species *Talitroides topitotum*. These amphipods did not show significant relative changes in abundance between the sites over either time period (2009-2010, t=-1.08, p=0.296; 2009-2011, t=-0.07, p=0.948).

Other major groups remaining to be examined include Diplopoda (millipedes), Chilopoda (centipedes), Blattodea (cockroaches) and Isopoda (sowbugs).

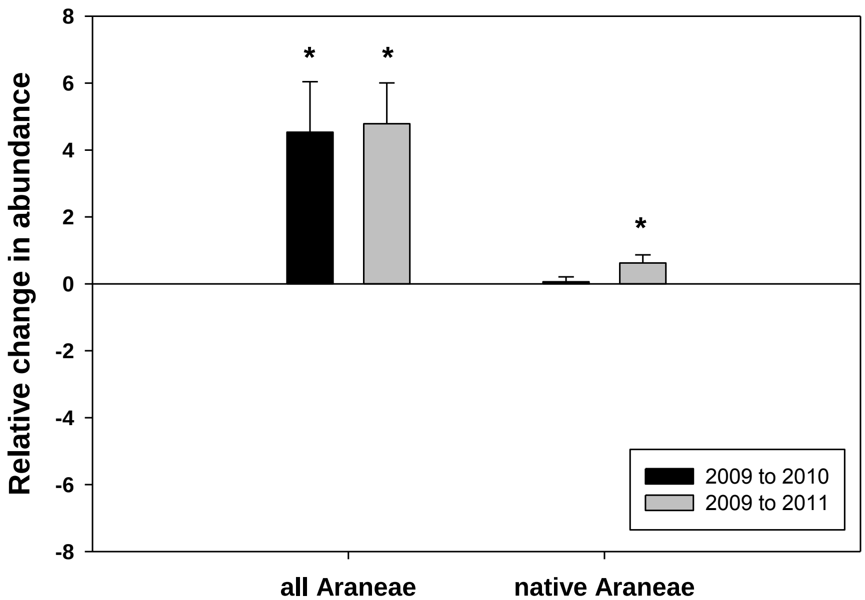


Figure 4. Mean changes in abundances of spiders at Kahanahaiki relative to Pahole, per pitfall trap, over one and two year periods. Positive values indicate increases at Kahanahaiki relative to Pahole, while negative values indicate increases at Pahole relative to Kahanahaiki. Comparisons that are significantly different from zero (at $p<0.05$) are indicated with an asterisk.

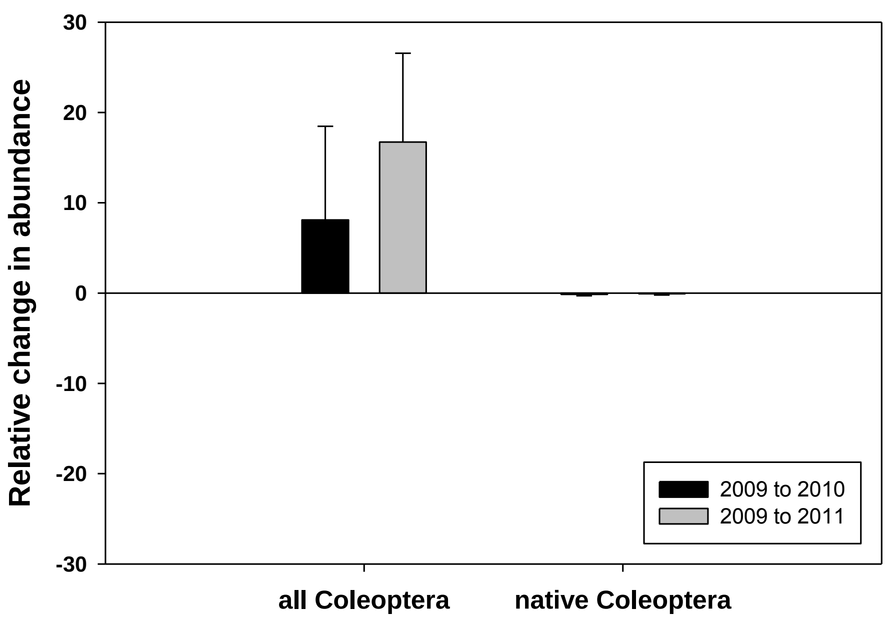


Figure 5. Mean changes in abundances of beetles at Kahanahaiki relative to Pahole, per pitfall trap, over one and two year periods. Positive values indicate increases at Kahanahaiki relative to Pahole, while negative values indicate increases at Pahole relative to Kahanahaiki. None of the comparisons were significantly different from zero (at $p<0.05$).

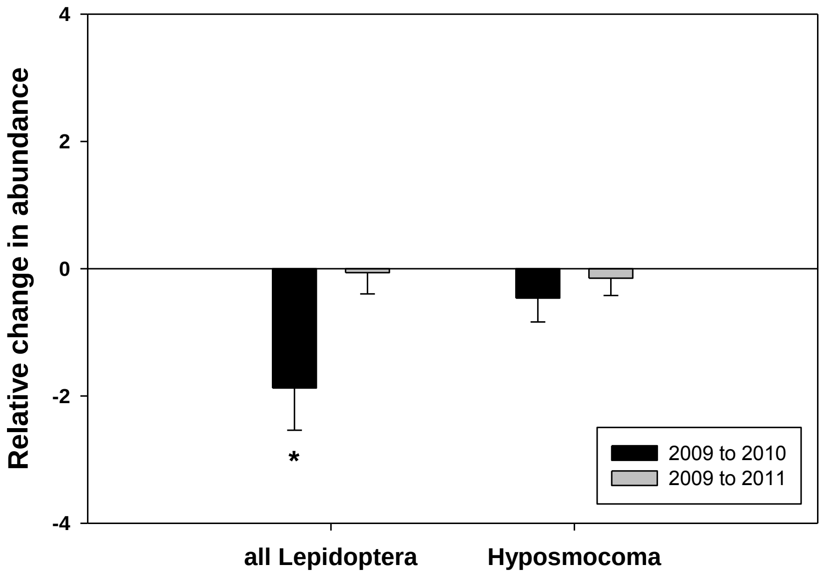


Figure 6. Mean changes in abundances of Lepidoptera at Kahanahaiki relative to Pahole, per pitfall trap, over one and two year periods. Positive values indicate increases at Kahanahaiki relative to Pahole, while negative values indicate increases at Pahole relative to Kahanahaiki. Comparisons that are significantly different from zero (at p<0.05) are indicated with an asterisk.

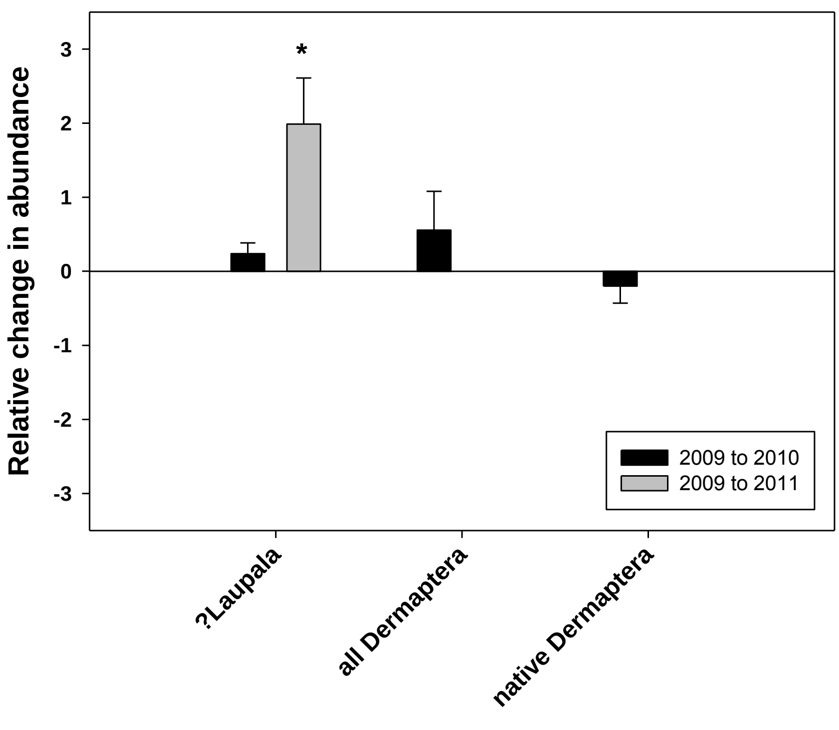


Figure 7. Mean changes in abundances of native ?*Laupala* crickets and earwigs (Dermaptera) at Kahanahaiki relative to Pahole, per pitfall trap. Data available for one year only for Dermaptera. Positive values indicate increases at Kahanahaiki relative to Pahole, while negative values indicate increases at Pahole relative to Kahanahaiki. Comparisons that are significantly different from zero (at p<0.05) are indicated with an asterisk.

C. Tentative conclusions

Because I have assessed numerous population changes involving multiple taxa without applying adjustments for multiple statistical comparisons, caution needs to be used when concluding that population fluctuations are real as opposed to resulting from statistical sampling error (the chances of which increase as number of comparisons increase). Furthermore, because of the nature of the design of this study, in which the treatment (rodent suppression) is only replicated once in each study area, further caution needs to be used when inferring a causal relationship between rodent trapping and population trends among arthropods. For this reason, single statistically significant results that don't appear to fit a larger pattern (at least yet) should be regarded as questionable evidence of a treatment effect. On the other hand, patterns of similar results among related taxa, or results that appear to be consistent over multiple time periods or between sampling methods, are unlikely to be due to haphazard population fluctuations or random sampling error, and can be regarded as tentative evidence of a response to rodent trapping. As patterns remain consistent over longer time periods, this evidence will strengthen.

After the first two years of sustained high intensity rodent trapping at Kahanahaiki Valley, the strongest evidence for a response to this effort has been among Araneae and Lepidoptera. Spiders, as a group, showed trends of increasing more at Kahanahaiki relative to Pahole over both one and two year time periods in the vegetation beating samples, although due to high variances among samples only the two year time period was marginally statistically significant ($p=0.059$). Nevertheless, the effect size appeared to get larger over time, and represents a relatively large proportional increase (44%) in spider abundance at Kahanahaiki. This pattern is supported by even stronger trends for the pitfall samples. Spiders in terrestrial communities increased at Kahanahaiki relative to Pahole over both time periods, and there was even evidence that this relative increase occurred among native spiders, at least after two years. It is not surprising that the apparent changes in native spiders were much weaker than for spiders overall, because most spider individuals captured are immature and are often very young stages, and are therefore difficult to assign to native vs. adventive species. A large proportion of spider individuals are typically categorized as unknown provenance.

Trends for Lepidoptera were also relatively consistent, at least for the vegetation beating samples. All Lepidoptera, as a group, as well as all native Lepidoptera, increased significantly more at Kahanahaiki relative to Pahole over both time periods. While the magnitude of these increases appear relatively small (Figure 3) for mostly herbivorous insects that are typically fairly abundant in the environment, the sampling methods used at these sites did not capture large numbers of adult or larval Lepidoptera. As a result, the changes in abundances measured at Kahanahaiki actually amount to an 80% to 125% increase in relative terms over the two years (at the same time that abundances decreased at Pahole). Native Lepidoptera were represented exclusively by larval forms of *Hyposmocoma* and *Eupithecia* species (the remaining caterpillars were unidentifiable and therefor of unknown provenance), and both of these groups also showed significant relative increases at the Kahanahaiki site. Both of these groups remain active on arboreal vegetation during the daytime when vegetation beating sampling was conducted, so, perhaps in contrast to many other groups of Lepidoptera, this sampling method can be expected to sample their populations fairly accurately. Moreover, the relatively low numbers of captures of *Eupithecia* caterpillars is in line with expectations for a predatory species (*Hyposmocoma* capture rates were at times fairly high, but tended to be so only in December sampling events). Unfortunately, pitfall trapping results did not corroborate these patterns of increase among Lepidoptera apparent in the vegetation beating samples. However, most trends for the pitfall data were small in size and not statistically significant. These discrepancies between pitfall and vegetation beating data could indicate that apparent trends are unrelated to rodent trapping, but alternatively they could reflect differences in responses between terrestrial and arboreal species. *Hyposmocoma* morphospecies at these sites, for example, show almost completely non-overlapping distributions between ground and arboreal samples.

These tentative conclusions of recovery among spiders and caterpillars following rodent suppression are consistent with the fact that spiders and especially caterpillars were among the most common arthropod prey items in rodent stomachs collected at Kahanahaiki (Shiels unpub. data). Other groups found in rodent stomachs included relatively large-bodied representatives of Coleoptera and Orthoptera. To date, population dynamics in these groups do not provide strong evidence of recovery at Kahanahaiki subsequent to rodent trapping. Beetle numbers (all species combined) typically suggested relative increases at Kahanahaiki relative to Pahole, but only one such comparison was statistically significant (vegetation beating 2009 to 2011), while one comparison suggested a change in the opposite direction (vegetation beating 2009 to 2010). At this point it is difficult to be confident that the significant relative increase in vegetation beating samples over the two year period is not simply a localized short-term population fluctuation unrelated to rodent trapping. In addition, the sampling methods used have to date captured almost entirely small sized beetle species. If rodents tend to directly impact larger species (St Clair 2010), then our sampling efforts may fail to detect their effects on beetles. Alternatively, population recovery among beetles may take longer, and larger species may increase in samples over time. Effects on native beetles appeared to be much smaller than beetles overall (Figures 2, 5). This is likely due to the fact that native beetles represent a fairly small proportion of total beetle numbers at these sites, especially in terrestrial communities.

Orthoptera captured in vegetation beating samples included native ?*Laupala* crickets, introduced katydids and one individual of the native katydid *Banza*. All Orthoptera captured in pitfall traps appeared to be ?*Laupala* crickets. Neither all Orthoptera nor native Orthoptera showed trends of relative increase or decrease among sites that were even close to being statistically significant for the vegetation beating samples. Pitfall trapping, however, provided evidence that ?*Laupala* cricket populations may be increasing at Kahanahaiki relative to Pahole, and this effect may be increasing over time (Figure 7).

Overall, the monitoring at Kahanahaiki and Pahole suggests that Araneae and Lepidoptera tend to be increasing in abundance at Kahanahaiki relative to Pahole, and the consistency of these patterns suggest that these effects may be due to rodent suppression. These results also concord with results from rodent stomach contents at Kahanahaiki. Results for other arthropod groups containing large-bodied species that are known to be common rodent prey items, such as Coleoptera and Orthoptera (St Clair 2010), must be regarded as still inconclusive. Evidence of a positive response to rodent trapping for these groups may become stronger over time, as populations have more time to recover.

Inference regarding the causal relationship between rodent trapping and arthropod population trends can be strengthened through comparison of patterns obtained at multiple independent sites. The arthropod sampling being conducted at the Palikea study area will serve this purpose. Because sampling efforts at that site are considerably more intensive than those at Kahanahaiki/Pahole, however, processing of the Palikea samples is much more time and labor consuming. To date I have focused on identification of those groups judged to be most likely to respond to rodent trapping (such as Araneae, Coleoptera, Lepidoptera, Orthoptera), and large numbers of specimens in these groups have been identified for many of the sampling events conducted so far, but no full datasets are yet available with which to begin assessing the effects of rodent trapping. However, one exciting and encouraging piece of data from Palikea regards the *Rhyncogonus* beetle sampling at this study area. In the four sampling events from November 2009 through March 2011, not a single *Rhyncogonus* was captured on the tagged *Rhyncogonus* sampling trees (or in any of the standardized vegetation sweeping samples) at either the rodent removal site or control site. During the July 2011 sampling event, approximately nine months after intensive rodent trapping was initiated at the removal site, six *Rhyncogonus* individuals were captured (and released) on five of the tagged sampling trees at the rodent removal site, while none were captured at the control site. All appeared to be individuals of *R. howarthi*, and were found on *Antidesma platyphyllum* (1 beetle on 1 tree/shrub), *Kadua terminalis* (4 beetles on 3 trees/shrubs) and a *Psychotria* sp. (1 beetle on 1 tree/shrub). It is still too early to tell if this represents the beginning of a population recovery due to rodent suppression, but it clearly indicates the importance of continued monitoring to track arthropod species and community changes.

II. Arthropod biodiversity patterns

The standardized plus opportunistic sampling for this project has resulted in the collection and identification, to date, of 274 arthropod species or morphospecies at the Kahanahaiki and Pahole sites and 305 species or morphospecies at the Palikea site. These numbers will increase as additional taxonomic groups are examined for lower-level identification. Most of the high-diversity orders, however, have already been worked on to some degree, so further increases in total species richness will likely be moderate. These inventories provide invaluable information regarding the native biological resources present at these sites, as well as the invasive species that may threaten them. At least one new endemic species has been discovered and is now described: the predatory carabid beetle *Mecyclothorax palikea*, which is apparently restricted to the southern Waianae mountains (Liebherr and Krushelnycky 2011).

The standardized samples enable exploration of various patterns of biodiversity among arthropods and their relationships to plant species and communities. At Kahanahaiki and Pahole, for example, vegetation beating samples collected on single host tree species permit comparison among these plant species. Interestingly, so far the total richness of arthropods on each of the four sampled tree species as well as in pitfall traps is fairly similar, and there is no statistically significant difference in the proportional composition of total richness of native, adventives and unknown provenance species between the tree species and pitfall traps (Figure 8). Surprisingly, *Psidium cattleianum* hosts a similar number of arthropod species, including native species, as the three other native trees. However, this analysis does not yet include all arthropod groups (such as Collembola and Psocoptera), and should therefore not be considered final and conclusive at this point. When the same data are viewed from the perspective of arthropod abundance rather than species richness, a very different preliminary picture emerges (Figure 9). The native trees host a much higher proportion of individuals of native arthropod species than does *Psidium cattleianum*, and terrestrial arthropod communities (as sampled in pitfall traps) are completely dominated by adventive individuals, with only 5% of all individuals captured in pitfalls belonging to native species. A further interesting preliminary pattern is that while *Psidium cattleianum* hosts a similar number of species as the three native tree species, the total abundance of arthropods on strawberry guava is considerably lower (Figure 10). Again, this analysis does not yet include all arthropod groups, so is subject to change (the main groups missing are Collembola and Psocoptera). However if this pattern holds, it could indicate that strawberry guava provides inferior foraging habitat for the endangered insectivorous elepaio. This conclusion would depend on patterns of abundances for arthropod taxa that serve as the main prey items in the elepaio diet.

Sampling at Palikea is not tied to individual host plant species, but instead occurs within the WCA vegetation plots at the site. Preliminary patterns among spiders and beetles are fairly similar to those at Kahanahaiki and Pahole, in that richness in arboreal communities (vegetation sweeping samples) is divided among native, adventive and unknown provenance species in similar proportions to that in terrestrial communities (pitfall and leaf litter samples) (Figure 11). Total richness for these two taxonomic groups is much higher for arboreal communities, however. Also similar to Kahanahaiki and Pahole, the proportion of native individuals is much higher in arboreal communities compared to terrestrial communities, at least among spiders and beetles (Figure 12).

Taking a broader taxonomic view of just arboreal communities, slightly over half of the species in Araneae, Coleoptera, Hemiptera and Lepidoptera combined are native (Figure 13). However, the richness of native species per plot varies dramatically, from a low of 3 native species per plot to a high of 21 native species per plot. The factors underlying this dramatic variation in native species richness are of great interest, as understanding them may be central to conserving and restoring native arthropod species and communities. Although this dataset represents just a small subset of the sampling conducted to date, preliminary analyses have so far found that the strongest associate of native arthropod richness in the Palikea plots is native richness of the plant community in the understory (Figure 14). Native plant richness in the understory was more strongly correlated with native arthropod richness than was native plant richness in the canopy, or total cover of native plants in either the understory or canopy. If this pattern holds, it would suggest that plant restoration efforts that increased native plant diversity in addition to native plant cover would have the strongest beneficial effects on native arthropods. As more samples are sorted and identified from Palikea, the ability to discern these types of patterns should increase greatly, providing excellent opportunities for developing a better understanding of the relationships between native arthropods, adventive arthropods and plant communities.

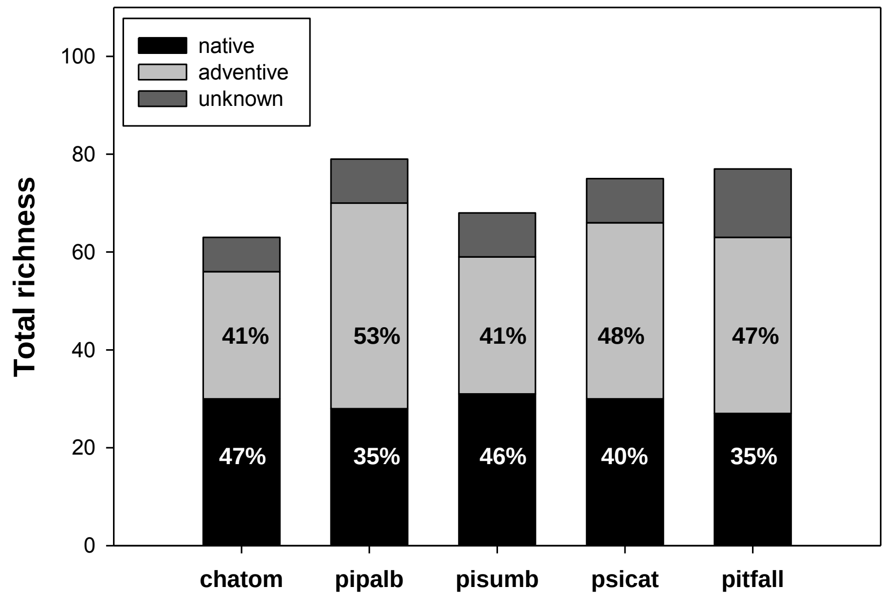


Figure 8. Total richness of arthropod species/morphospecies captured in vegetation beating samples on the four tree species and pitfall samples on the ground at Kahanahaiki and Pahole. Dataset includes all samples collected in summer 2009, winter 2009 and summer 2010, and the following taxonomic groups: Araneae, Coleoptera, Hemiptera, Lepidoptera plus several other families or lower taxonomic groups. Richness totals are subdivided by provenance of species, with percentages indicating contributions from native and adventive species. Abbreviations are: Chatom = *Charpentiera tomentosum*, pipalb = *Pipturus albidus*, pisumb = *Pisonia umbellifera*, psicat = *Psidium cattleianum*, pitfall = pitfall traps. There was no significant difference in proportions of native, adventives and unknown provenance species among the tree species or pitfall traps (chi square = 5.798, p = 0.67).

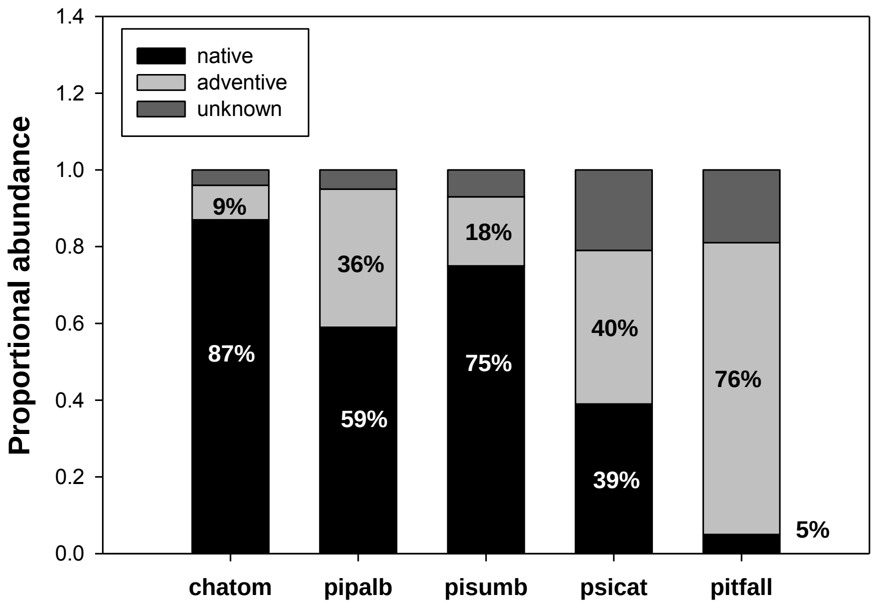


Figure 9. Proportional abundance of native, adventive and unknown provenance individuals in the arthropod communities on the four tree species and in pitfall traps at Kahanahaiki and Pahole. Dataset includes all samples collected in summer 2009, winter 2009 and summer 2010, and the following taxonomic groups: Araneae, Coleoptera, Hemiptera, Lepidoptera plus several other families or lower taxonomic groups. Abbreviations as in Figure 8. There was a significant difference in proportions of native, adventives and unknown provenance individuals among the tree species and pitfall traps (chi square = 207.904, $p < 0.001$).

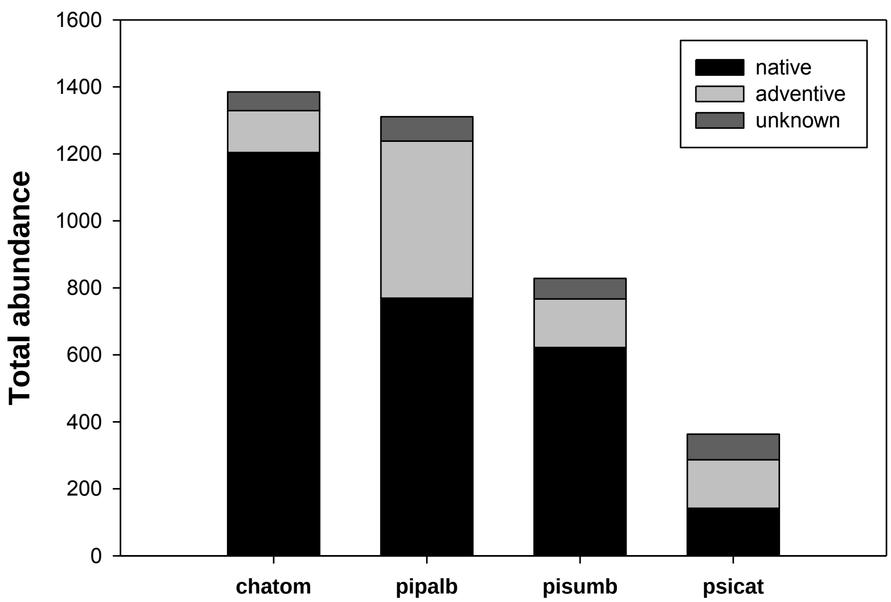


Figure 10. Total abundance of native, adventive and unknown provenance individuals in the arthropod communities on the four tree species at Kahanahaiki and Pahole. Dataset includes all samples collected in summer 2009, winter 2009 and summer 2010, and the following taxonomic groups: Araneae, Coleoptera, Hemiptera, Lepidoptera plus several other families or lower taxonomic groups. Abbreviations as in Figure 8.

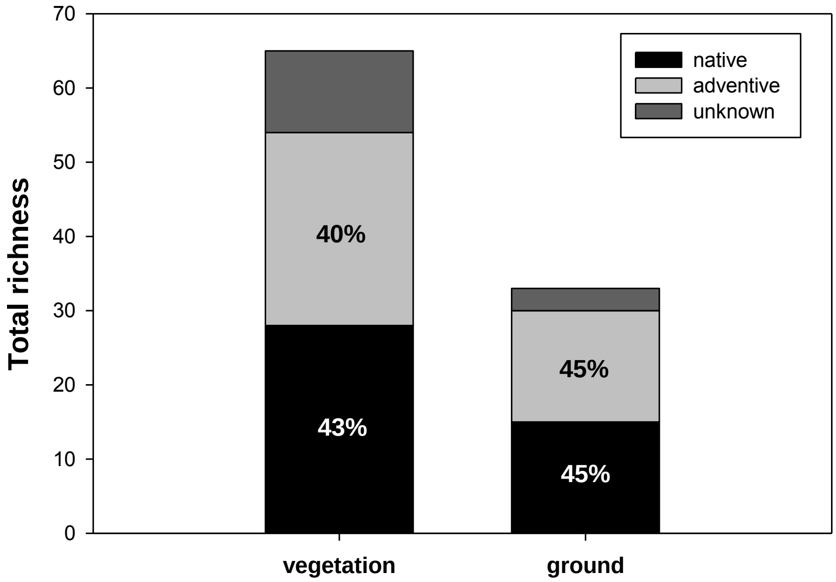


Figure 11. Total richness of spider and beetle species/morphospecies captured in arboreal and terrestrial communities in November 2009 at Palikea. Arboreal communities sampled with timed day and night vegetation sweeping, terrestrial communities sampled with pitfall traps and leaf litter extraction. Richness totals are subdivided by provenance of species, with percentages indicating contributions from native and adventive species. There was no significant difference in proportions of native, adventives and unknown provenance species among the two community types (chi square = 1.124, p = 0.570).

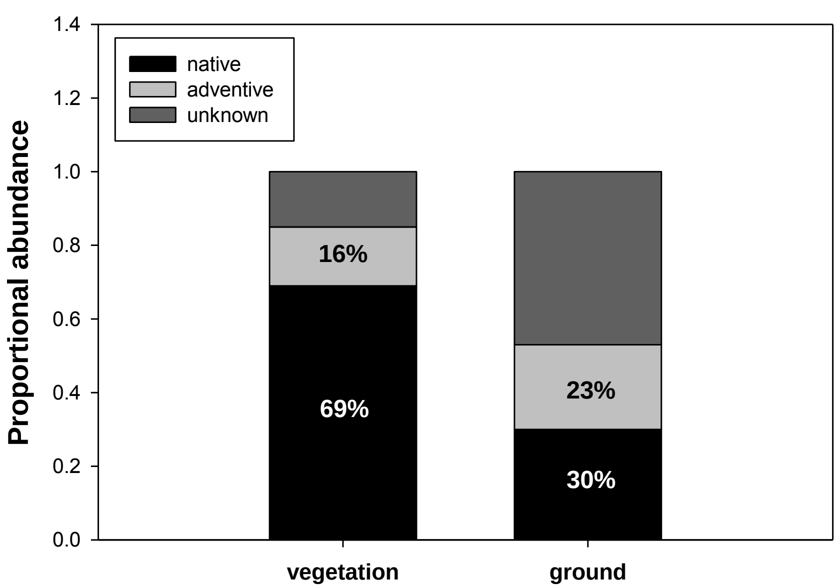


Figure 12. Proportional abundance of native, adventive, and unknown provenance spider and beetle individuals in arboreal and terrestrial arthropod communities at Palikea, November 2009. There was a significant difference in proportions of native, adventives and unknown provenance individuals among the two community types (chi square = 261.008, p < 0.001).

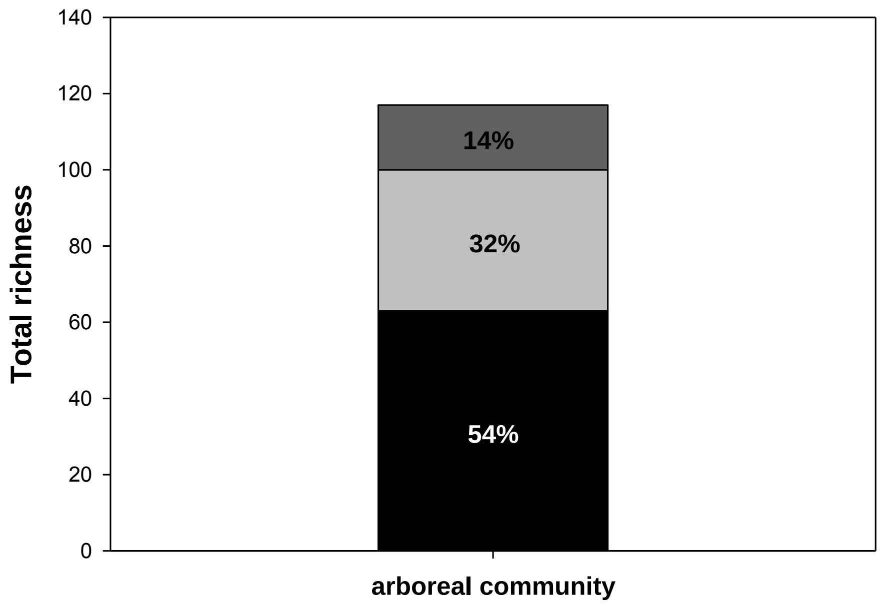


Figure 13. Total richness of Araneae, Coleoptera, Hemiptera and Lepidoptera species/morphospecies captured in arboreal communities in November 2009 at Palikea. Arboreal communities sampled with timed day and night vegetation sweeping. Richness totals are subdivided by provenance of species, with percentages indicating contributions from native and adventive species.

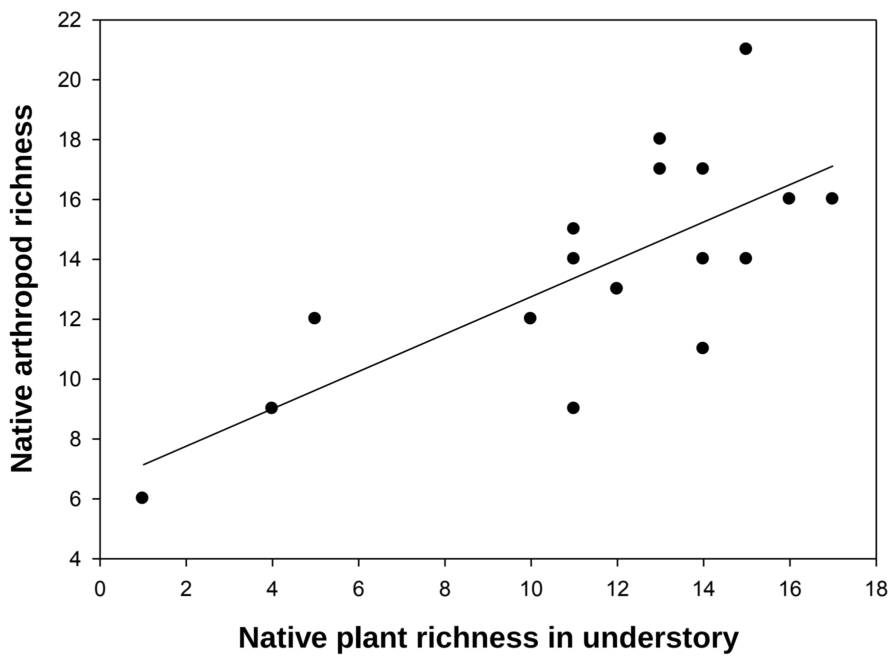


Figure 14. Relationship between richness of native arthropods (including Araneae, Coleoptera, Hemiptera and Lepidoptera) and richness of native understory plants in arboreal communities in November 2009 at Palikea (r^2=0.54, p=0.001).

LITERATURE CITED

Liebherr, J.K., and P.D. Krushelnycky. 2011. *Mecyclothorax palikea*, sp. n. from the Waianae Range, Oahu, and the biogeographical history of Hawaii's *M. flavomarginatus* species group (Coleoptera: Carabidae: Moriomorphini). Insect Systematics and Evolution, in press.

Otte, D. 1994. The Crickets of Hawaii: Origin, Systematics and Evolution. Academy of Natural Sciences, 400 pp.

St Clair, J.J.H. 2010. The impacts of invasive rodents on island invertebrates. Biological Conservation, in press.

APPENDIX 1-1
Environmental Outreach 2011

OUTREACH PHOTOS:

Volunteer helps to control the incipient *Sphagnum palustre* along the Kaala boardwalk corridor.

Volunteers help to up-pot *Acacia koa* seedlings in the Kahanahaiki field nursery.

Volunteers control invasive weeds at Pahipahialua, KTA.

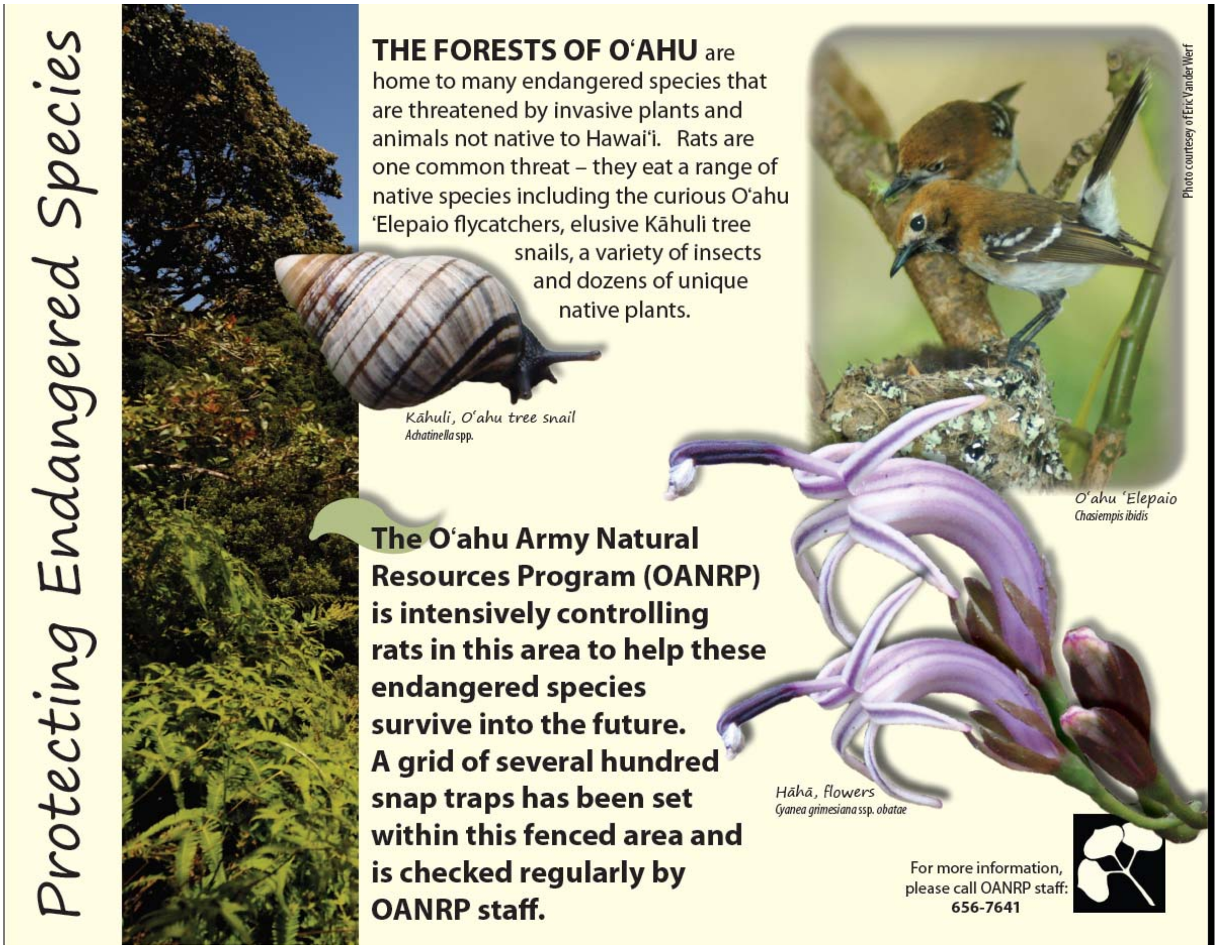
Volunteers plant *Carex wahuensis* at Pahipahialua, KTA.

Summer intern and new staff "Education Day" at Kahanahaiki.

Volunteer Appreciation/Birding Hike at Palikea (for volunteers who contributed more than 32 hours this year).

Outreach Display at University of Hawaii Earth Day Festival, 2011.

EDUCATIONAL MATERIALS:



Above: Informational sign describing OANRP efforts to control rats with snap-trap grids within management units. Below: Modified Display used with hands-on native seed planting activity.

Poster and flyer describing the threat of "*Chromolaena Odorata*" found in Kahuku Training Area. http://manoa.hawaii.edu/hipicesu/DPW/chrodo_poster.pdf & http://manoa.hawaii.edu/hipicesu/DPW/chrodo_flyer.pdf

PUBLIC RELATIONS:

Paintball, woodchips part of environmental discussion

Thursday, February 24, 2011 at 1:52 PM
Hawaii Army Weekly in Directorate of Public Works (DPW),
(OANRP), Sustainability, conservation

Kapua Kawelo
Oahu Army Natural Resource Program

Fencing to keep out wild pigs, goats is discussed du

HONOLULU — The Oahu Army Natura
completed a series of meetings aimed at reviewing a
conservation work with endangered species.

Recent projects included the completion of more tha
150 acres of weed control, the reintroduction of mor
control around 75 pairs of nesting Elepaio birds.

"I'm incredibly proud of the accomplishments of ou
Directorate of Public Work's Environmental Divisic
in the mid-90's, … there was a tremendous amount
ecosystem management on Army lands. There chall
proud of what we've done and what we've accompli

OANRP also discussed progress made on the resear
paintball equipment to deliver herbicide to target we
large-scale weed control projects, state-of-the-art rat
slug bait to protect endangered plant seedlings in the

Every year, the Makua Implementation Team gather
the "Makua Implementation Plan" conservation mea
challenges. The MIT is the Army's sounding board
serves as a regulatory monitor of the Army's progre
requirements.

The MIT — which includes biologists, botanists, ge

"Paintball, woodchips part of environmental discussion," (2/24/11) and "Forces Combine to Manage one of Oahu's Rare Natural Gems," (10/27/11) both printed in Hawaii Army Weekly. For full issues of: http://www.hawaiiarmyweekly.com/full-issues2011/

Forces combine to manage one of Oahu's rare natural gems

MICHELLE MANSKER
Oahu Army Natural Resource Program, Environmental Division, Directorate of Public Works, U.S. Army Garrison-Hawaii

MOUNT KAALA – On a sunny morning, Sept. 24, 15 volunteers gathered to do their part for Hawaii's public lands.

Staff members from the Oahu Army Natural Resource Program, or OANRP, Environmental Division, Directorate of Public Works, U.S. Army Garrison-Hawaii, and the state's Department of Land and Natural Resources, or DLNR, came together for National Public Lands Day, the largest single-day volunteer effort for public lands in the U.S.

The annual event normally draws a crowd of more than 180,000 volunteers nationwide.

For the past three years, OANRP has successfully submitted NPLD proposals for funding. This year, the team received more than $6,500, the largest award yet.

The proposal involved Oahu's only high-elevation bog that is perched, here, atop the Waianae Mountain habitat. This habitat is home to many rare and endangered species, all of which are only found in Hawaii and some only in the bogs. At 4,025 feet, the bog is located on the island's highest peak.

The Army and DLNR share ownership of this bog.

Mount Kaala is a DLNR Natural Area Reserve, set aside to preserve and protect examples of native Hawaiian ecosystems. OANRP actively manages its half of the bog, controlling threats to the native ecosystem, such as invasive plant and animal species.

Bog environments are special because their acidic soils cause the plants that inhabit them to be stunted in their growth form. These environments are very fragile, and scientists have estimated that it takes hundreds of years for the bog to recover from a single footprint.

With this in mind, DLNR and volunteers installed a boardwalk over the fragile habitat 20 years ago, allowing people to enjoy the beauty of this place without harming it.

Courtesy of Oahu Army Natural Resource Program, Environmental Division, Directorate of Public Works, U.S. Army Garrison-Hawaii

Michelle Mansker, OANRP, Environmental Div., DPW, USAG-HI, repairs the boardwalk over the fragile bog area atop Mount Kaala on National Public Lands Day, Sept. 24.

This year's NPLD volunteers, including some of the original volunteers from 20 years past, spent the day assisting OANRP and DLNR in replacing this essential structure.

The new boardwalk was constructed from redwood boards set atop plastic lumber spacers. Hammers and nails in hand, volunteers installed wire mesh over the redwood boards to create the no-skid surface. Since the habitat is often shrouded in clouds, installation of the no-skid surface on top the boards is important.

The work was difficult and often dangerous, as volunteers' many scratches and scrapes can attest to.

In spite of the difficulty, volunteers received an ideal reward – a rare, sunny day atop the peak, with views clear to Diamond Head and beyond.

"Hawaii Confronts Invasive Superweed on Kahuku Training Area" article in Public Works Digest publication, May/June 2011. View this and other Public Works Digests issues at: http://www.imcom.army.mil/hq/kd/cache/files/E2884331-423D-452D-49A8A29C0B56003D.pdf

Hawaii confronts invasive superweed on Kahuku Training Area

by Jane R. Beachy

Like stamps in a passport, *Chromolaena* collects names as it moves from place to place invading new ecosystems. In Australia and the United States, it is called bitter bush, devil weed and Siam weed. In Guam, it's called *masigsig*; in Chuuk, *otuot*; in Kosrae, *mahsrihsrihk*; in Palau, *kesengesil*; in the Philippines, *agonoi*; in Honduras, *rey del todo*; and the list continues.

Native to Central America, *Chromolaena odorata*, a member of the aster family, has become a highly invasive pest across much of the world. Management agencies struggle to control its spread in Africa, and conservationists in Australia strategize on effective control measures.

Chromolaena spans Southeast Asia, from Indonesia to Japan. It has skipped across the Pacific, infesting every island it comes into contact with. This year, *Chromolaena* reached Hawaii.

Oahu Army Natural Resources Program staff members discovered an infestation during routine road surveys Jan. 11 in the Kahuku Training Area on Oahu's North Shore. The crew collected a specimen. A quick check in a reference book suggested the plant was *Chromolaena* and tipped off the group that the plant was not known in Hawaii.

The specimen was submitted to the Bishop Museum's Oahu Early Detection program. Museum botanists verified that the specimen was *Chromolaena odorata*, considered one of the 100 worst weeds in the world.

How did it get there?

Hawaii is separated by hundreds of miles of ocean from anywhere. How does a new pest reach it?

Most such pests are carried unintentionally by people. Human activity has dramatically increased the rate of species introduction to Hawaii, and Hawaiian ecosystems are critically endangered by these invasive threats.

It is hard to discern the exact path *Chromolaena* took to KTA, but a few plausible scenarios exist. Perhaps contaminated seed was planted in the agricultural area below KTA, or the seed rode in on a dirt bike, since part of KTA is used as a public motocross track on weekends. However, the infestation lies in a part of KTA that is heavily used for military training, the most likely cause for its introduction. Occasionally, units from Guam train in Hawaii, so perhaps, tiny *Chromolaena* seeds, hidden in packs or boots, hitched a ride with one of these units.

Acronyms and Abbreviations	
KTA	Kahuku Training Area
OANRP	Oahu Army Natural Resources Program

Why worry about *Chromolaena*?

Chromolaena is toxic to humans, livestock and even other plants. It forms dense, monotypic tangles. Each shrubby plant grows up to 12-feet tall and can produce 800,000 seeds in a year.

The small, narrow seeds, topped with a tuft of fibers, are easily dispersed via the wind. The small seeds also burrow into clothing, gear and fur, and they move quickly along trails and roads. As if all this dispersal isn't enough, cut branches root and grow into new, healthy plants.

Chromolaena doesn't thrive in deep shade, but it thrives just about everywhere else. In parts of Asia, fields have been abandoned to *Chromolaena*, as crops and farmers couldn't compete with the super weed.

OANRP staff, with help from the Oahu Invasive Species Committee, Bishop Museum and the Hawaii Department of Agriculture, is developing a detailed map of the *Chromolaena* infestation in KTA. This map will be the first step in creating a comprehensive plan for addressing the species.

Just one day of surveys revealed the weed is much more widespread than expected. Further surveys are needed to define its boundaries, but it's expected the infestation may encompass as much as 150 acres.

What are the next steps?

Is *Chromolaena* already too widespread in Hawaii to eradicate? Can the island's imperiled ecosystems handle yet another threat? Can Hawaii's natural resource managers afford not to control *Chromolaena*?

As surveys are concluded, OANRP and its partner agencies will think critically about these questions and others, and work to develop a realistic management strategy. The odds are stacked in *Chromolaena's* favor, but managers won't give up. Effective control methods exist, and new labor-saving techniques are being developed. The infestation is easy to reach, and the ➤

The highly invasive weed Chromolaena odorata, *discovered for the first time in Hawaii in January, grows along a road in Kahuku Training Area. Photos courtesy of OANRP*

A member of the sunflower family, the Chromolaena odorata *plant produces tiny — 4 to 5 millimeter — white to pinkish flowers that can produce up to 800,000 seeds per plant.*

San Antonio Military Me

by Maj. Edwin H. Rodriguez

The existing Brooke Army Medical Center at Fort Sam Houston, Texas, took 10 years to design and construct. The new San Antonio Military Medical Center, a huge facility that will join with and replace Brooke, will be completed in just four years. Despite the project's fast pace, SAMMC will offer world-class medical facilities to the San Antonio military community.

The SAMMC project accomplished this feat by using the integrated design-bid-build project delivery method, which allowed compression of the design and construction schedule. Architectural plans for the hospital were developed in accordance with evidence-based design, which creates an environment that results in improved patient outcomes, privacy, comfort, stress reduction and safety for patients and staff.

The 2005 Base Realignment and

Acronyms and Abbreviations	
BAMC	Brook Army Medical Center
BRAC	Base Realignment and Closure
SAMMC	San Antonio Military Medical Center

for cardiovascular, maternal-child, and

(continued from previous page)

terrain, while challenging, is not extreme.

Chromolaena seeds persist about a year in soil. With careful planning, innovative strategy and hard work, managers may be able to contain the infestation, manage it and perhaps even eradicate it entirely.

However, the best defense against invasive species is simply to stop them from arriving in the first place. The cost of preventing a pest from entering Hawaii is many times smaller than the cost of controlling an established pest. Hawaii Department of Agriculture inspectors monitor shipments into Hawaii as well as those between islands. Each Christmas, they inspect containers of Christmas trees and turn back any harboring nonnative insects, slugs or bats.

The OANRP surveys roads and landing zones on Oahu's training ranges once a year. These surveys are critical in detecting new pests early and enabling staff to respond rapidly to new threats. On some roads, these monitoring efforts began more than 10 years ago. The road where *Chromolaena* was first spotted had been surveyed only once before.

The Army has a commitment to mitigate any negative impacts of training, including invasive weed spread. The discovery of *Chromolaena* in KTA highlights the importance of maintaining strict sanitation on Army training ranges.

OANRP will invest a significant amount of Department of Defense time and money in managing *Chromolaena*. In the meantime, everyone — hikers and range workers alike — is being asked to inspect boots, clothes, packs and other field gear before entering natural areas. Hikers are also asked to clean mud and debris off their gear at the end of the day, and to wash and vacuum vehicles at least once a week. Many training ranges operate wash racks that troops and contractors are being asked to take advantage of to clean wheel wells and undercarriages on tactical and other vehicles.

These efforts and those of the OANRP staff and its partners will help prevent other species like *Chromolaena* from invading Hawaii.

POCs are Kim Welch, environmental outreach specialist, OANRP, 808-656-7641, kmwelch@hawaii.edu; and Aiko Brum, chief, Internal Communication, Public Affairs Office, U.S. Army Garrison Hawaii, 808-656-3155, aiko.brum@us.army.mil.

Jane R. Beachy is the Ecosystem Restoration Program manager, OANRP, U.S. Army Garrison Hawaii.

EMP
Ecosystem Management Program Bulletin
Volume 52 Spring 2011

Special local needs registration for *Sluggo* approved in the state of Hawai'i through 2015

By Stephanie Joe

FOR THOSE OF you seeking to control slugs in forested areas for the protection of native plants, a new option has arrived. The Hawai'i Department of Agriculture (HDOA) has approved special local needs (SLN) labeling for *First Choice Sluggo Snail and Slug Bait* (EPA Reg. No. 67702-3-34704), a certified organic iron phosphate based product. The SLN label may be downloaded from HDOA at the following website:
http://hawaii.gov/hdoa/labels/sln/1004_2015.pdf

Until now, young seedlings like these from the endangered plant *Cyanea superba*, had little defense against slugs, preventing them from growing beyond a small size. (Photo by OANRP staff)

As someone involved in the process of crafting this label, I wanted to provide further instructions on the proper use of *Sluggo* and call attention to some of the restrictions put in place to protect native snails. I am also interested in receiving feedback describing your experiences with this product so that I can modify the SLN label accordingly when it comes up for renewal.

The active ingredient in *Sluggo* (iron phosphate) is not a contact poison and must be ingested by the target pest to have an effect. It biodegrades and becomes a natural component of the soil. It is not a restricted use pesticide and therefore may be used by anyone (not just certified applicators). It is nontoxic to vertebrates.

Of particular importance are the following label instructions:

"Area must be thoroughly searched by experienced malacologists during the day and at least one night prior to application ...to ensure that non-target endemic Hawaiian snail species are not impacted. Do not apply in areas where it may come into contact with known

To provide feedback, or for any questions regarding interpretation of the new special local needs *Sluggo* label, please contact Stephanie Joe via email:
sjoe@hawaii.edu

Limax maximus, a non-native slug found in Hawaiian forests, can feed on native plant seedlings. (Photo by Steph Joe, OANRP)

Inside this issue:

Special local needs registration for *Sluggo* approved in the state of Hawai'i through 2015, By Stephanie Joe...1
Pōhakuloa Training Area's Natural Resources Office steps in to protect the endangered A'e from desperate ungulates, By Jen Lawson.........2
A strategic partnership for the conservation of O'ahu's rarest plants and animals - the Mākua Implementation Team, By Kapua Kawelo...........4
Fire control efforts blossom to protect the endangered Ma'o hau hele (*Hibiscus brackenridgei* subsp. *mokuleianus*), By Kim Welch..5

Sample of an EMP Bulletin from the Spring edition, 2011. View this and other EMP Bulletin volumes at: http://manoa.hawaii.edu/hipicesu/dpw_emb.htm

Date: Dec. 1, 2011

Chromolaena odorata Management Summary and Control Plan

Background and Goals

Long-Term Goal:

1. Eradicate *Chromolaena odorata* (Chromolaena) from the greater Kahuku area.

Priorities:

1. Identify the boundaries of the Chromolaena infestation at Kahuku, including outliers.
2. Prevent the spread of Chromolaena from Kahuku to other locations around the State.
3. Control all known Chromolaena sites.
4. Determine what defines 'eradication' of Chromolaena.
5. Conduct regular monitoring and control.

Chromolaena Information:

Discovery of Chromolaena

Chromolaena was first reported from an annual road survey in Kahuku on 11 January 2011. It was found by Orange team staff (Kahale Pali, Scott Heintzman, Jamie Tanino) along the Bravo Road survey (RS-KTA-05). It was identified in the field using Wayside Plants of the Islands (Whistler, 1995). A sample was collected and submitted to the Oahu Early Detection (OED) program at Bishop Museum. Identification of the sample was quickly confirmed, and OED staff shared that Chromolaena was new to the State and on the State Noxious Weed List.

Threat Posed by Chromolaena

Chromolaena received a Hawaii Weed Risk Assessment (HWRA) score of 28, suggesting that it has the potential to be highly invasive in Hawaii (Chimera, 2009). It is a well-documented pest worldwide, including Australia, South Africa, India, Philippines, Micronesia, Palau, and Guam. It is native to Central/South America (Chimera, 2009). While Chromolaena thrives in open, sunny areas, it also can grow in shade, and at Kahuku has been observed growing beneath *Casuarina* sp. stands; it does not thrive in dense shade (Chimera, 2009). It readily colonizes open, disturbed areas (Chimera, 2009). Chromolaena is drought tolerant, and can withstand a variety of soil conditions (Chimera, 2009). It is adapted to disturbance, such as fire, and dry, dense stands pose a fire hazard (Chimera, 2009). It forms dense monocultures and has alleleopathic qualities (Chimera, 2009). Steroids and other toxins are produced by the plant; Chromolaena is toxic to animals, and may cause rashes/allergies in humans (Chimera, 2009). Chromolaena is fast-growing, produces huge quantities of seeds, and can reproduce vegetatively from cut stems (Chimera, 2009). If allowed to spread unchecked, Chromolaena likely would become ubiquitous across dry, mesic-dry, mesic, and even mesic-wet landscapes; it would become a major weed in Hawaii, furthering stressing native forest remnants. In Kahuku, OANRP works around one endangered plant, *Eugenia koolauenesis*. Chromolaena could directly affect *E. koolauensis* by further degrading its habitat.

Chromolaena Biology

Chromolaena grows quickly, and plants can flower at 1 year old, although most don't flower till 3 years old (Witowski and Wilson, 2001). Each plant can produce approximately 800,000 seeds/year (Witowski and Wilson, 2001). Seed production in stands of Chromolaena increases until the stand is ten years old (Witowski and Wilson, 2001). Seeds are wind, animal, human, and vehicle dispersed (Chimera, 2009). Seed set varies. In one study, most seed did not remain viable for more than twelve months; the remaining 1-3% of seed persisted more than a year (Witowski and Wilson, 2001). Seeds tend to degrade in high moisture and temperature environments (Witowski and Wilson, 2001). A short-term persistent seed bank is formed (Witowski and Wilson, 2001). A Guam publication indicated that Chromolaena flower in December-January in the northern hemisphere, and that flowering was typically triggered by a decrease in rainfall and day length (Zachariades, *et. al.*, 2009). However, flowering has been observed in Kahuku from January to March. Further observations are necessary to determine if Chromolaena has a set flowering season in Hawaii. Biocontrols for Chromolaena have been studied extensively (Muniappan, *et. al*., 2005; Muniappan, *et. al*., 2006). If biocontrols become an important control strategy, existing research can guide Hawaii efforts.

<u>Identification:</u>

Distinctive Chromolaena characteristics (Whistler, 1995)

- Sprawling shrub, up to 3m tall, most often 1-1.5m tall
- Leaves arrowhead shaped, fuzzy, 3-prong pitchfork veination
- Distinctive odor when crushed
- Aster flowers, held in small clusters. Corollas white to lilac. Usually with distinct long stamens
- Seeds achenes with long pappus. Seeds are black with white stripes. Pappus off-white/yellowish
- See the Chromolaena identification and habit slides attached at the end of this document for additional pictures



Look-alike plants

- *Waltheria indica*, uhaloa (native)
- *Pluchea carolinensis*, sour bush (alien)
- *Ageratina adenophora*, maui pamakani (alien)
- See the “Chromolaena odorata Alert” flier attached at the end of this document for more pictures

Waltheria indica

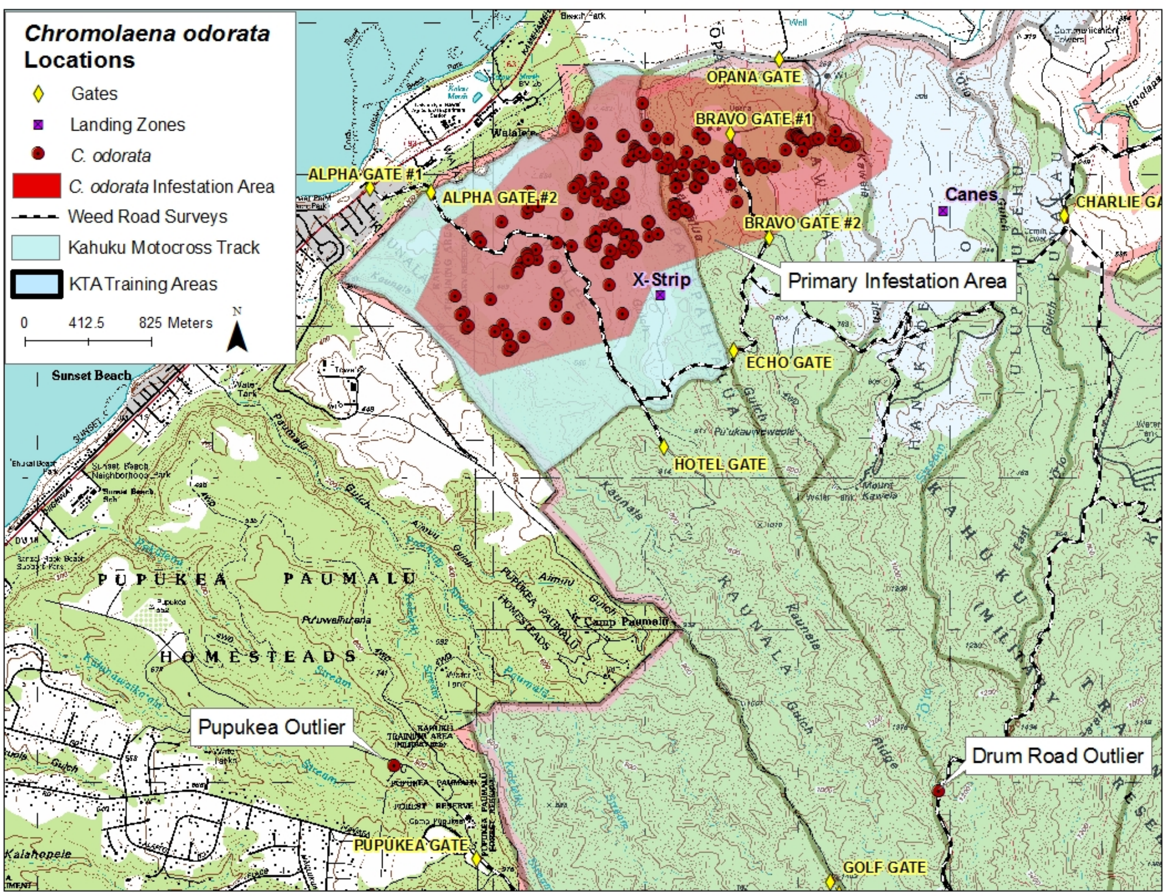
Ageratina adenophora

Pluchea carolinensis

Site Description:

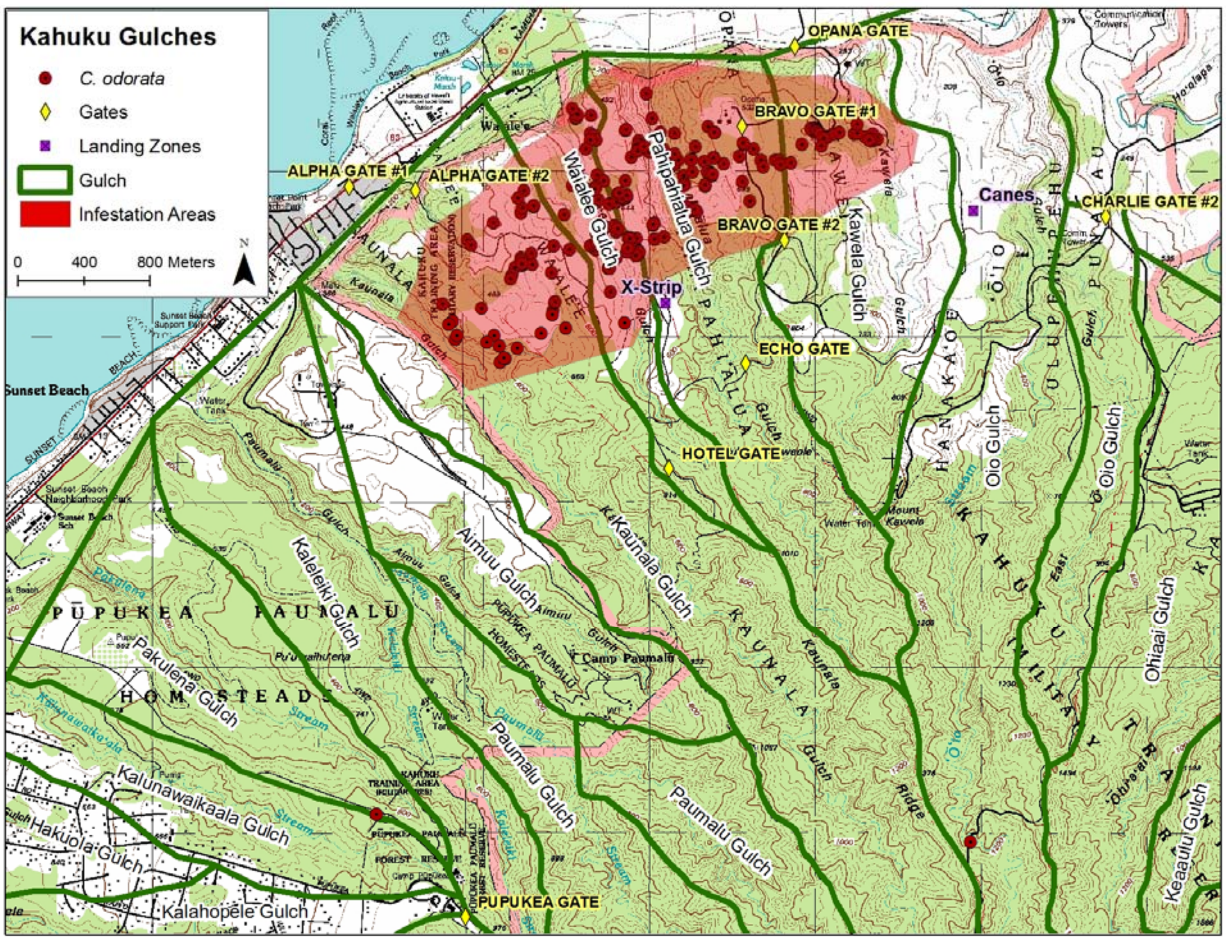
Chromolaena is only known from the greater Kahuku region. There is one primary infestation (Kahuku) and two outlier sites (Drum Road and Pupukea).

Chromolaena Locations



All sites are degraded, dominated by alien weeds including but not limited to *Casuarina* sp., *Psidium cattleianum, Digitaris ciliaris, Schinus terebinthifolius, Panicum maximum, Pimenta dioica, Ardesia elliptica,* and *Leucaena leucocephala*. Portions of the area are dominated by broad slopes of *Osteomeles anthyllidifolia* (ulei), a common native plant. Almost all the known Chromolaena plants are found on the Kahuku Training Area (KTA). KTA is divided into large training ranges, one of which, Alpha 1, is leased from the State. On the weekends, Alpha 1 is open to the public as the Kahuku Motocross Track. There are six access points to KTA, although only two are used regularly. Charlie 1 Gate is used by all military-associated personnel (including contractors) as it is closest to Kahuku Range Control. Alpha 1 Gate is used on weekends for motocross. The remaining four, Delta 1 (off the map to the east), Opana, McCormick, and Pupukea, are used infrequently. The Charlie/Alpha Road connects Range Control to Alpha 1, runs roughly parallel to the coast, and is a useful reference. Cane's and X-strip are large landing zones along the Charlie/Alpha Road. Refer to the Kahuku Gulches map for a full list of the gulches in and around KTA.

Kahuku Gulches

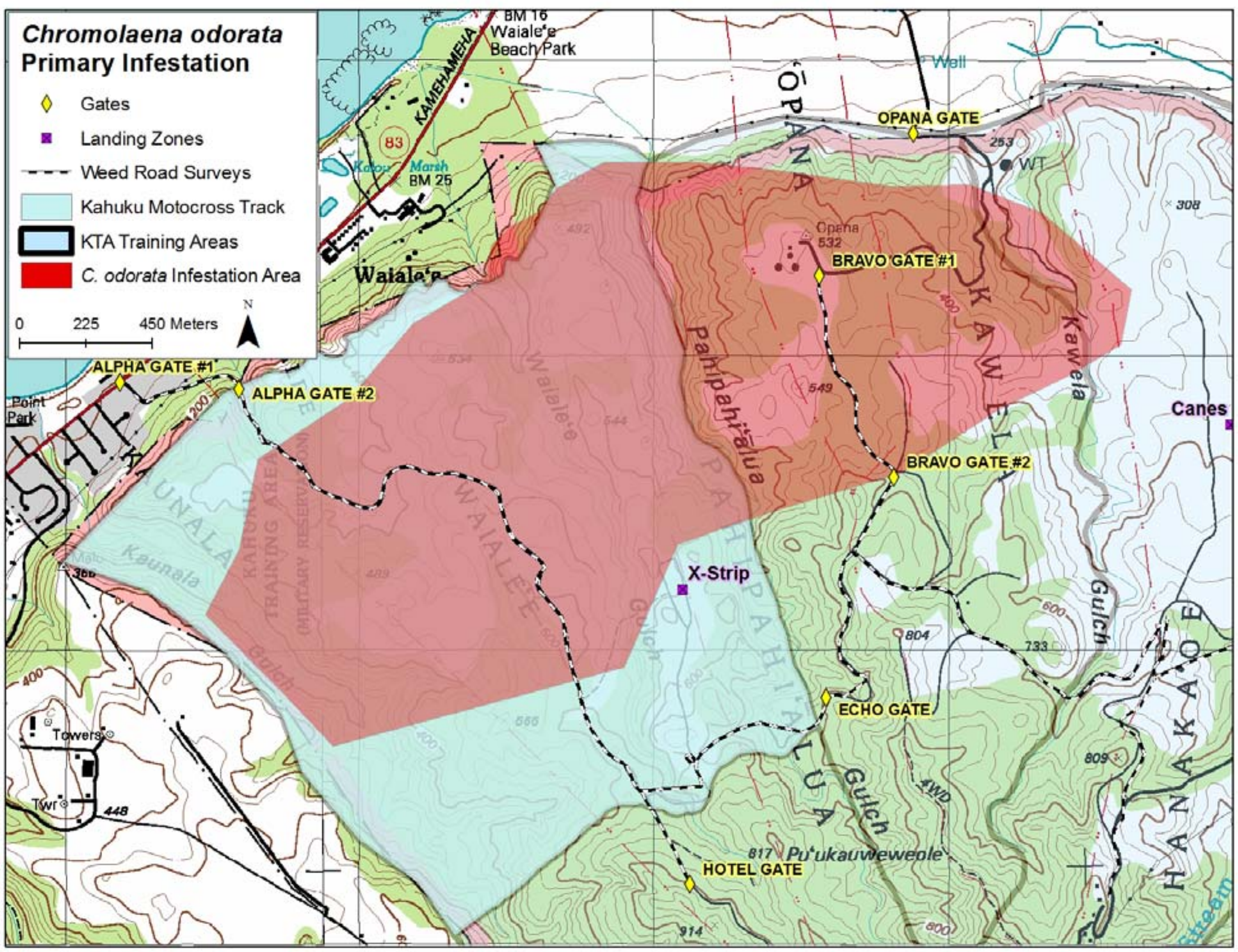


Primary infestation, Kahuku

The infestation resides almost entirely between 100ft and 650ft in elevation. It is located makai of the Charlie/Alpha Road. Chromolaena has been found in four gulches; from west to east, they are: Kaunala, Waiale'e, Pahipahi'alua, and Kawela. This area is heavily used for military training during the week and for motocross on the weekends. It is crisscrossed by trails of various widths, in various states of drivability. Across most of the known infestation area, Chromolaena plants are found in widely scattered, small patches less than $5x5m^2$. Two high-density hotspots have been found, one in Pahipahialua Gulch and another in Kaunala Gulch. The entire primary infestation currently covers 837.7 acres (339 hectares), and approximately 1,500 immature and mature plants have been found.

Chromolaena seed covering the ground at the Pahipahialua hotspot

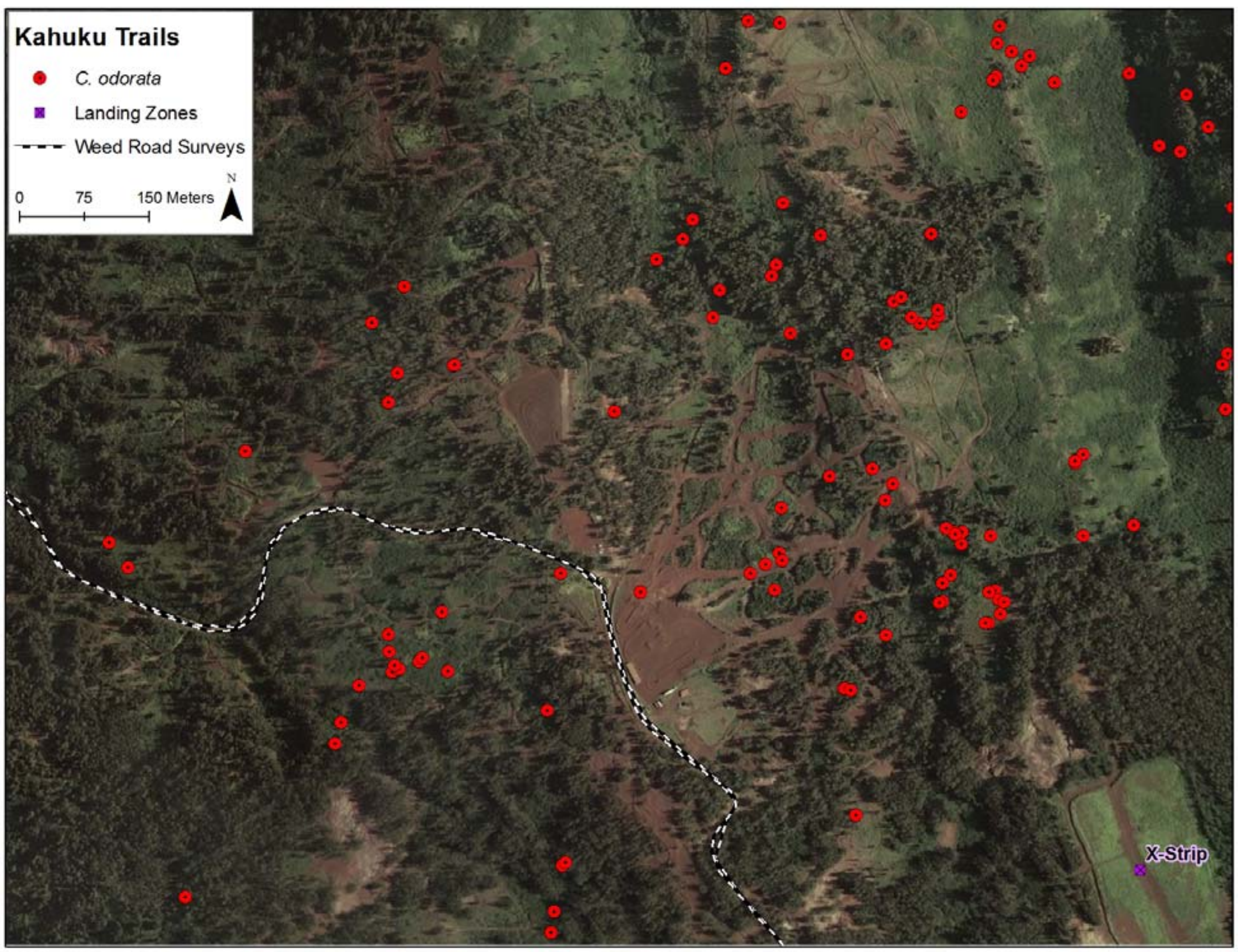
Primary Infestation



Human activity in the primary infestation area is very high, as is evidenced in the photos and trail map below. The trails map is focused on the heart of the motocross track. Portions of the track are purposefully kept free of vegetation. The trail network is extensive, and includes named tracks marked with signage as well as narrow trails such as those in the photos.

Some of the many trails in the primary infestation area

Kahuku Trails Map



Outlier Sites

Two outlier sites have been found during the course of other management work. See Chromolaena Locations map, above. One is located along Drum Road, the other below Pupukea Boy Scout Camp. At both sites, only one immature plant has ever been seen. At Pupukea, the plant was found growing alongside a road, next to a gate. It was handpulled. Staff were conducting rare plant surveys in this region at the time, and swept through much of the area to the east of the outlier; no other plants were seen. Along Drum Road, the plant was found growing along the road, near a stream crossing. It also was pulled. Staff were controlling another invasive weed, *Melochia umbellata* at the time, and surveyed some of the area to the west of the outlier; no other Chromolaena were seen. It is likely that these two outliers are the result of seeds being transported on vehicles, riders, or hikers. Discovering these outliers by chance highlights the need for an effective containment strategy.

Partner Agencies:

Since Chromolaena is a listed State Noxious Weed, and poses a major ecological threat to the State, a variety of partner agencies have participated in management efforts. See table below:

Agency		**Involvement**
OISC	Oahu Invasive Species Committee	Heavily involved in field and outreach efforts. Chromolaena is an OISC target. Assisting with FWS wash rack proposal.
HDOA	Hawaii Dept of Agriculture	Heavily involved in field and outreach efforts. HDOA is involved because Chromolaena is a State Noxious Pest.
OED	Oahu Early Detection	Involved in field efforts. OED does not focus on alien species control, rather, it conducts early detection and makes recommendations for control to OISC. OED participates as feasible.
MCBH	Marine Core Base Hawaii	Marines frequently use KTA for training. MCBH participates in surveys/control as feasible.
DOFAW	Dept of Fish and Wildlife (State)	Kahuku Motocross Track is State land, leased to the Army. Various DOFAW groups are involved with Chromolaena work. If a wash rack is built for the Motocross Track, DOFAW will assist with this. DOFAW participates in surveys/control as feasible.
FWS	Fish and Wildlife Service (federal)	FWS submitted a proposal to obtain funding for a wash rack for the motocross track.
HMA	Hawaii Motorsports Association	HMA runs the Kahuku Motocross Track. They have been very open to information presented by OISC and OANRP. They are interested in participating with control efforts.

Strategy

Chromolaena management efforts thus far have focused on identifying the boundaries of the Chromolaena infestation. During the course of surveys, staff (OANRP and Partner Agency) determined that the infestation covers at least 339 ha. Despite this, all involved agencies feel that Chromolaena is an important target. The infestation area is small in comparison to other, high priority weeds (*Miconia calvescens*). Staff have compared the discovery and spread of Chromolaena to that of *Clidemia hirta*.

General control strategy:

1. Survey for Chromolaena outside of the known infestation area, with the goal of determining the boundaries of the Kahuku primary infestation. This will involve surveying off of KTA, on private land. OANRP will coordinate surveys on KTA. OISC will coordinate surveys off of KTA.

2. Survey/control sparse Chromolaena across the known primary infestation area, in the Incipient Control Areas, via basal treatments and/or foliar sprays.
3. Conduct targeted control at the two Chromolaena hotspots in Kaunala and Pahipahialua, possibly via aerial sprays. If additional hotspots are found, consider aerial control for those too.
4. If possible, treat hot spots aerially, via helicopter spraying.
5. Monitor known 2 known outlier sites every 6 months. If many additional outlier sites are found, this monitoring frequency may need to be revisited.
6. Sweep the entire primary infestation area every two years.
7. Help secure additional funding for partnership control efforts.

General containment strategy:
1. Implement sanitation procedures for staff and partner agencies conducting control.
2. Motocross: raise awareness of Chromolaena, assist in providing a wash rack so vehicles are cleaned before leaving KTA.
3. Army: raise awareness of Chromolaena, require all vehicles leaving KTA to go through wash rack (once it is constructed), educate military command, research training records to see when and where units from Guam have trained.
4. Investigate limiting access to the 2 hotspots. For Army, may involve putting out Seibert stakes around hot spot or temporarily closing down A1 and B1 ranges. For Motocross, may involve working with HMA to close trails passing through the hotspots.
5. Publicize Chromolaena information to encourage reporting of potential new locations.

Chromolaena may already have spread out of KTA. Via military training, it may have spread to other Army training ranges on Oahu, or to Pohakuloa Training Area (PTA) on the Big Island, or to the Kaneohe Marine Core Base Hawaii (MCBH). Staff at PTA and MCBH have already been notified to look out for Chromolaena. Via motocross/public use, it may have spread to other areas popular with motocross users. Many 4WD/motocross aficionados ride on unmanaged, unmonitored lands in Waikane, Mililani, Ewa, and numerous other locations.

Island-wide survey strategy
1. OANRP: survey other Army training areas for Chromolaena. Highest priority ranges are SBW, SBS, and SBE, but DMR, KLOA, and MMR should also be checked.
2. OISC: identify high-usage motocross areas outside of Kahuku Motocross Track to be surveyed. Survey these areas for new Chromolaena populations

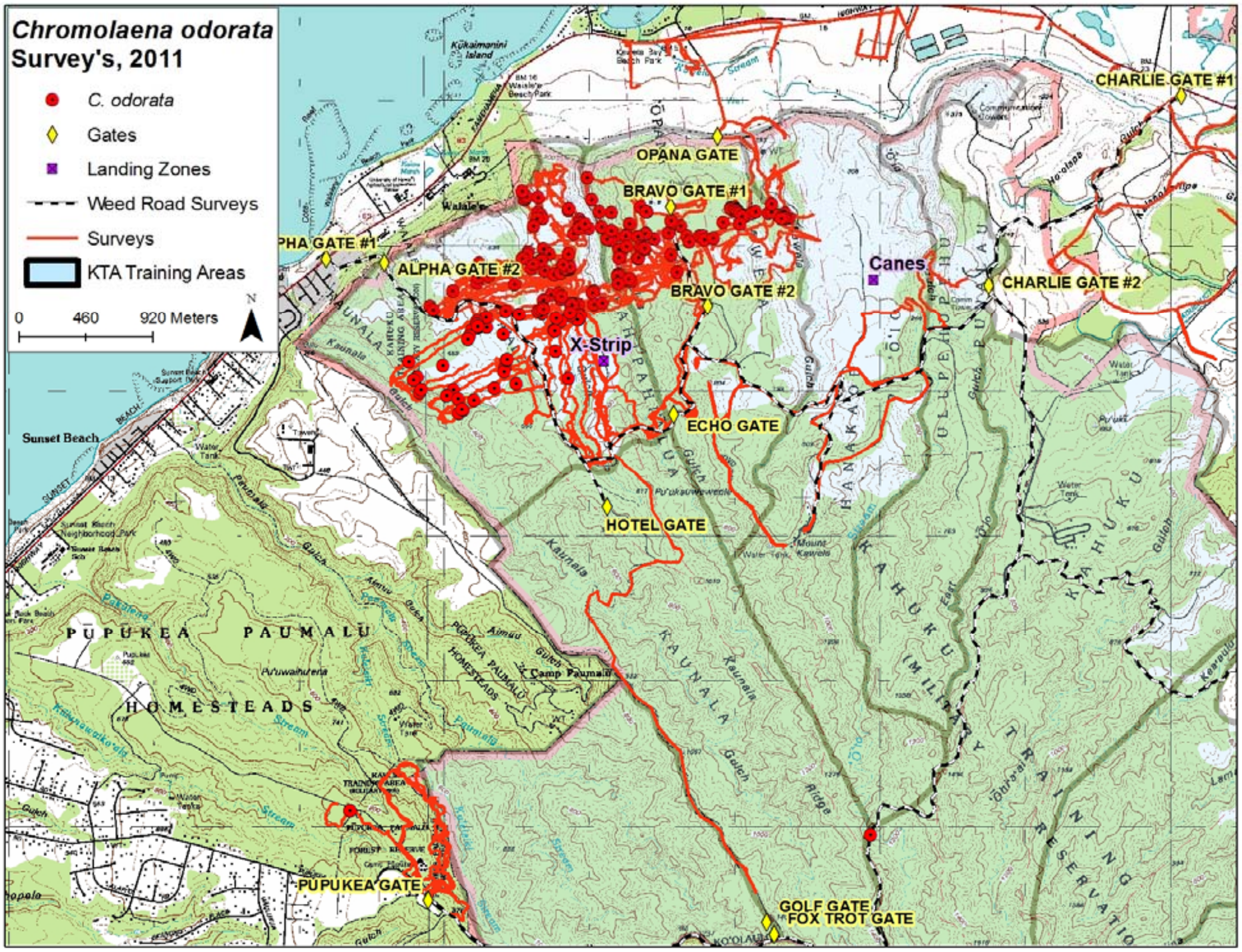
Management Efforts Jan-Sept. 2011

Between March and August, over 475 person hours have been spent surveying for Chromolaena (see Chromolaena Survey Efforts map). Not included in this are three trips conducted around the two outlier points, where Chromolaena wasn't a primary target, and two trips conducted by HDOA to check out agricultural areas around the primary infestation. In all, ten trips were made to the greater Kahuku region for Chromolaena. Despite this, the full extent of the infestation is not yet known. Since Chromolaena is dispersed by vehicles, people, and wind, defining a survey buffer is difficult. Checking all the trails and roads in the area alone is a huge task. OANRP will work with partner agencies to further define survey buffers.

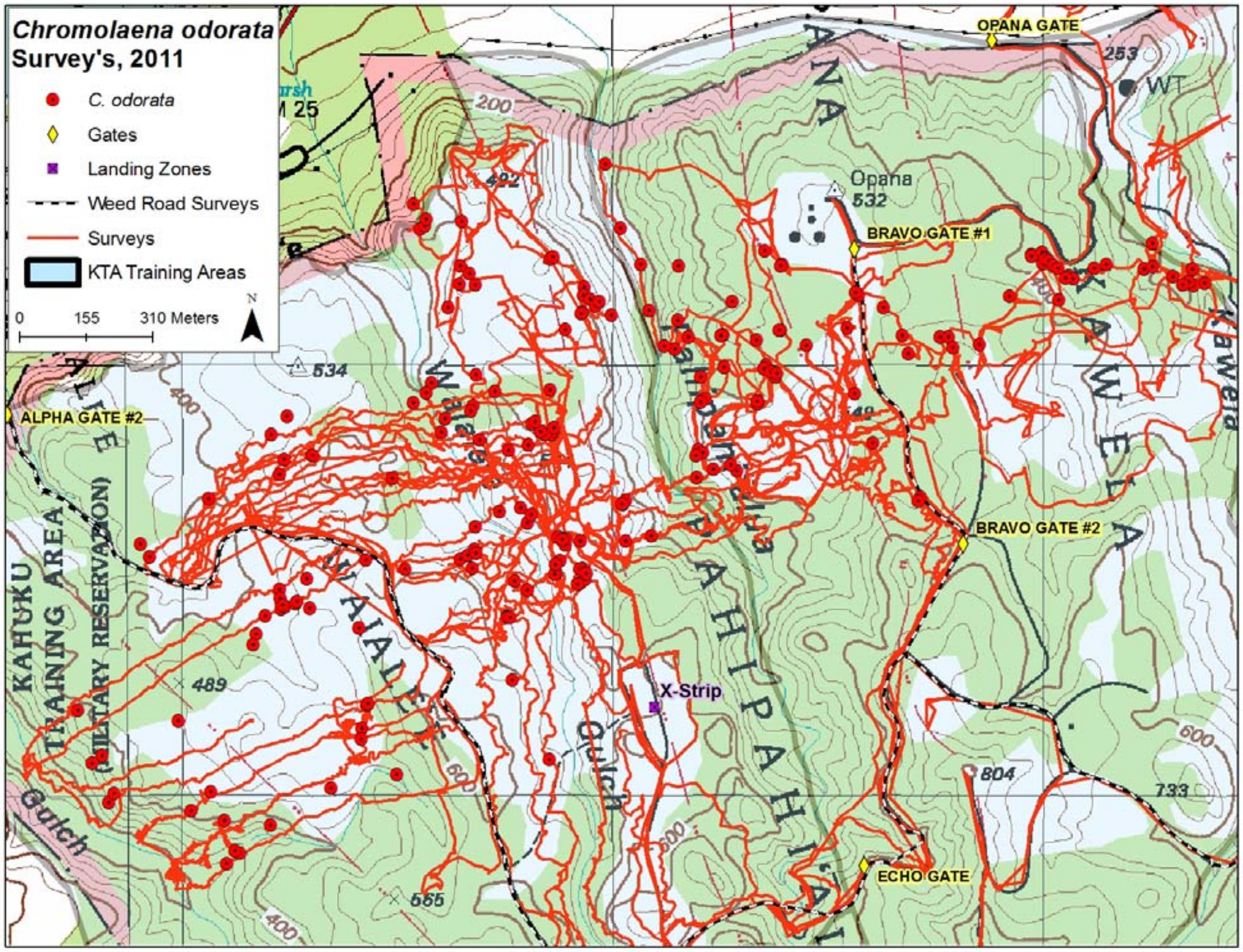
Possible areas to be surveyed include:

- East of the infestation: Cane's LZ Ridge, Oio Gulch (all on Army lands)
- South of the infestation: the mauka portion of Kaunala gulch, the remaining area between the primary infestation and Charlie/Alpha Road, trails mauka of the Charlie/Alpha Road (all on Army lands)
- West of the infestation: the east-facing slope of Kaunala gulch (Army land), portions of Aimuu and Paumalu gulches (private lands)
- North of the infestation: makai-facing cliffs (Army, State, and private land)

Chromolaena Survey Efforts, Landscape (through September 2011)

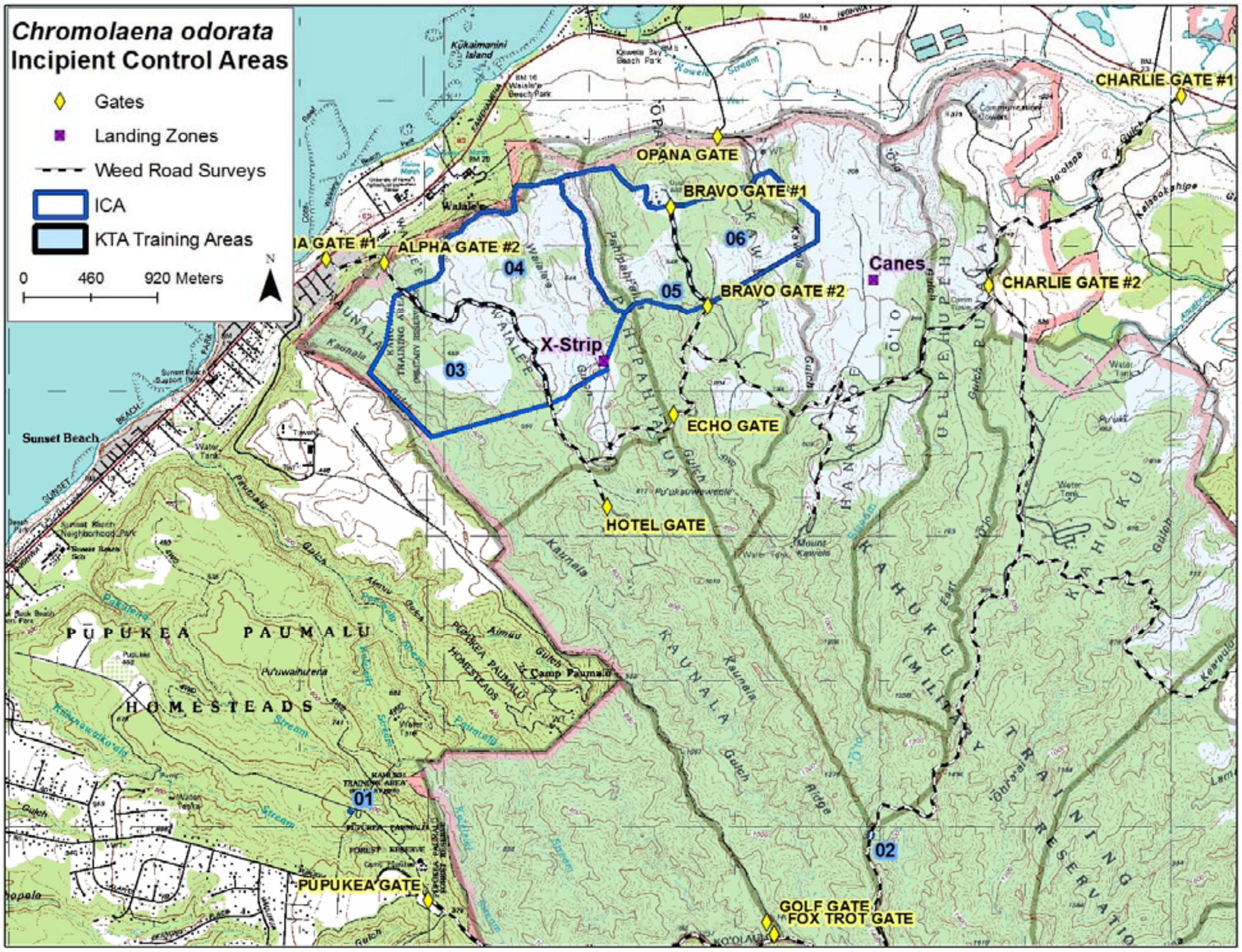


Chromolaena Survey Efforts, Zoom (through September 2011)



While conducting surveys in July, staff began controlling all Chromolaena seen, except very large patches. This change was made as previous survey trips turned up relatively few plants and staff determined that all plants seen could be treated without greatly slowing down survey efforts. This eliminates the need to re-sweep areas a second time to conduct control. To facilitate tracking of control efforts, the primary infestation was divided into Incipient Control Areas (ICAs). The two outlier spots were also designated as ICAs (see Chromolaena ICAs map and table). Areas weeded in each ICA are tracked and GPSed (see Areas Weeded for Chromolaena map). In the primary infestation area (ICAs 3-6), 22 mature, 416 immature, and 2 seedlings were controlled. One immature was controlled at each of the outliers. At Pupukea, the site was checked four months later, with no plants seen. The plants at the Kaunala hotspot (ICA 3) were mapped, but were not treated. The Chromolaena ICAs and Control Efforts table summarizes the effort spent in each ICA through September 2011, excluding aerial sprays.

Chromolaena ICAs



Chromolaena ICAs and Control Efforts

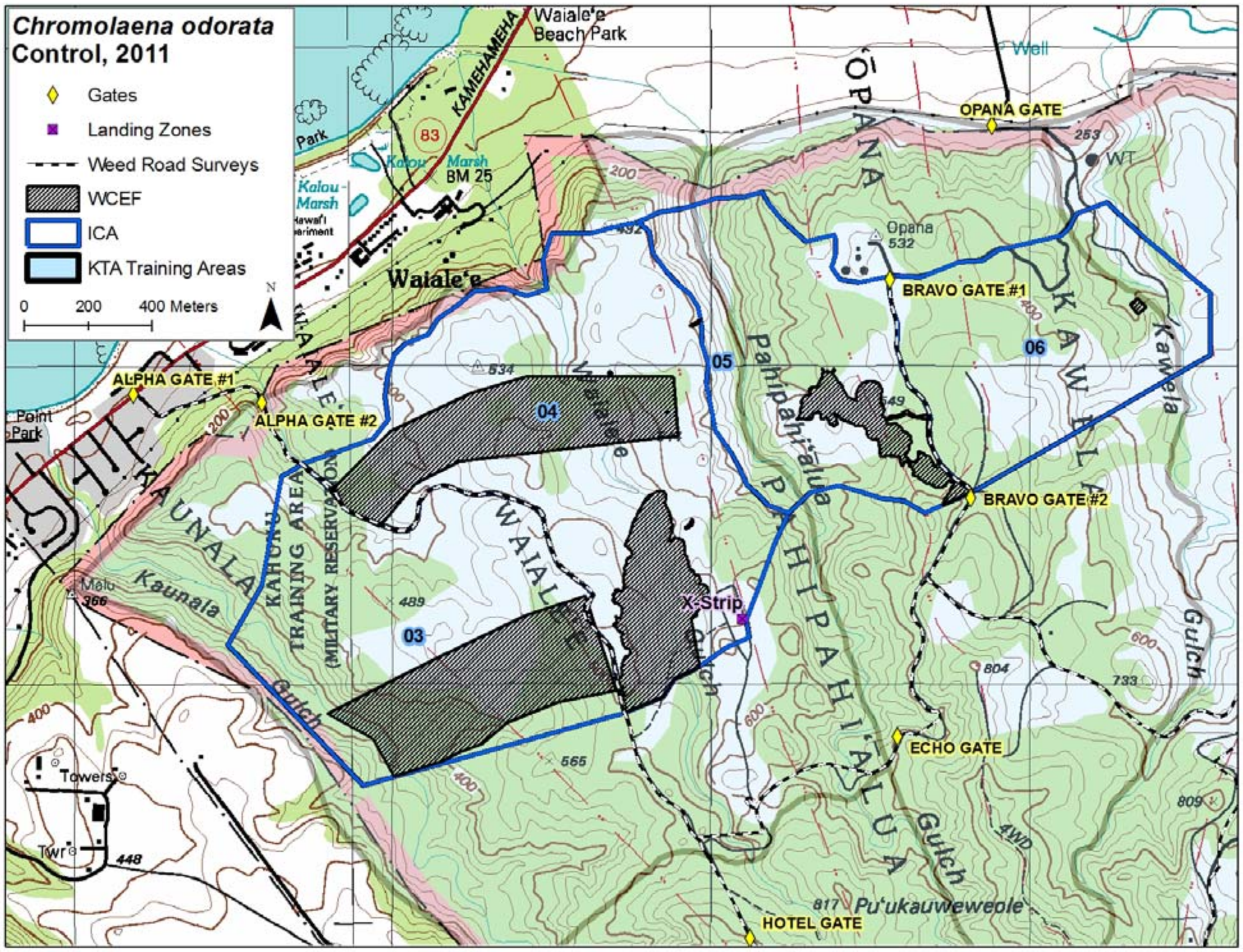
ICA Code	ICA Name	Status	Area (acres)	Area Swept (acres)	Effort (person hours)
WaimeaNoMU-ChrOdo-01	Pupukea Boy Scouts Camp ChrOdo	Outlier	$5m^2$	$5m^2$	2*
KTA-ChrOdo-02	ChrOdo at MelUmb	Outlier	$5m^2$	$5m^2$	2*
KTA-ChrOdo-03	Kaunala ChrOdo	Primary Infestation	198	57[†]	18.6
KTA-ChrOdo-04	Waialee ChrOdo	Primary Infestation	267	85	39
KTA-ChrOdo-05	Pahipahialua ChrOdo	Primary Infestation	138	13	9
KTA-ChrOdo-06	Kawela ChrOdo	Primary Infestation	136	0.29	20 *

* = survey time included in effort

[†] = hotspot included in this acreage, but was not treated

Table does not include aerial spray efforts

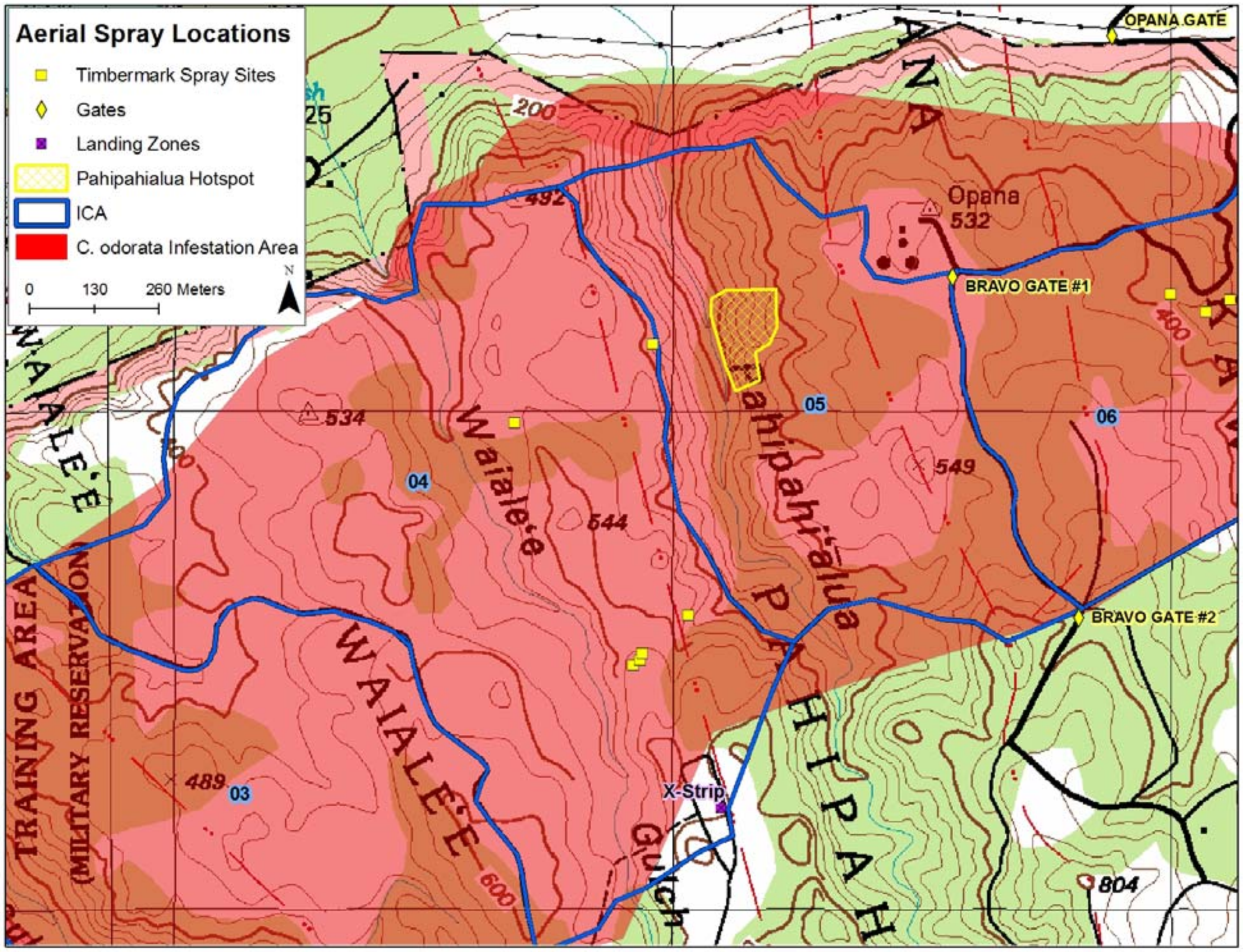
Areas Weeded for Chromolaena (through September 2011)



OARNP was able to leverage aerial spraying of several large Chromolaena patches and the Pahipahialua hotspot in May 2011. The Integrated Vegetation Management Program (IVMP), a contract run by Schofield Range Control, conducted aerial sprays of fuel breaks on Schofield and Makua Ranges. OANRP was able to add Chromolaena control to their contract, at no additional cost. The IVMP team has extensive experience in conducting aerial sprays, was equipped with all necessary gear, and had already submitted an aerial spray plan to HDOA (a major hurdle). OANRP selected the spray locations, and provided a staff person (KK) to ride with the pilot during control and help direct herbicide application.

The Pahipahialua hotspot in ICA-05 was sprayed with a boom sprayer. A cocktail of herbicides was used: 1.5 quarts Garlon 4 Ultra, 44.5oz Roundup ProMax, 16 oz. Polaris, 4oz. Oust XP, and 20 oz. MSO at a rate of 10 gallons spray per acre. About 50 gallons of solution was sprayed across 4.7 acres. Oust is a preemergent herbicide, and was added to the mix in hopes of minimizing seedling growth. This treatment was fairly effective, with burned/dying vegetation visible from across the gulch as soon as late June, barely two months after treatment. Staff have not walked through the site yet, but expect that much of the Chromolaena has been knocked back, although it might not have been killed. The boom sprayer had fairly good coverage, although some untreated vegetation is visible in the photos below.

Aerial Spray Sites for Chromoloaena, May 2011

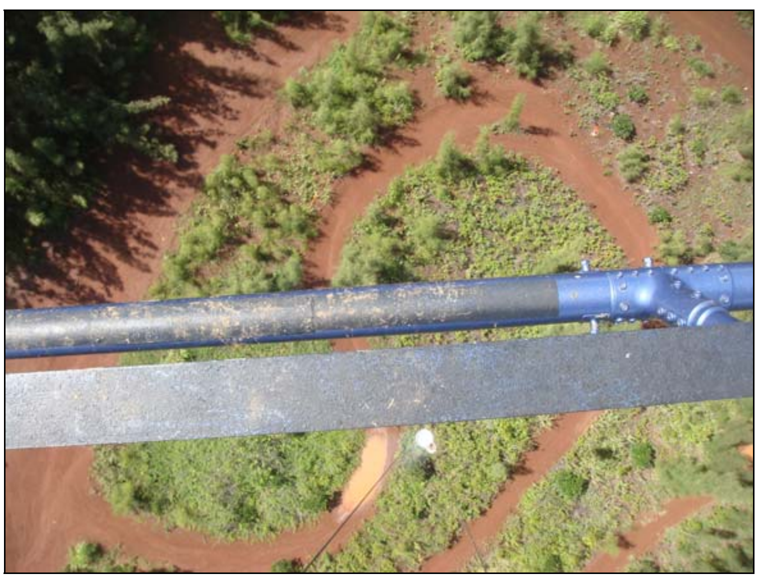


Pahipahialua core, prior to spraying,

Boom spraying in progress, May 2011

Pahipahialua core, post spraying, 22 June 2011
The red circles in the prior and post spraying photos note the same *Casuarina* patch

Four large patches of Chromolaena in ICA-04 were sprayed with the TimberMark® ball sprayer system. Similar to ball sprayer systems used elsewhere in the State, the TimberMark sprayer is powered by compressed air. A cocktail of Garlon 4 Ultra (1.6 qt/ac), Roundup ProMax (51.2 oz/ac), Polaris (16 oz/ac), MSO (25.9 oz/ac), and Oust (2 oz/ac) was used to create 60 gallons of solution, which was sprayed at these four sites (and many other non-Chromolaena targets as part of a larger trial). It was difficult to find these sites from the air, despite having GIS points for them on board the helicopter. Large flagging markers were critical, and should have been deployed at all sites.



Treating Chromolaena with the ball sprayer, May 2011

Resprouting Chromolaena

TimberMark spray site, post-spraying October 2011

Seedlings in the spray site

Staff visited three of the sites in October 2011, and found that the sprays were fairly effective. At all locations, most of the Chromolaena plants in the spray zone were dead, while untreated, healthy Chromolaena were present on the edges of the spray zone. Staff did note some resprouting Chromolaena and some Chromolaena seedlings within the spray zones. Most other plants in the spray zones were also dead, creating large gaps. Since most of the vegetation in these areas was alien, this non-target affect was acceptable (and unavoidable). If the opportunity arises to work with the IVMP contract again the in the future the Kaunala hotspot will be prioritized for aerial spraying.

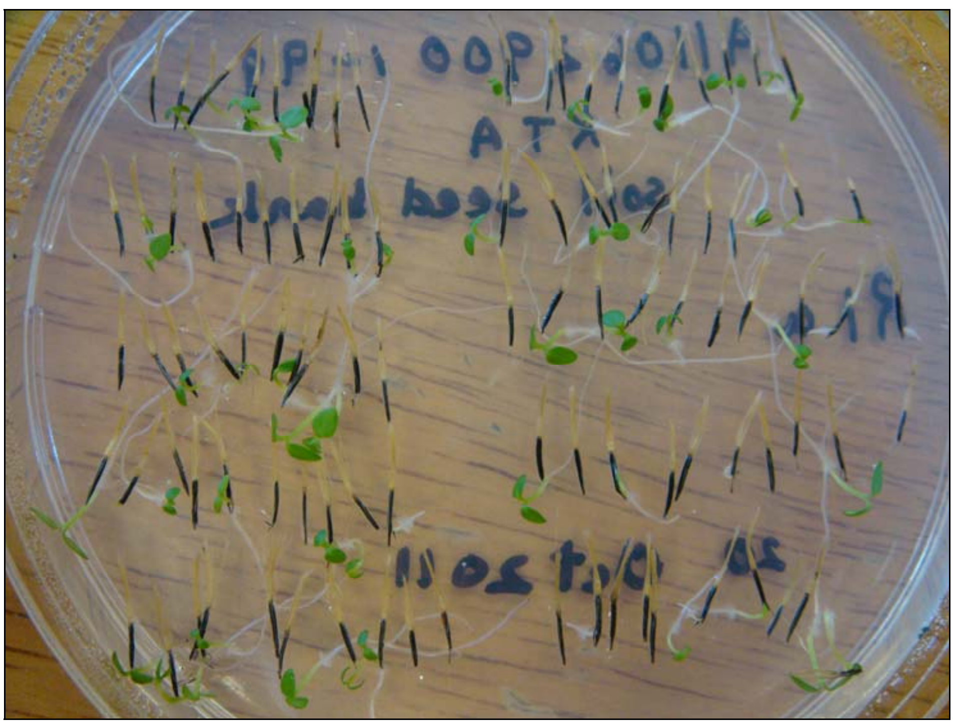
Defining 'Eradication' of Chromolaena:

The most conservative definition of eradication of an invasive species includes the following:

- Removing all extant individuals;
- Exhausting the seed bank for the taxon.

To achieve these goals, staff must control all known plants, monitor/control ICAs regularly to control new plants before they mature and set seed, and continue monitoring until no viable seeds remain in the soil. Given that Chromolaena can mature in a year (though most take longer), and that most seed do not persist for more than a year, front-loading control efforts is critical. In order to learn more, a soil seed bank test was initiated this year to test longevity of Chromolaena seeds buried in the ground for up to five years. The first bags were recovered after three months, in October 2011. Seed bags will be dug up quarterly for the first year of the trial, then annually until 2016. The results of the trial will be used to guide management decisions, and hopefully help to refine the definition of eradication for Chromolaena in Hawaii. Once the seed bank timeline is known, a buffer of 25% of the total seed bank life will be added to the seed bank life to define a conservative 'all clear' date. For example, if Chromolaena seeds are found to persist no more than four years in the field, the 'all clear' date would be five years after the last known mature or immature plant was controlled. When all known Kahuku Chromolaena sites pass this 'all clear' date, Chromolaena can be considered eradicated from the region.

Left: Seed Bank Trial, with packets of seed marked by blue flags.
Right: seed packet dug up for testing after three months.



Germinating Chromolaena seeds

Outreach Efforts:
Over the past year, staff and partner agencies have worked to publicize the discovery of Chromolaena, and share information about this pest with conservation and community groups. A Weed Alert flier was created by OANRP and publicized via posting to the ALLISC listserv and emailing community groups directly. It was also included in the OANRP quarterly Ecosystem Management Bulletin with an accompanying article; the article was also published in the Public Works Digest. The Pacific Pest Detector News picked up on the discovery, and included Chromolaena in their quarterly bulletin. OANRP also created a poster version of the weed alert flier; these posters will be distributed to Kahuku Range Control and the Hawaii Motocross Association. See http://manoa.hawaii.edu/hpicesu/dpw.htm for copies of these documents. OISC contacted the president of the HMA, who then attended a Chromolaena strategy meeting. OISC and OANRP followed up by visiting the motocross track on one weekend and talking with track users.

Field Operations and Logistics

Control Techniques:
Chromolaena control can be divided into three categories:

- Survey/control sweeps: for areas with low densities of Chromolaena
- Spot treaments: foliar sprays for patches of Chromolaena too large to control during surveys
- Hotspot/core sprays: targeted treatment of the Pahipahialua and Kaunala hotspots.

Dead Chromolaena, three months after basal Garlon 4 treatment.

Survey/control sweeps. A review of the available literature suggests that Chromolaena is highly susceptible to triclopyr (Garlon 4) and imazapyr (Stalker, Polaris) (Ikuenobe and Ayeni, 1998). Imazapyr has pre-emergent qualities, but triclopyr does not . During sweeps over the past year, staff controlled Chromolaena by handpulling and basal treatment with 20% Garlon 4 diluted in biodiesel. Handpulling is effective on small plants, but since Chromolaena can grow from cuttings, this technique is less than ideal. All handpulled plants were hung in trees. Basal Garlon 4 treatment appears to be highly effective. Granular pre-emergent herbicides, such as Oust (sulfometuron methyl) could be scattered around any mature plants found, although the efficacy of this should be tested. During survey/control sweeps, all staff should carry small quantities of Garlon 4 to control any plants seen. All plants/patches should be flagged orange and GPSed. Any patches too big to treat during the survey should be noted and revisited for a spot treatment.

Spot treatments. Foliar sprays, except aerial sprays, have not yet been conducted by staff. This technique is efficient when treating patches of Chromolaena, rather than single plants. The literature suggests that imazapyr may be most effective at suppressing Chromoleana, although triclopyr is equally effective for initial control (Ikuenobe and Ayeni, 1998). Imazapyr may have some type of preemergent effect. Both products (and a cocktail of the two) should be considered for use at KTA. In addition, other pre-emergent products, such as Oust should be added for additional suppression.

Backpack sprayers and power sprayers (on ATVs or 4WD trucks) should be used to treat accessible patches of Chromolaena. In ICA-04, there are many such patches on the broad ridge north of X-Strip LZ. These and any other patches along roads and trails should be prioritized for control. In ICAs 04 and 03, there are many trails where an ATV-mounted sprayer would be very efficient. DOFAW may be able to provide an ATV (with driver). On the more difficult terrain of the gulch slopes, backpack sprayers may be useful, but work areas should be scoped out ahead of time.

Water is critical for foliar applications. There are no water sources at KTA. The HMA has a water tanker truck, which they may be willing to loan. OARNP has a number of water tanks which can also be used. Kahuku Range Control may be able to direct staff to fill up locations near Kamehameha Highway, but if none exist, all water will need to be driven in. Alternatively, small catchments could be built on site.

Hotspot/core sprays. Foliar sprays may be the most efficient technique in these areas. Both hotspots are in areas with some steep terrain. These areas are appropriate for aerial sprays, if available. Pre-emergent herbicides should be used in the hotspots.

ICA control notes:

ICA Code	Control Actions
WaimeaNoMU-ChrOdo-01	• Monitor and retreat as needed; no known plants
KTA-ChrOdo-02	• Monitor and retreat as needed; no known plants
KTA-ChrOdo-03	• Survey/control sweep across all WCA • Spot spray; appropriate for ATV on east slope, close to road • Hotspot/core spray; consider aerial treatment
KTA-ChrOdo-04	• Survey/control sweep across all WCA • Spot spray; appropriate for ATV across much of area, since it is a broad flat ridge
KTA-ChrOdo-05	• Survey/control sweep across all WCA • Spot spray; most likely easiest to cover on foot, as area is more sloped, but should evaluate for ATV also. Eastern slope is most gradual. Western slope very steep. • Hotspot/core spray; consider additional aerial treatment
KTA-ChrOdo-06	• Survey/control sweep across all WCA • Spot spray; most likely easiest to cover on foot, as area has some thick vegetation, but should evaluate for ATV also.

It is difficult to estimate precisely how much time is needed to sweep the entire, known infestation area. Based on the few survey/control sweeps done, we estimate that an additional 40 person days are needed to sweep the rest of the defined ICAs one time. This does not include extra time needed to conduct intensive control in the two hotspots. These ICAs will need to be swept multiple times over the next five years to treat recruiting Chromolaena plants; it is unclear whether a similar time input will be required for each sweep. The full extent of the infestation is not defined; when it is, more accurate predictions of effort can be made.

Gear checklist:

Survey/Control Sweeps	Foliar Sprays
Garlon 4, 20% in biodiesel	Herbicide: Garlon 4, imazapyr, turf mark, oust
Applicator bottles	Backpack sprayers
Gloves	Power sprayer rig (engine, hose, wand, gas, oil, water tank)
Dry bags	Water
GPS	Graduated cylinder/beaker
Compass	Gloves, respirator, eye protection, ear plugs
Orange flagging	Dry bags
Hip chain?	GPS
Oust?	Orange flagging
Water, soap, wash tub	ATV and operator (DOFAW, HMA)

Sanitation Practices:
At the end of every Chromolaena work trip, all gear/vehicles should be cleaned and inspected. This includes shoes, backpacks, and clothing. Cleaning should be done at KTA or at OANRP/partner agency baseyards. All vehicles driving through the infestation area should be vacuumed and washed. When the KTA Army wash rack is built, vehicles should be washed at KTA. Until then, washing should be done at OANRP/partner agency baseyards, and baseyards should be monitored for Chromolaena recruitment.

Volunteer Considerations;
OARNP has an official volunteer program, and all volunteers must be approved by RCUH prior to any field work. This involves submitting paperwork at least a week in advance. If volunteers are used to treat Chromolaena (HMA, for instance), they either need to become RCUH volunteers, or work under the auspices of the State of Hawaii and OISC.

Since Chromolaena control involves the use of pesticides, staff must be confident that volunteers receive a thorough safety briefing. Volunteers should demonstrate competency in using herbicides and sprayers for the safety of themselves and others.

Volunteers from the HMA may be able to provide quads/bikes to aid in transporting water and sprayers.

Data Tracking:
Surveys:

- Take GPS tracks of survey routes. At the least, take tracks along the edges of the survey sweep (2 GPS units ideal). These tracks will be used to document areas that have and have not been checked.
- Flag and take GPS points at every Chromolaena plant/patch seen. Note total # of plants (estimate if large), as well as numbers of matures, immatures, and seedlings. Note if patch on/close to a trail. Number of plants controlled.
- Record survey effort in Chromolaena Survey Log spreadsheet; process GPS data and add in to OANRP GIS database.

Control:

- Use GIS data and field notes to fill out WCEFs

- One WCEF should be filled out per control date, per ICA.
- The WCEF asks for the number of matures, immatures, and seedling controlled. The purpose of tracking the number of individuals treated is to show whether numbers are increasing or decreasing with control, aka, to track success.
- WCEFs should be entered into the Weed Database and GIS database.

Effort
- Staff and partner agency time must be entered under the proper action ID in the Scheduling Database.

Action IDs:
Record all time spent on Chromolaena using the Scheduling Database action IDs in the table below. If additional Chromolaena is found outside of the existing ICAs, ICA boundaries may need to be redrawn, or new ICAs created.

Action ID	Category	Category Priority	Sub-Category	ICA	Location	Action Comments
5712	W	W1	Weed Survey	-	Kahuku	Survey KTA for ChrOdo, define boundaries of infestation, identify core areas, identify areas with scattered plants, and identify any outliers.
5802	W	W1	Trials	-	Cane's	Conduct ChrOdo field seed bank trial. Dig up 2 seed packets each at 3, 6, 9, 12, 24, 36, 48, and 60 months and give packets to Propagule Specialist.
5889	W	W1	Trials	-	Kahuku	Determine optimal methods for killing Chrodo and suppressing the seed bank.
5732	W	W1	Incipient Control	WaimeaNoMU-ChrOdo-01	Pupukea Boyscout Camp	Monitor/control Chrodo at Pupukea site quarterly to every 6 months. Pick and remove from field any potentially viable fruit.
5862	W	W1	Incipient Control	KTA-ChrOdo-02	Drum Road MelUmb Site	Monitor/control Chrodo at Drum Road/Melumb site quarterly to every 6 months. Pick and remove from field any potentially viable fruit.
5885	W	W1	Incipient Control	KTA-ChrOdo-03	Kaunala	Sweep entire ICA at lower Kaunala/motocross site for Chrodo 1-2x year. Pick and remove from field any potentially viable fruit. Coordinate with interagency hui.
5886	W	W1	Incipient Control	KTA-ChrOdo-04	Waialee	Sweep entire ICA at lower Waialee/motocross site for Chrodo 1-2x year. Pick and remove from field any potentially viable fruit. Coordinate with interagency hui.
5887	W	W1	Incipient Control	KTA-ChrOdo-05	Pahipahialua	Sweep entire ICA at lower Pahipahialua/motocross site for Chrodo 1-2x year. Pick and remove from field any potentially viable fruit. Coordinate with interagency hui.

Action ID	Category	Category Priority	Sub-Category	ICA	Location	Action Comments
5888	W	W1	Incipient Control	KTA-ChrOdo-06	Kawela	Sweep entire ICA at lower Kawela site for Chrodo 1-2x year. Pick and remove from field any potentially viable fruit. Coordinate with interagency hui.
5796	O	O1	Outreach Event – Public	-	-	Conduct outreach to motocross community and others regaring the ChrOdo infestation in KTA

Safety Precautions

Personal Protective Equipment (PPE): A variety of products may be used to treat Chromolaena. Follow recommendations on the MSDSs for PPE. In general, this means the following PPE should be worn during mixing and application: long sleeve shirt, long pants, shoes plus socks, gloves (neoprene, nitrile, or oil/solvent resistant), and eye protection. If spraying (backpack or power sprayer), recommend wearing a respirator and ear plugs (power sprayer only).

General Precautions: Eye protection is required to avoid eye injuries in heavy brush. Give first aid as needed to prevent scratches and wounds from later infections. Glove liners like leather or cotton gloves can be worn under chemical resistant gloves if desired. Any damaged nitrile gloves should be replaced immediately to avoid chemical exposure. Any chemical should be handled with caution. When spraying, reduce worker's exposure by spraying well away from your eyes and face and by setting the spray droplet size to avoid fine airborne mists. Always be aware of the locations of fellow workers, and avoid spraying them.

Chemical Safety:
The Material Safety Data Sheets for the herbicides being used are available in a binder in the truck for any worker or volunteer to see. The MSDSs and Labels detail the signs and symptoms of acute exposure, proper first aid measures, and procedures for accidental spills. Report any exposure to the field supervisor. Wash off skin with lots of soap and water. Flush eyes with water for 15min and consult a doctor.

Motocross:
This is only relevant if any management is conducted on weekends. The Kahuku Motocross Track is open on Saturdays and Sundays, and is very popular. On weekends, expect to see motocross/quad/4WD vehicles on any and all trails west of Echo Gate and north of Hotel Gate. Some riders may also venture east of Echo Gate and south of Hotel Gate, but as these areas are outside of the Motocross Track, they are only used by expert riders. Riders do not expect to see hikers on these trails.

Army Training:
During the week, KTA is actively used for military training exercises. Kahuku Range Control staff should brief you as to whether any training is happening that day. Be aware Range Control treats training as top priority, and environmental work as second priority. Often, we have co-use of the Range, meaning troops are training in the same general areas where we are working. Some training exercises involve the use of flash-bangs (hopped up fire crackers), which create a loud bang and smoke. Avoid regions where troops are training.

Works Cited:

Chimera, Chuck. "Chromolaena_odorata_WRA.pdf." *US Forest Service, Pacific Island Ecosystems at Risk (PIER)*. 13 May 2009. Web. 02September 2011. <http://www.hear.org/pier/wra/wra_c.htm>

Ikuenobe, C.E. and A.O. Ayeni. "Herbicidal control of *Chromolaena odorata* in oil palm." *Weed Research* 38 (1998): 397-404. Print.

Muniappan, R., K. Englberger and G.V.P. Reddy. "Biological control of *Chromolaena odorata* in the American Pacific Micronesian Islands." *Proceedings of the Seventh International Workshop on Biological Control and Management of Chromolaena odorata and Mikania micrantha*. Eds. P. Lai, G.V.P. Reddy, and R. Muniappan. Taiwan, September 12-15, 2006. 49-52. Print.

Muniappan, R., G.V.P. Reddy and P. Lai. "Distribution and biological control of *Chromolaena odorata*." *Invasive Plants: Ecological and Agricultural Aspects*. Ed. S. Inderjit. Basel, Switzerland: Birkhauser Verlag, 2005. 223-233. Print.

US Forest Service, Pacific Island Ecosystems at Risk (PIER). Web. Accessed 02September 2011. <http://www.hear.org/pier/>

Whistler, W. Arthur. *Wayside Plants of the Islands*. Honolulu: Isle Botanica, 1995. Print

Witowski, E. T. F., and M. Wilson. "Changes in density, biomass, seed production and soil seed banks fo the non-native invasive plant, *Chromolaena odorata*, along a 15 year chronosequence." *Plant Ecology* 152 (2001): 13-27. Print.

Zachariades, C., M. Day, R. Muniappan, and G.V.P. Reddy. "Chapter 8: Chromolaeda odorata (L. King and Robinson (Asteraceae)." *Biological Control of Tropical Weeds using Arthropods*. Eds. R. Muniappan, G.V.P. Reddy and A. Raman. Cambridge, UK: Cambridge University Press, 2009. 130-162. Print.

APPENDIX 1-2-b

ALERT! A highly invasive weed (listed as a state noxious pest) has been discovered in the Kahuku and Pūpūkea regions of the Koʻolau Mountains:

Your kōkua is needed to prevent its spread and protect people and our native plants and animals!

Chromolaena odorata

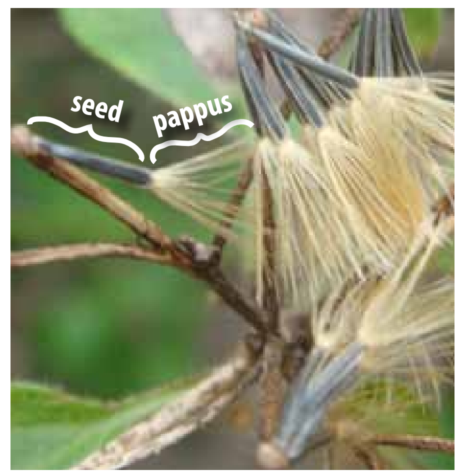
(Common names include: Siam Weed,Bitter Bush, Devil Weed, Rey del Todo and others)

Facts about *C. odorata*:

- *C. odorata* is a candidate for one of the top 100 worst weeds in the world;
- This is the first record of this weed in the Hawaiian Islands;
- Tolerates a wide range of soil conditions and severe drought;
- Prefers full sun to partial shade (does not tolerate heavy shade);
- Rapidly forms dense thickets in disturbed/cleared areas;
- Creates a fire hazard;
- Alleleopathic (prevents other plants from growing nearby);
- **Allergen/toxic to humans** (causes skin problems and asthma in allergy-prone people);
- Can be toxic to animals, causing diarrhea and death in extreme cases;
- Host for recognized pests and pathogens;
- Can grow and spread from cut stems;
- Can mature in a year and begin producing seed;
- Produces many wind-dispersed seeds (up to 800,000 per plant) persisting more than a year in soil;
- **Seeds are easily spread unintentionally by hikers, vehicles, equipment and mammals.**

C. odorata characteristics:

- Shrub; forms dense tangled bushes 1.5-2 m in height (some branches can grow up trees to 20 m);
- Leaves extend from stem in opposite pairs, light green with ***velvety hairs***, ***triangular shape***, leaf edges can have large serrations (teeth) or can be smooth;
- Leaves have distinctive 3-vein "pitchfork" pattern;
- Distinct odor when leaves crushed;
- ***Stems have short, soft hairs*** (older stems woody);
- Flowers in small round clusters, white to mauve color, 4-5 mm long; individual flower shape is slender trumpet; ***long, whispy structure (style) extends beyond flower petals (corolla)***, see comparison photos, below;
- Seeds are dark, 3-4 mm long, with a 5 mm long fluffy structure (pappus) – see photo, right.



Can be easily confused with:

Ageratina adenophora
(Maui Pamakani, Pamakani Haole; *not native*)

- Plant not hairy
- Stems dark red/purple
- Leaves dark green
- Seeds smaller (1.5 mm long), pappus 4 mm long

Pluchea carolinensis
(Sourbush; *not native*)

- Does not form tangled shrub
- Leaves dull gray-green, oblong to elliptic shape
- Seeds smaller (1 mm long), pappus 2-3 mm long

	C. odorata	Look-a-like weed *A. adenophora*	Look-a-like weed *P. carolinensis*
FLOWERS:			
LEAVES:			

A. adenophora & P. carolinensis photos by Forest & Kim Starr

What you can do:

If you think you've spotted *C. odorata*:

- Please report all sightings to the Oʻahu Invasive Species Committee (OISC) so it can be identified and removed – note where you found it, and take photos, if possible;
- **DO NOT** try to pull it out, as it grows from any fragments that may be left behind.

For more information, or to report a sighting of *C. odorata*, please contact **OISC** at:
oisc@hawaii.edu, 266-7994

OISC O'AHU INVASIVE SPECIES COMMITTEE

BISHOP MUSEUM

HAWAII DEPARTMENT OF AGRICULTURE

Oʻahu Army Natural Resources Program

Habit: sprawling shrub


Habit: prefers light gaps

Habit: persists beneath ironwood

Habit: twines into canopy, 2+m high

Habit: grows along trails, tracks, roads

Leaves: pitchfork veination, arrowhead shape, fuzzy, distinctive odor when crushed

Flowers: white to lilac, long stamens

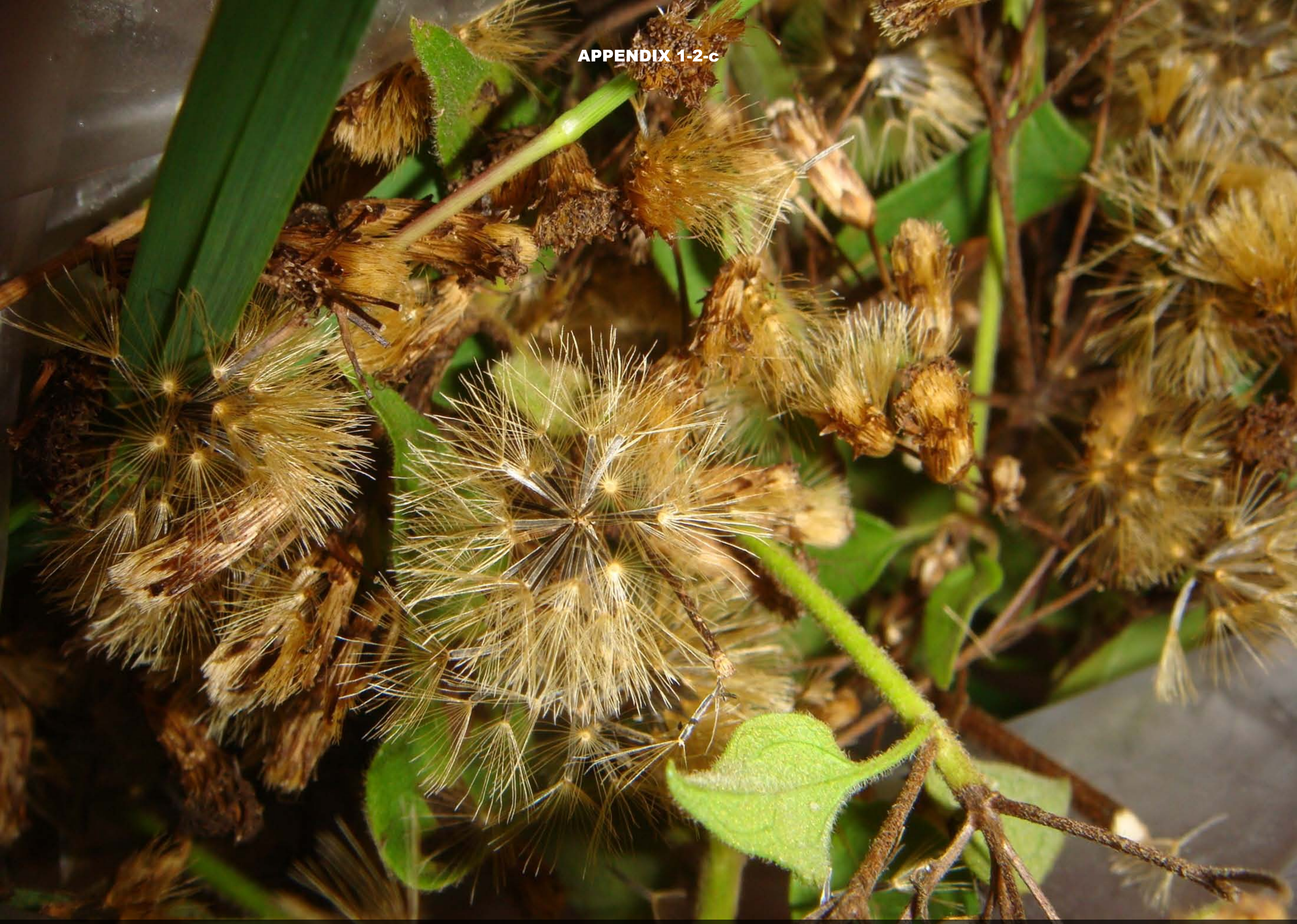
APPENDIX 1-2-c

Flowers: white to lilac, long stamens

Flowers: white to lilac, long stamens

Flowers: stamens occasionally absent

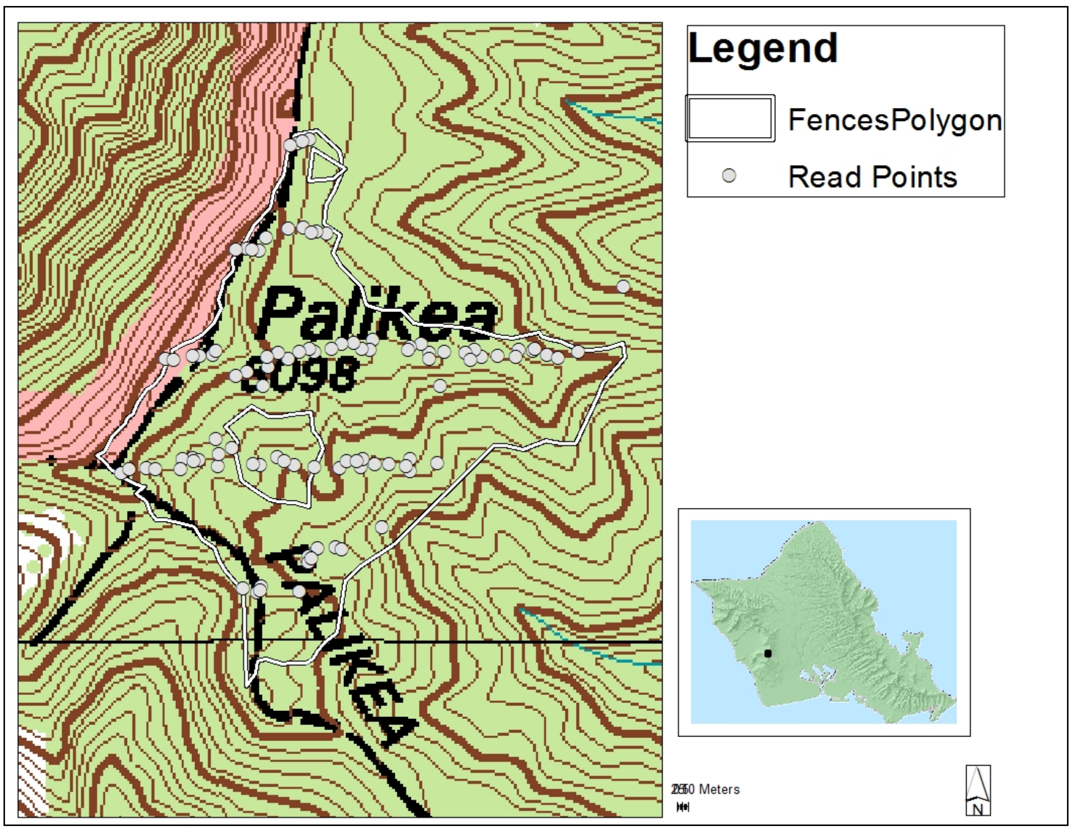
Seeds: achenes with distinct pappus



Seeds: prolific seed production, achenes wind and vector (vehicle, animal, people) dispersed

Vegetation Monitoring
Trend Analysis for the Palikea MU

In 2008, NRP conducted MU level vegetation monitoring at the Palikea management unit (MU). The goal set by the IT in 2010 was to re-read these plots every three years. In the spring of 2011 these plots were re-monitored and trend analysis was conducted. Now that a two dataset have been collected; the vegetation monitoring sub-committee will be meeting to re-evaluate how often to re-monitor these plots. Since the vegetation monitoring protocol was designed to address two separate MIP goals, the following analysis is separated into two sections. The statistical thresholds used for both sections were copied directly from the Makua Implementation Plan.



Section 1: Alien Percent Cover Goal

Alien Percent Cover Management Objective:

- Assess if the percent cover for both the alien understory and canopy is 50% or less across the entire management unit.

Sampling Objective:

- Be 95% confident of detecting a 10% change in vegetation cover for both alien understory and canopy.

- The acceptable level of making a Type 1 error (detecting a change that did not occur) is 10% and a Type 11 error (not detecting a change that did occur) is 20%.

Vegetation Monitoring Protocol:
Refer to the monitoring section in the 2008 year-end report.

Analysis:
Understory cover: The median percent cover for the alien understory was 35% in 2008. In 2011, NRP staff re-monitored these plots and trend analysis was conducted. This analysis showed that the median percent cover for the alien understory did not significantly change between 2008 and 2011 (Mann-Whitney U test, median was 35%, P-value was 0.84). The percent cover for both years met the MIP goal set by the IT.

Canopy cover: The original methodology used to estimate the percent cover in 2008 was inconsistent between observers so the protocol was revised. Thus, the 2008 alien canopy data was not used and the 2011 analysis will be treated as the baseline. The median percent cover in the canopy in 2011 was 55%. This percent cover was higher than the MIP goal set by the IT.

Statistical Thresholds and Sample Size Considerations:
Since there was no detectable change in the alien understory, the chance of making a Type 11 error (not detecting a change that really did occur) and the Power of detecting a change were calculated using re-sampling analysis. In order to determine the Power and Type II error, the observed data was increased by the minimum detectable change desired (10%), truncating at 100%, re-sampled 1000 times, and a p-value was calculated for each sample using a two sided Mann-Whitney-Wilcoxon test (using a Type I error rate of 0.05). The number of significant results generated from the re-sampling test was used as the measure of power and type 11 error (1-Power).

Discussion:
From 2008 to 2011, weed control was conducted across 49.5% of the Palikea MU. With this level of weed control effort there was no detectable change in the percent cover of the alien vegetation in the understory. This was an encouraging sign that, given the management strategy implemented between 2008 and 2010, the alien vegetation cover in the understory did not significantly increase and that NRP continued to meet the MIP goal.

Management response:
The weed control strategy will be re-evaluated if future vegetation monitoring analysis indicates that the MIP alien vegetation cover goals have not been met in either the understory or canopy and there is not a clear indication that the MIP goals are closer to being reached through current management.

Section 2: Frequency of Occurrence Analysis

Frequency data was collected for all species that occurred within Palikea in both 2008 and 2011. This data was analyzed to tracking species richness, spatial distribution, and density of dominate species on an MU scale. This analysis was used by management to help determine if Palikea was getting more or less native over time.

Species Richness Analysis and Vegetation Monitoring Checklist:
A species checklist of vascular plants found within the Palikea management unit (MU) was compiled from the 2008 and 2011 monitoring datasets. The results of this inventory provided an updated checklist for the MU (refer to the Species List and Frequency tables below). Within the canopy, a total of 45 plant species were recorded. Of all the species that were documented in the canopy, 37 (82%) were native and 8 (18%) alien. In the understory a total of 132 species were recorded. Of all the species that were documented in the understory; 97 (73%) were native and 35 (27%) alien. In addition to updating the species list, analysis was conducted to determine if there had been a change in species richness between 2008 and 2011. Within the three year time period there was no detectable change in species richness for any of the strata (Alien Canopy, W=97.5, p=0.14; Alien Understory, W=409.5, p=0.604; Native Canopy, W=297.5, p=0.78; Native Understory, W=506.5, p=0.71). This indicates that the species diversity was stable between 2008 and 2011.

Management Objective for Priority Alien Species Control:

- Assess the spatial distribution and frequency for priority 2 weed species.
- Provide an updated priority weed species list for the Palikea MU.
- Track species richness for alien species across the MU.

Sampling Objective:

- Be 95% confident of detecting 10% change in occurrence of priority 2 weed species (refer to the WCA section of the Palikea MU Five Year Plan for more details).

Vegetation Monitoring Protocol:

- Refer to the monitoring section in the 2008 annual status report.

Priority Weed Species Frequency Analysis:
Alien species which are of particular interest to NRP due to their ecosystem altering nature are ranked as priority weeds and controlled on a WCA or PU scale. Three species that were targeted on a WCA scale between 2008 and 2011 were *Schinus terebinthifolius, Morella faya*, and *Psidium cattleianum.* Since there were established stands of these species throughout the MU, the weed management strategy was to focus on controlling them in native forest patches and around rare plant populations. From 2008 to 2011 there was no detectable change (Chi-Square test, $P < .05$) for any of these species.

Management Response:
Since there has not been a detectable change for any of the priority species in the last three years, NRP will continue with the current management strategy. If future monitoring indicates that there has been an increase in the frequency of occurrence for of any of the priority weed species, NRP will identify potential adaptive management strategies.

Management Objective for Native Species:

- Ensure the plant communities within the MUs are stable and native-dominated (MIP.

Sampling objectives:

- 95% confident of detecting a 10% change in occurrence of native species.

Vegetation Monitoring Protocol:

- Refer to the monitoring section in the 2008 annual status report.

Native Species Frequency Analysis:
From the list of native species which occurred at Palikea in 2008 and 2011, there was a significant increase in *Alyxia oliviformis* (Chi-Square Test, P = 0.012) and *Diplazium sandwichianum (Chi-Square Test, P = 0 .068)*. In addition, analysis of *Cocculus orbiculatus* indicated that it was approaching a significant increase in frequency (Chi-Square Test, P = 0.115). For all other species there was no detectable change in occurrence between 2008 and 20011 (Chi-Square test, P >.05). This was encouraging and may indicate that since the removal of ungulates, there has been some recovery of the native understory.

Management Response:
Since trend analysis only detected positive change in the frequency of occurrence of native species, NRP will continue with the management strategy outlined in the 2008 Palikea MU Five Year Plan. If future monitoring analysis indicates that there was a decrease in native species, NRP will discuss if action should be taken to try and reverse the negative trend.

Alien Canopy:

Species Name	Percent Occurrence (out of 49 plots)
Schinus terebinthifolius	71.43%
Psidium cattleianum	55.10%
Morella faya	42.86%
Passiflora suberosa	24.49%
Cryptomeria japonica	22.45%
Psidium guajava	6.12%
Lantana camara	4.08%
Grevillea robusta	2.04%

Alien Understory:

Species Name	Percent Occurrence (out of 49 plots)
Clidemia hirta	85.71%
Psidium cattleianum	71.43%
Rubus rosifolius	59.18%
Passiflora suberosa	55.10%
Schinus terebinthifolius	53.06%
Blechnum appendiculatum	48.98%
Christella parasitica	44.90%
Youngia japonica	44.90%
Melinis minutiflora	36.73%
Deparia petersenii	34.69%
Paspalum conjugatum	34.69%
Morella faya	24.49%
Ageratina riparia	22.45%
Ehrharta stipoides	18.37%
Ageratum conyzoides	10.20%
Ageratina adenophora	8.16%
Cryptomeria japonica	8.16%
Lantana camara	8.16%
Phytolacca octandra	8.16%
Christella dentata	6.12%
Crassocephalum crepidoides	6.12%
Oxalis corniculata	6.12%
Phlebodium aureum	6.12%
Crocosmia X crocosmiifolia	4.08%
Drymaria cordata var. pacifica	4.08%
Epidendrum x obrienianum	4.08%

Species Name	Percent Occurrence (out of 49 plots)
Sphaeropteris cooperi	4.08%
Adiantum radianum	2.04%
Buddleia asiatica	2.04%
Conyza bonariensis	2.04%
Erichtites valerianifolia	2.04%
Grevillea robusta	2.04%
Physalis peruviana	2.04%
Psidium guajava	2.04%
Schefflera actinophylla	2.04%

Native Canopy:

Species Name	Percent Occurrence (out of 49 plots)
Metrosideros polymorpha	67.35%
Hedyotis terminalis	28.57%
Alyxia oliviformis	16.33%
Lepisorus thungbergianus	14.29%
Cheirodendron trigynum	12.24%
Perrottetia sandwicensis	12.24%
Coprosma foliosa	10.20%
Coprosma longifolia	10.20%
Pittosporum confertiflorum	10.20%
Psychotria mariniana	10.20%
Acacia koa	8.16%
Dicranopteris linearis	8.16%
Pipturis albidus	8.16%
Adenophorus tamariscinus	6.12%
Antidesma platyphyllum	6.12%
Cibotium chamissoi	6.12%
Dodonaea viscosa	6.12%
Cyrtandra waianaeensis	4.08%
Freycinetia arborea	4.08%
Ilex anomala	4.08%
Labordia kaalae	4.08%
Adenophorus pinnatifidus	2.04%
Broussaisia arguta	2.04%
Cocculus orbiculatus	2.04%
Elaphoglossum crassifolium	2.04%

Species Name	Percent Occurrence (out of 49 plots)
Lobelia yuccoides	2.04%
Melicope oahuensis	2.04%
Myrsine sandwicensis	2.04%
Nothocestrum longifolium	2.04%
Peperomia tetraphylla	2.04%
Polypodium pellucidum var. pellucidum	2.04%
Pouteria sandwicensis	2.04%
Psychotria hathewayi	2.04%
Scaevola gaudichaudiana	2.04%
Smilax melastomifolia	2.04%
Syzygium sandwicensis	2.04%
Wikstroemia oahuensis var. oahuensis	2.04%

Native Understory:

Species Name	Percent Occurrence (out of 49 plots)
Metrosideros polymorpha	57.14%
Dicranopteris linearis	53.06%
Dryopteris glabra	44.90%
Hedyotis terminalis	44.90%
Alyxia oliviformis	38.78%
Cocculus orbiculatus	38.78%
Asplenium macraei	34.69%
Dianella sandwicensis	34.69%
Cibotium chamissoi	32.65%
Nephrolepis exaltata subsp. hawaiiensis	32.65%
Wikstroemia oahuensis var. oahuensis	30.61%
Diplazium sandwichianum	28.57%
Hedyotis schlechtendahliana	28.57%
Lepisorus thungbergianus	28.57%
Peperomia membranacea	28.57%
Asplenium contiguum	26.53%
Elaphoglossum paleaceum	26.53%
Microlepia strigosa	26.53%
Coprosma longifolia	22.45%
Elaphoglossum aemulum	18.37%
Carex wahuensis	16.33%

Species Name	Percent Occurrence (out of 49 plots)
Perrottetia sandwicensis	16.33%
Antidesma platyphyllum	14.29%
Asplenium acuminatum	14.29%
Athyrium microphyllum	14.29%
Coprosma foliosa	14.29%
Dryopteris sandwicensis	14.29%
Elaphoglossum crassifolium	14.29%
Vaccinium dentatum	14.29%
Cheirodendron trigynum	12.24%
Cyrtandra waianaeensis	12.24%
Freycinetia arborea	12.24%
Peperomia tetraphylla	12.24%
Pipturis albidus	12.24%
Sphenomeris chinensis	12.24%
Broussaisia arguta	10.20%
Charpentiera obovata	10.20%
Diplopterygium pinnatum	10.20%
Dodonaea viscosa	10.20%
Labordia kaalae	10.20%
Nephrolepis cordifolia	10.20%
Pittosporum confertiflorum	10.20%
Psilotum complanatum	10.20%
Elaphoglossum alatum	8.16%
Grammitis tenella	8.16%
Myrsine lessertiana	8.16%
Polypodium pellucidum var. pellucidum	8.16%
Psychotria mariniana	8.16%
Pteridium aquilinum	8.16%
Selaginella arbuscula	8.16%
Vaccinium reticulatum	8.16%
Vandenboschia cyrtotheca	8.16%
Asplenium horridum var. horridum	6.12%
Carex meyenii	6.12%
Chamaesyce multiformis	6.12%
Doodia kunthiana	6.12%
Melicope oahuensis	6.12%

Species Name	Percent Occurrence (out of 49 plots)
Myrsine sandwicensis	6.12%
Psychotria hathewayi	6.12%
Sadleria cyatheoides	6.12%
Scaevola gaudichaudiana	6.12%
Acacia koa	4.08%
Asplenium kaulfussii	4.08%
Bidens torta	4.08%
Cibotium glaucum	4.08%
Cyanea grimesiana subsp. grimesiana	4.08%
Dryopteris fusco-atra	4.08%
Dubautia plantaginea	4.08%
Ilex anomala	4.08%
Leptecophylla tameiameiae	4.08%
Melicope clusiifolia	4.08%
Psilotum nudum	4.08%
Pteris excelsa	4.08%
Rumex albescens	4.08%
Adenophorus pinnatifidus	2.04%
Adenophorus tamariscinus	2.04%
Asplenium unilaterale	2.04%
Clermontia kakeana	2.04%
Cyrtandra sp.	2.04%
Elaeocarpus bifidus	2.04%
Elaphoglossum sp.	2.04%
Hedyotis sp.	2.04%
Lobelia yuccoides	2.04%
Mecodium recurvum	2.04%
Myrsine emarginata	2.04%
Nothocestrum longifolium	2.04%
Peperomia sandwicensis	2.04%
Pisonia brunoniana	2.04%
Pouteria sandwicensis	2.04%
Scaevola mollis	2.04%
Smilax melastomifolia	2.04%
Solanum sandwicense	2.04%
Syzygium sandwicensis	2.04%
Tectaria gaudichaudii	2.04%

Species Name	Percent Occurrence (out of 49 plots)
Urera glabra	2.04%
Vandenboschia davallioides	2.04%
Viola chamissoniana	2.04%

Gap Analysis Report

Prepared for U.S. Army Garrison – Hawaii

29 June 2011

This report is prepared under Contract #: W911S0-04-D-0002-0183 to CALIBRE Systems Inc., (prime contractor, POC: Heather LaRowe) and teammates Crop Production Services-Timberland Division (POC: Ron Lemin) and Arbor Global (POC: Kevin Eckert)

CALIBRE Our Success Follows Yours

ARBOR GLOBAL Arboriculture & Vegetation Management Consulting

Crop Production Services TIMBERLAND DIVISION

Executive Summary

Team CALIBRE (i.e., CALIBRE Systems, Inc., Crop Production Services, and Arbor Global) began operational research in 2010 at Schofield Barracks Military Reservation and Makua Military Reservation to support initiation of a long-term U.S. Army Garrison, Hawaii (USAG-HI) Integrated Vegetation Management Plan (IVMP) intended to (1) support and enhance training while simultaneously minimizing risk of fire and environmental impacts to the site and surrounding area; (2) improve and maintain a sufficient fire line/buffer for threatened and endangered (T&E) species; and (3) develop and prepare the most cost efficient and sustainable approach to vegetation management using techniques such as cultivation of desirable vegetation cover, mowing/harvesting, biological control (including grazing), and herbicide and/or plant growth regulator application. The IVMP goal is to develop and cost-effectively maintain a low growing (6”-12”) vegetative ground cover that remains green throughout the year such that fire cannot propagate and spread to off-site areas.

The purpose of this Gap Analysis Report is to (1) summarize results of Team CALIBRE’s literature review and interviews of key personnel at USAG-HI and subject matter experts in the field of vegetation management, and (2) describe the process and findings of preliminary herbicide testing conducted by Team CALIBRE to address gaps in support of developing an effective USAG-HI IVMP.

Based on results of the Gap analysis and preliminary testing, Team CALIBRE recommends further actions needed for development of a long-term IVMP that will support military training, while protecting USAG-HI sensitive natural and cultural resources.

Table of Contents

1. Introduction 1
2. Methodology 2
  2.1. Identification of Existing Conditions 2
  2.2. Identification of Management Alternatives 10
  2.3. Identification of Specific Trial Areas 11
  2.4. Identification of Research Protocols 13
    2.4.1 Herbicide Application Equipment 13
    2.4.2 Herbicide Mixing Protocols 15
    2.4.3 Weather Considerations 16
    2.4.4 UXO Considerations 17
    2.4.5 Cultural Resources Considerations 17
    2.4.6 Marking of Test Plots and Sensitive Sites 18
    2.4.7 Vegetation Data Collection 20
    2.4.8 Soil Sampling 21
3. Results 23
  3.1. Analysis of Existing Data and Current Conditions 24
    3.1.1 Topography and Soils 24
    3.1.2 USAG-HI RD Vegetation Treatment Methods 27
    3.1.3 Vegetation Conditions (SBMR WR) 29
    3.1.4 Vegetation Conditions (MMR) 29
    3.1.5 Vegetation Conditions (Kahuku Training Area) 30
    3.1.6 Vegetation Conditions Summary 30
  3.2. Preliminary Trials of Herbicide Application 30
4. Control Method Recommendations 34
  4.1. Biological Control 34
  4.2. Mechanical Control 35
  4.3. Cultural Management of Vegetation 35
  4.4. Chemical Applications 37
5. Conclusion 38

1. Introduction

The mission of US Army Garrison – Hawaii (USAG-HI) is to "provide sustainable installation support and services for Joint Warfighters, their families and the military community that meets current and future mission requirements, safeguards human health, improves quality of life, and enhances the natural environment." Important to fulfilling the mission is the goal to "maximize training support while minimizing the impact on the natural environment and community." The objective is to provide realistic, relevant, and available training facilities to the 25th Infantry Division and other tenant units. USAG-HI is responsible for conserving over 100 federally listed endangered species. Fire is the number one threat to endangered species from military training. Significant restrictions exist on the use of live-fire training infrastructure during periods of high fire hazard due to access challenges, limitations put forth within Biological Opinions that guide Range management, transformational changes in equipment and doctrine, increased environmental pressures, the presence of invasive grass species that facilitate the rapid spread of fire, and numerous wildland fires that have encroached into sensitive natural and cultural areas.

To reduce fire hazards created from live fire training, permit exploded Ordnance (UXO) clearance and support the construction of a new Range, the USAG-HI Range Division (RD) allocates a large portion of funds [approximately $750,000 over the past five years on Schofield Barracks Military Reservation (SBMR), Figure 1, alone] to apply herbicide, conduct prescribed burning, then apply a second herbicide treatment to reduce vegetation. The initial result of this treatment regime is the creation of bare ground, which results in soil destabilization, runoff and water quality problems associated with herbicides and other contaminants that leach from the site into groundwater. The unintended result of this treatment regime is reestablishment of aggressive, highly flammable, invasive species that now comprise the primary vegetation community at SBMR, Makua Military Reservation (MMR) (cover photo), and other USAG-HI training sites.

Figure 1. Schofield Barracks Military Reservation, Oahu, 2011.

Team CALIBRE reviewed readily available references, formed a team of vegetation experts to analyze data gaps and define methodologies, protocol, and best management practices; evaluated existing field conditions; and initiated preliminary testing of precision-applied herbicides to determine prescriptions that warrant further rigorous testing.

2. Methodology

2.1. Identification of Existing Conditions

In order to initiate the gap analysis, knowledge and understanding of past treatments of USAG-HI ranges, significant current conditions, and vegetation management practices and goals was required. Team CALIBRE's extensive knowledge and experience with vegetation management throughout Hawaii and the US mainland facilitated analyzing the effectiveness and challenges of past treatments, current conditions and the likely result of alternative treatments. To identify USAG-HI vegetation management goals, past practices and research that were conducted, Team CALIBRE interviewed the following knowledgeable, experienced personnel at USAG-HI Range Division (RD) and Environmental Division (ENV):

- Vic Garo, Chief Operations Officer, RD
- Frank Raby, Range Operations Manager, RD
- Ken Torre, Training Support Manager, RD
- Michelle Mansker, Chief, Natural Resource Section, ENV
- Joby Rohrer, Senior Natural Resource Management Coordinator, ENV
- Jane Beachy, Ecosystem Restoration Program Manager, ENV

Information collected during these interviews included vegetation management goals and desired results, vegetation management techniques and materials that were currently applied, the reason that each technique was used, the advantages and disadvantages of each technique, timing of vegetation management applications, and location of applications. We collected information on past formulations of herbicides, tank mix rate, application rates, and method of application via personal communications with personnel named above and documented reports.

Team CALIBRE completed focused site visits and reviews of conditions at MMR and SBMR in August 2010, accompanied by RD and ENV staff that provided general information and responded to questions regarding past treatments and vegetation management goals. Team CALIBRE already possessed a comprehensive knowledge and understanding of past management practices and vegetation management challenges through its members' extensive experience and knowledge gained by working within the vegetation management industry and living in Hawaii.

To assist in identifying necessary research to complete gaps in knowledge and provide the framework for the IVMP, Team CALIBRE reviewed numerous documents and online resources. Content that was considered relevant to this Gap analysis is summarized in the remainder of this section or is referenced throughout the document using footnotes. Most of the descriptions are taken directly and verbatim from key portions of executive summaries, abstracts or conclusions statements within the reference and amended to focus on the general areas relevant to this study. Publications are listed in alphabetical order, by author.

- Alexander, M.E. and L.G. Fogarty. 2002. A pocket card for predicting fire behaviour in grasslands under severe burning conditions. Fire Technology Transfer Note Number.

The grassland fire behaviour pocket card recently developed for use by wildland and rural firefighters in Canada and New Zealand offers a practical field guide for quickly estimating the near worst case fire behaviour potential in grasslands. At the same time it reinforces an awareness of the need for adopting safe work practices when attempting to contain grass fires in an effort to avoid burnovers and entrapments, thereby eliminating firefighter injuries and fatalities.

- Ansari, S., H. Hirsh, and T. Thair. 2008. Removal of Invasive Fire-Prone Grasses to Increase Training Lands in the Pacific. SWCA Environmental Consultants. PROJECT NUMBER 07-362.

Three control treatments were tested including mechanical removal, herbicide application and grazing using cattle to reduce the fuel loads at Marine Corps Training Area Bellows (MCTAB), on the island of O'ahu, Hawai'i. The total fine fuel load at MCTAB was found to average 6 tons/acre. Results indicated that grazing by cattle was most effective in lowering the fuel bed depths of Guinea grass on MCTAB. Effect of treatment on reduction of Guinea grass fuel loads varied with time. Mechanical treatment was the most effective in rapidly reducing Guinea grass; however, the grazing treatment was most effective in maintaining low fuel loads over 5 months post application of treatment. At the end of the experiment, fuels in the grazing plots also appeared to be less continuous than other treatments and; therefore, not expected to carry fast moving fires. Grazing treatment appeared to be most effective in maintaining lower total fine fuel loads, five months post application of treatments.

- Beavers, A.M. 2001. Creation and Validation of a Custom Fuel Model Representing Mature *Panicum maximum* (Guinea grass) in Hawaii. Center for Ecological Management of Military Lands, Colorado State University, Fort Collins, CO.

Panicum maximum cannot be accurately modeled using standard NFFL fuel models. The types of fire behavior observed during test burns prove beyond any doubt that this fuel type has a propensity for fast moving, high intensity grass fires. There seemed to be a break point in the RH and fuel moisture, below which fires exhibited behavior that would be uncontrollable in a wildland suppression situation; however, such observations are difficult to confirm with empirical data.

Winds did not appear to have as great an effect on fire behavior as would be expected. In fact, the most intense fire behavior was observed during periods of low winds. This may have been due to the high heat output released by the burning fuels. This model is applicable to any location dominated by the *Panicum maximum* fuel type, a large portion of the lowland landscape on the island of Oahu. By combining the model with accurate spot weather forecasts, fire behaviorists can give a very good estimate of what the fire perimeter and fire behavior will be in the coming 12-24 hours.

The future of fire behavior prediction, associated FDRS's, and fire management improvements is still open. New technologies and methods of prediction are currently being developed that incorporate a spatial component into the system. The current system rates fire danger based upon the highest fire danger throughout the installation. With a spatially based FDRS, locations of the training area that are at lower fire danger ratings could continue to be used despite the fact that some areas are under higher fire danger rating.

- Beavers, A.M., R. Burgan, F. Fujioka, R.D Laven, and P.N. Omi. 1999. Analysis of Fire Management Concerns at Makua Military Reservation. Center for Ecological Management of Military Lands, Colorado State University, Fort Collins, CO.

This publication suggested challenges of fire management at MMR can be overcome with proper fuel management, effective data collection and analysis, and appropriate fire suppression training and preparedness. If fuel management (including appropriate future maintenance) is carried out successfully and guidelines are enforced, the fires that do occur will burn under conditions that allow effective fire suppression before endangered species habitat is impacted. Although fire risk can never be eliminated completely, the Army will have improved capabilities for managing the fires that may occur. By initially proceeding with caution, monitoring conditions under which operations are conducted safely, and improving fire management techniques whenever possible, undesired fire impacts will be reduced and the Army will have the use of MMR as a live fire range for the foreseeable future.

- Beavers, A.M and R. Burgan. 2001. Wildland Fire Risk and Management on West and South Ranges, Schofield Barracks, Oahu. Center for Ecological Management of Military Lands, Colorado State University, Fort Collins, CO.

Existing fire management at Schofield Barracks is adequate, but there is room for improvement. The most logical course of action is to reduce or eliminate the possibility of an ignition occurring in dry, windy conditions. The best way to accomplish this task is with a fire danger rating system. The current state of fuel distribution allows for the opportunity to continue to stop fires at the fire break, as long as aggressive fuels management is implemented immediately. Maintenance of the fire break road and minimization of the extent and density of pyrophytic grasses above the fire break should be top priorities. If the recommended improvements in this report are implemented and combined with current management practices, there is no reason to believe that the Schofield fire management program can't be one of the most successful in the Islands.

- Goodman, Sherri,W. 1995. Deputy Under Secretary of Defense, Memorandum for Defense Environmental Council.

This memorandum provides interim policy on the certification of installation pesticide applicators and contractor employees performing pest management work on DoD installations. The measures of merit for installation pest management are: Measure of Merit 1 dictates that by the end of FY 97, 100 percent of all DoD installations will have pest management plans prepared, reviewed, and updated annually by pest management professionals. Measure of Merit 2 dictates that by the end of FY 2000, the amount of pesticide applied annually on DoD installations will be reduced by 50% from the FY 93 baseline in pounds of active ingredient. Measure of Merit 3 dictates that by the end of FY 98, 100 percent of all DoD installation pesticide applicators will be properly certified within two years of employment.

- Nickerson, N.H. 1992. Impacts of Vegetation Management Techniques on Wetlands in Utility Rights-of-Way in Massachusetts. Journal of Arboriculture 18(2).

This project compared five rights-of-way treatments to determine their impacts on wetlands on utility rights of way (ROW). The conclusion reached was that there was no significant impact to wetlands from any of the vegetation management techniques used on utility ROW in Massachusetts. Mechanical treatments resulted in higher impacts on the cover value for wildlife than those involving herbicides. Residue from petroleum products (bar oil and hydraulic fluid) were recovered on the leaf letter from mechanically treated sites. No herbicide residues were recovered from herbicide treated sites.

- Nowak, C.A. and B.D. Ballard. 2005. A framework for applying integrated vegetation management on rights-of-way. Journal of Arboriculture.

Integrated Vegetation Management, or IVM, is being used by many right-of-way management organizations across the United States. IVM is an in-depth and sophisticated system of information gathering, planning, implementing, reviewing, and improving vegetation management treatments. IVM is used to understand, justify, choose among, selectively apply, and monitor different types of treatments, with an overall goal of eliciting site specific, ecosystem-sensitive, economically sensible, and socially responsible treatment effects that lead to refined achievement of management objectives.

- Ray, C., M. Sanda, J. Dusek, B. Loo, H. Pavelkov, M. Sobotkova, and J. Lichwa. 2007. Leaching of Selected Pesticides in Hawaii Soils as Influenced by Soil Properties and Hydrologic Conditions: Field and Laboratory Evaluations. Water Resources Research Center, University of Hawaii, Honolulu, HI.

Leaching behavior of six pesticides and bromide were investigated at five test sites in Hawaii: Poamoho, Kunia, and Waimanalo on Oahu; Kula on Maui; and Mana on Kauai. The intent of the study was to evaluate the relative leaching behavior of the pesticides and to compare their leaching behavior to that of bromide tracer. Soil properties that affect transport are water conduction, organic carbon content, mineralogy, pH, and texture/structure. These factors affect pesticide half-life, sorption coefficient, and their movement in soils. Compounds with a longer half-life persist for a longtime in soil. Compounds with a high sorption coefficient adsorb strongly to soil and are less likely to be carried down by percolating water. Compounds with low sorption potential and long half-life are candidates for excessive leaching, unless they are extremely volatile and the volatilization is the primary mode of pesticide loss.

The soil profile data revealed that the bromide center of mass at the Kunia site moved about 1.5 m in 16 weeks. The imazaquin front at the Kunia site traveled more than 1.2 m over 8 weeks. However, the concentration front dissipated over the 8 weeks to below detection. At other sites, the front did not get past 0.6 m. Most of the chemicals were still present in the top 0.6 m after the 16-week study period.

Laboratory sorption data showed that imazaquin and sulfometuron methyl have very low sorption potential (< 10 mL/g). Also, most metabolites appear to be mobile. The mean half-life values for several chemicals from laboratory degradation studies may not be reliable due to extreme variations in data.

The Attenuation Factor screening model used by the Hawaii Department of Agriculture suggests that all chemicals, with the exception of trifloxystrobin, have the potential to leach. Many of these are applied at low doses. Low dose pesticides raise issues about their potency. Some pesticides are considered less toxic to mammals and are considered “safer” from this perspective. However, low dose pesticides residues may be of concern to aquatic ecosystems downstream and downstream water users.

- Shahin, A., H. Hirsh, and T. Thair. 2008. Removal of Invasive Fire-Prone Grasses Increase Training Lands in the Pacific, PROJECT NUMBER 07-362. SWCA Environmental Consultants, Honolulu, HI.

Invasive fire prone grasses like Guinea grass (*Panicum maximum*) have become the dominant cover on several training areas in the Pacific including Marine Corps Training Area Bellows (MCTAB), Hawaii. Dense stands of Guinea grass provide fuel for fast moving, high intensity fires thereby aggravating fire risk to weapons firing training and threatening wildlife and their habitats. Military installations spend millions of dollars to mitigate risk from such fire prone grasses. Traditionally, mechanical removal and prescribed fire were used to reduce Guinea grass fuel loads in Hawaii. MCTAB personnel and land managers in the Pacific seek alternative fuel reduction treatments such as mechanical, herbicide and grazing to reduce Guinea grass fuel loads; however, very little information is available.

- Smith, C.W. 1982. 1982. Technical Report 45- The prospects for biological control of nonnative plants in Hawaiian National Parks. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa, Department of Botany.

Encroachment of exotic (nonnative) plants into natural NPS areas is inconsistent with policy. Previous attempts to control such plants in Hawaiian NPS areas have involved mechanical removal or treatment with herbicides, but these methods as presently employed are inadequate to provide control on a long-term basis for many exotic species; they are also expensive and continuous. Previous efforts to control noxious weeds in Hawaii with phytophagous insects were conducted by the Hawaii State Department of Agriculture primarily for agricultural interests. Similar approaches for the control of exotic plants in Hawaii Volcanoes and Haleakala National Parks may have positive as well as cautionary aspects, which must be considered. A literature review revealed numerous references to insects and diseases associated with Hawaii's exotic plants, or related species, in other regions of the world. Some of these, or other suitable organisms not included in this report, may offer potential in future biological control programs.

- U.S. Army Garrison, Hawaiʻi. 2010. Integrated Natural Resources Management Plan, 2010-2014, Island of Oʻahu, Schofield Barracks Military Reservation, Schofield Barracks East Range, Kawailoa Training Area, Kahuku Training Area, Dillingham Military Reservation, Mākua Military Reservation, and Tripler Army Medical Center. Prepared for the Directorate of Public Works, Environmental Division, Natural Resources Section. Center for Environmental Management of Military Lands, Colorado State University, Fort Collins, CO.

The INRMP guides implementation of USAG-HI's integrated natural resources management program on its properties from 2010 through 2014. This plan is prepared in cooperation with the U.S. Fish and Wildlife Service (USWFS) and the Hawaiʻi Department of Land and Natural Resources (DLNR).

SBMR is the primary range complex with limited light maneuver training areas for USAG-HI at 9,520 ac (3,506 ha). There are four native vegetative communities located on SBMR: Montane Wet, Lowland Wet, Lowland Mesic, and Aquatic Natural communities.

Collectively, there are approximately 3,544 ac (1,433.9 ha) of forest outside of the cantonment area in SBMR. *Metrosideros/Acacia/ Dicranopteris* and *Schinus spp.*-dominated forests account for approximately 93 percent of the land area outside of the cantonment area. Four endangered animals (one bird, one terrestrial snail, two insects) have been documented at SBMR, along with 23 federally listed and 8 candidate plant species. About 1,900 ac (774 ha) of SBMR have been designated as critical habitat for the Oʻahu ʻelepaio (*Chasiempis sandwichensis ibidis*). Four Oʻahu IP management units are located on SBMR and on five Mākua IP management units. Species of greatest conservation need include 8 bird taxa, 1 mammal species, 3 invertebrate species, and possibly 4 fish taxa, along with 68 plant taxa. Present on SBMR are some 8 non-native mammals; 10 endemic/indigenous and 31 non-native birds; 6 endemic and 14 non-native fish; 12 endemic terrestrial and 10 endemic aquatic invertebrates, along with 4 non-native terrestrial and 6 aquatic invertebrates; and possibly as many as 15 non-native herpetofauna. Some 259 plant taxa have been documented. Three ant species are considered invasive as are 20 plant species. The Oʻahu Natural Resources (ONR) staff has identified 13 incipient plant species.

The primary drainages for the military reservation are the Waikōloa Gulch and the Waikele Stream. Also, the North Fork of the Kaukonahua Stream flows along the northeast boundary of SBMR, along with two tributaries. All streams on SBMR flow north into the Pacific Ocean at Waialua, with the exception of the Waikele, which flows into Pearl Harbor from the north. Many streams on SBMR are intermittent. All streams are somewhat degraded; especially drainages affected by the impact area and associated erosion. Stream quality is also affected by non-point pollution from adjacent crop lands. Soil erosion is locally significant in areas where natural drainage and gulches occur, particularly in the military reservation along Ayres Avenue and McMahon Road in the north, and Duck Field in the south. However, the dry climate and lack of permanent streambeds may reduce the risk of erosion, as well as areas where soils are not developed because of exposed lava.

MMR is located in an amphitheater-shaped valley, covering 4,190 ac (1,736 ha). Wildland fires resulting from live-fire training are the greatest threat to natural resources and endangered species located at and adjacent to MMR. Two native vegetative communities have been identified at MMR: Lowland Mesic and Lowland Dry Vegetation communities. Four forest communities are present and account for 469 ac (189 ha) of land cover, or about 11 percent. One federally listed bird, 1 mammal, and 1 snail species are documented on MMR, along with 33 federally listed and 5 candidate plant species have been documented at MMR. Seven additional federally listed plant species occur within the Mākua Action Area. Oʻahu ʻelepaio critical habitat was designated on MMR. Critical habitat for 32 plant species is present within the MMR action area, but there is no critical habitat for plants on the installation. Four bird, 2 marine mammals, and 1 invertebrate species, along with 79 plant species of greatest conservation need may be present. There are four

Mākua IP management units located on the installation and 19 management units off the installation. Potentially, 2 marine mammals and 3 non-native mammal species (e.g., pigs, goats, and rats) have been observed at MMR. Bird observations (mostly informal) include 2 forest species, 1 raptor, 1 sea bird, 1 migratory shorebird, and 11 non-native species. Thirteen herpetofauna may be present at MMR, including one threatened marine turtle. There are no records for fish. Nine endemic/indigenous and 13 non-native invertebrates have been observed. Six non-native ant species have been documented. Some 284 plant species have been identified. Nineteen invasive/weed species have been located at MMR, along with 17 incipient species that the NR staff control and eradicate.

The primary drainages at MMR are the Punaohaku Stream from the north and the Mākua Stream from west-central MMR; both are intermittent. There are possible palustrine wetlands on MMR, characterized by native trees, shrubs, or persistent emergent species. Possible riverine wetlands and possible palustrine wetlands associated with seep areas in the Mākua Stream drainage are protected using a variety of training restrictions. Soil erosion can be significant where slopes are steep because of the high shrink-swell potential of soils. Erosion and sediment control practices are used when road and firebreak repair/maintenance is performed to minimize sediment impacts to stream channels.

The grass/wildland fire cycle is an unresolved issue. Because of the rapid and widespread expansion of non-native invasive species grasses throughout the Island of Oʻahu and the resulting increase in fuel loads, wildland fire now poses a significant threat to native habitats, particularly dry forest systems. Ecological approaches to break the grass/wildland fire cycle are needed. Fire models must be adapted for the Pacific Islands region to predict fire hazards/severity (behavior). Elements of the models should include, but are not limited to, fuel loading, fuel moisture dynamics, live/dead rations, and microclimate and weather. Of particular importance to DoD are self-sustaining means to prevent and control fire in highly vulnerable areas (e.g., military training areas).

- U.S. Department of Agriculture – Soil Conservation Service (USDA-SCS). 1972. Soil Survey of Islands of Kauai, Oahu, Molokai, and Lanai, State of Hawaii. Soil Conservation Service.

This survey describes the soil series and mapping of the five Islands surveyed, including Oahu.

- U.S. Fish and Wildlife Service. 2004. Reinitiation of the 1999 biological opinion of the U.S. Fish and Wildlife Service for routine military training at Makua Military Reservation, island of Oahu, September 24, 2004. Pacific Islands Fish and Wildlife Office; Honolulu, HI.

This publication describes firebreaks and fuelbreaks developed for the MMR and includes Kaluakauila, Kahanakahiki, Pahole, Upper Kapuna, Wes Makaleha, Ohikilolo, and Lower

Ohikilolo. Fuelbreak areas are defined and illustrated within each area. The new fire protection systems will be operational within five years or prior to implementation of Column C in the Weapons Restrictions Table, whichever occurs earlier. Because mowing or aerial herbicide treatment is expected to produce a thick layer of dead grass that will take several years to decompose, aerial herbicide and mowing treatments will begin no later than two years after the completion of this Biological Opinion in order to ensure that the fire break is operational within five years.

- Yahner, R.H. and R.J. Hutnik. 2004. Integrated vegetation management on an electric transmission right-of-way in Pennsylvania. U.S. Journal of Arboriculture 30(5).

Integrated Vegetation Management (IVM) has been used for the maintenance of vegetation along an electric utility transmission right-of-way (ROW) at the Green Lane Research and Demonstration Area, Montgomery County, Pennsylvania, U.S., since 1987. The wire–border zone method creates a forb–grass–short shrub cover type in wire zones and a tall shrub cover type in border zones. This area has been studied annually since 1987, which makes this project one of the longest continuous studies documenting the effects of mechanical and herbicidal maintenance on flora and fauna along an electric transmission ROW. Excellent control of target trees was noted in 1999 in wire zones of mowing plus herbicide units; in contrast, tree control was poor in wire zones of mechanical units (mowing and handcut). Competition with existing plants and wildlife predation on tree seeds on a ROW keeps tree invasion to a minimum. Thus, over the years since 1987, IVM and the wire–border zone method of ROW maintenance have increased the time between treatment cycles, thereby reducing labor and chemical costs for ROW maintenance.

2.2. Identification of Management Alternatives

Based on research and analysis of past vegetation management practices, Team CALIBRE identified practical management alternatives thought to possess the best potential to cost-effectively manage undesirable vegetation and achieve USAG-HI vegetation management goals. These alternatives are based on standard integrated vegetation control options within the categories of biological, mechanical, manual, cultural and chemical as modeled on successful utility vegetation management programs.[1] Proposed alternatives were reviewed with ENV and RD staff to determine priorities for preliminary testing. Alternatives selected to be actively researched by Team CALIBRE included planting (cultural), and herbicide applications (chemical). Prescribed grazing (biological) is shown to be effective in maintaining a low-growing vegetation layer[2]. According to USAG-HI ENV

[1] Nowak, Christopher A. and Ballard, Benjamin D. A framework for applying integrated vegetation management on rights-of-way. Journal of Arboriculture. Jan 2005.
[2] Steven D. Warren, Stephen A. Sherman, and James A. Zeidler. Assessment of Livestock Grazing Impacts on Fuels and Cultural Resources at Mākua Military Reservation (MMR), Island of O„ahu, Hawai„i. Center for Ecological Management of Military Lands, Colorado State University. Fort Collins, CO. November 2007

staff, mowing (mechanical) is currently practiced in certain areas of MMR. The results of these practices, published and unpublished, will be reviewed and incorporated within the final IVMP.

2.3. Identification of Specific Trial Areas

Specific trial areas for preliminary research and testing were identified on MMR and SBMR through coordination with USAG-HI ENV Natural Resource staff and Cultural Resource staff. To ensure cost-efficiency of limited funds during conduct of trials, the majority of vegetation management test applications were located on sites identified by ENV and RD staff as fuels management areas or fire breaks.

RD identified a required fire break along the access road along the west end of the impact area at SBMR West Range (WR) (Figure 2). This fire break was defined to be 60 meters wide and generally followed along the east side of the access road. Via site visits, Team CALIBRE determined that vegetation conditions within this area included a diversity of grasses, shrubs, medium-sized and tall trees.

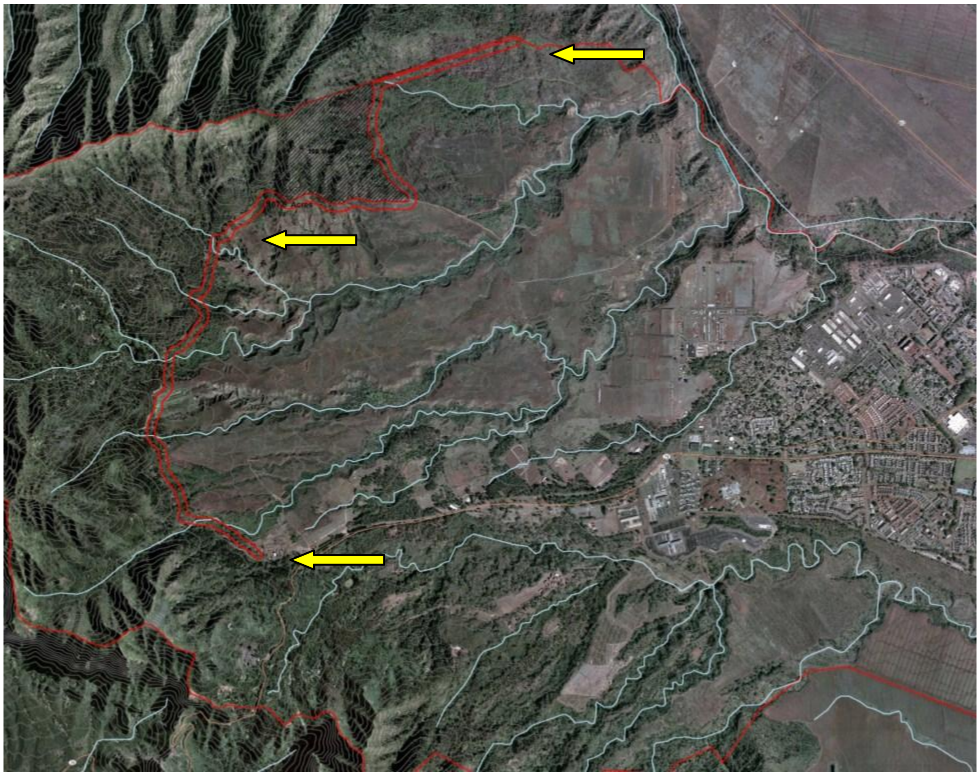


Figure 2. SBMR fire break treatment site extending along road, 2011.

ENV identified a number of fire breaks and fuels management areas at MMR (Figure 3). These areas were described within the "Reinitiation of the 1999 Biological Opinion of the U. S. Fish and Wildlife Service for U.S. Army Military Training at Makua Military Reservation Island of Oahu," dated June 2007. Via helicopter, Team CALIBRE and ENV staff redefined some of the boundaries of the fuels management areas on the slopes and ridges in January 2011. Vegetation conditions changed since these areas were originally defined in 1999. The modified target areas better delineated current grasslands and avoided sites with a tree cover that could resist fire. An additional fuels management area was added by ENV and Team CALIBRE in January 2010 along Farrington Highway at the south end of MMR. The previously defined fire break along Farrington Highway was modified to address cultural resource concerns.

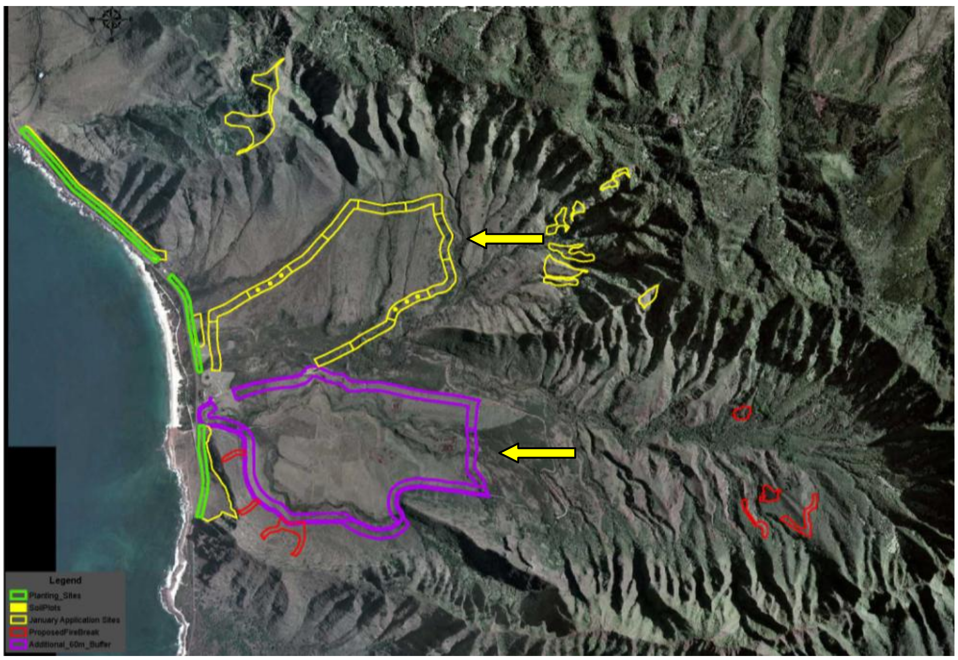


Figure 3. MMR Treatment Sites. Areas denoted in yellow and purple are test plot application sites, 2011.

In January 2011, Team CALIBRE initiated trials of herbicides shown to be effective in controlling target species found at MMR and SBMR, specifically Guinea grass (*P. maximum*)[3] and common broadleaf species[4]. These trials were approved by USAG-HI to provide further information for review and consideration in establishing a research plan necessary for developing an effective IVMP. Based on results of preliminary field monitoring on mortality and long-term control of target vegetation, Team CALIBRE was confident that satisfactory control would be accomplished within all test plots.

Additional sites for treatments in March and May 2011 were identified by Team CALIBRE and ENV staff. These sites were located within the upper slopes and isolated areas of MMR (yellow and red areas in Figure 3) and in the Kahuku Training Area (KTA) (Figure 4) and

[3] Personal communications with Edison Hidalgo supported by unpublished, greenhouse research data conducted by Mr. Hidalgo.
[4] Experience of Team CALIBRE‟s Kevin Eckert

included tree and shrub target species that are not currently present in test plots at SBMR WR or the primary testing sites at MMR.

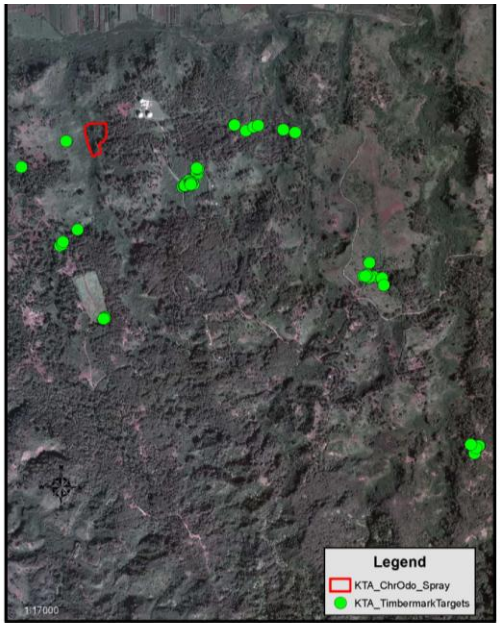


Figure 4. KTA Treatment Sites – Test Plot Application Sites (Green and Red)

2.4. Identification of Research Protocols

To identify specific control methods to be tested, Team CALIBRE reviewed and presented existing data to key Hawaii, US and international vegetation management professionals (referred herein as the Gap Analysis Team) to assist in identification of potentially effective control methods or herbicide applications. The following individuals contributed to this review:

- Michelle Mansker, Joby Rohrer and Jane Beachy, USAG-HI ENV,
- Shannon Payne and Mike Bresell, USAG-HI RD consultants,
- Dr. James Leary, University Hawaii,
- Dr. Diane Drigot, Marine Corps Base Hawaii, Environmental Division,
- Edison Hidalgo, Allen Teshima, and Ronnie Turner, DuPont,
- Matt Kapaliku Schirman, Hui Ku Maoli Ola native plant specialists, and
- Chad Kacir, U.S. Natural Resources Conservation Service.

Based on recommendations of the Gap Analysis Team and expertise of Team CALIBRE, research protocols were identified to allow testing of techniques and methods while protecting sensitive natural and cultural resources. Protocols are described below.

2.4.1 Herbicide Application Equipment

All herbicide applications were conducted using a Bell JetRanger helicopter with a conventional boom and 61 - 0.020 Accuflo nozzles on stainless drop down tubes. The equipment is capable of providing a Global Positioning System (GPS) assisted spray pattern of greater than 1000 micron droplets in a 50-70 foot effective swath (Figure 5). To ensure a safe and effective application of herbicides, the aircraft uses a SATLOC brand GPS navigation system that utilizes a Differentially Corrected Global Positioning System (DGPS) for electronic navigation. All aerial applications and TimberMark spot treatments incorporated GPS-assisted swath placement and/or location to maintain a uniform and precise application. In addition to GPS navigation, the aircraft was equipped with a "real-time" moving map display that showed the treatment site(s), sensitive "no-spray" areas, and areas previously treated. The boom/nozzle configuration (including controlled pressure and nozzle orientation) provides a 95% controlled droplet application, with skips not to exceed 5%. The application equipment and onboard GPS provided GPS guidance information to be exported into a Geographic Information System (GIS) depicting both spray on and off data. The aircraft was equipped with nozzles capable of uniform distribution at the specified rate. Nozzles were directed with the slipstream not to exceed a maximum of 10 degrees downward and nozzles were positioned uniformly along the boom. The spray boom height was at an adequate distance from target species, low enough to obtain proper distribution, uniform coverage and to ensure a safe, accurate, responsible and efficacious treatment. Additionally, the application equipment provided GPS data that was exported into a GIS and supplied to USAG-HI ENV for permanent record and archival. Flight paths (depicted spray and non-spray) and spot treatment locations were recorded and provided to USAG-HI.

Jet Ranger Helicopter

GPS Unit

Application Nozzles

Figure 5. Application equipment used by Team CALIBRE to complete aerial application of herbicides, 2011.

For spot treatments, the helicopter was equipped with the TimberMark™ Aerial Spot Treatment Device (Figure 6), a helicopter-mounted herbicide application device originally designed for marking of timber stands and capable of delivering an accurate spot treatment application of herbicide to small, hard to reach areas. The nozzles provide spot applications using large droplet spray technology (> 1000 micro droplet size) to minimize drift. TimberMark™ utilizes on-board computer controls and a GPS to provide precise application, coverage, and mapping to meet specific target requirements. In addition, the on-board computer provides constant regulation and an accurate GPS record of each application treatment delivered.

TimberMark Unit **Ground View** **Aerial View**

Figure 6. TimberMark application device used by Team CALIBRE.

TimberMark's aerial spray technology was used on individual target trees, small sites and areas that were difficult to access with a helicopter boom. TimberMark was also used to pick up misses, and can be further used to paint mark sensitive area boundaries, and provide treatment of vegetative spots that may re-colonize following the first application.

2.4.2 Herbicide Mixing Protocols

To prevent contamination of test mixes with other herbicides and ensure the integrity of the applications, specific mixing and equipment cleaning protocols were developed by Team CALIBRE based on extensive research experience and subject matter expertise provided by Edison Hidalgo, DuPont's Global Weed Scientist for Specialty Crops.

The standard mixing protocol required that initial herbicide solutions be prepared using only the basic herbicides, such as glyphosate and sulfometuron methyl. Additional herbicides were then added to the basic solution as specified for subsequent test solutions. With this protocol, the first batch to be prepared and applied included the fewest compounds. The next batch prepared contained an increase in the amount of those same compounds or involved the addition of a third compound. Residuals of the previous batch in the hoses were recirculated in the tank to ensure consistent application (Figure 7).

Figure 7. Team CALIBRE's Herbicide Mixing Operation

When eliminating a highly active compound from a batch, including Oust, Escort and/or imazapyr, all mixing and application tanks and equipment were thoroughly cleaned as follows:

- The previous solution was totally drained and all spray tanks, booms and hoses were thoroughly rinsed with clean water.
- The tank was filled with clean water and a commercially approved spray tank cleaner or one gallon of household ammonia for every 100 gallons of water.
- Cleaning solution was circulated through the tank and hoses for at least 15 minutes;
- Hoses, booms, and nozzles were flushed with the cleaning solution,
- Nozzles and screens were removed and cleaned separately in a bucket containing cleaning agent and water,
- Rinsate was disposed of on a labeled site or at an approved waste disposal facility (if a commercial cleaner was used, label directions for disposal of rinsate were followed),
- Steps above were repeated when the tank was empty, rinsing with equivalent amounts of an ammonia solution to better solubilize sulfometuron methyl in the cleanout procedure,
- A final rinse of the tank, boom, and hoses was completed with clean water

For small batches, test batches were mixed in separate tanks that were either new or cleaned according to the established protocol.

2.4.3 Weather Considerations

Efficacy of herbicide applications can be influenced by precipitation and off-target movement by wind. Application of herbicides did not take place when wind speed was variable, when wind speed created a significant off-site herbicide drift potential, or during periods of rain or predicted heavy rain. The threshold for discontinuing applications during precipitation was when water could be observed flowing off leaves. If heavy rain was forecasted within 1 hour of application, then applications were discontinued since herbicide could be washed off the leaves and the application could become ineffective. "Rainfast windows" refer to the time required for the product to pass through the leaf cuticle and get into the plant. The rainfast window for Garlon 4 Ultra is 45 minutes, for

Roundup Pro Max it is approximately one hour before a heavy rain. Conversely, Oust XP needs to be "watered" into the soil. Therefore, a moderate rain (not heavy precipitation that erodes soil) is beneficial to carry the herbicide into the soil where it is absorbed into the target plants. Thresholds are dependent on the product being used.

2.4.4 UXO Considerations

Given the history of weapons testing on MMR and SBMR, hazards from UXO are present[5]. To minimize risks from UXO, wherever UXO may be present, U.S. Army EOD staff accompanied Team CALIBRE during on-site data collection to assess vegetation conditions prior to treatment and at post-treatment intervals.

2.4.5 Cultural Resources Considerations

Numerous, sensitive archeological sites are located on MMR and SBMR[6,7]. Many of these sites are identified, but the presence of UXO, difficult terrain, heavy vegetation cover and lack of records potentially render some sites undiscovered at this time. To avoid damage to sensitive archeological sites, no sites were disturbed without consultation and approval of the USAG-HI Cultural Resources Division (CR).

USAG-HI CR advised that aerial applications conducted at SBMR would not adversely impact archeological sites and therefore no identification was required[8]. Ground activity conducting soil sampling and installation of plants at MMR did pose the potential for disturbance of archeological sites. USAG-HI CR provided Team CALIBRE with maps and GIS polygons to overlay and site each archeological site on treatment maps. No soil disturbance will be conducted until completion of a Section 106 permit process and approval by the USAG-HI CR.

Soil disturbance for sampling was postponed due to delays in completion of the Section 106 permit process initiated by USAG-HI CR.

---

[5] Personal communication with Vic Garo, RD.

[6] Personal communication with Michelle Mansker, ENV.

[7] Site List and Terrain Analysis for the Identification of Public Access Priorities, Makua Military Reservation, Oahu, Hawaii, February 2009.

[8] Personal communication with Alton Exzabe and Lauren Morawski, USAG-HI Environmental Division Office, January 10, 2011.

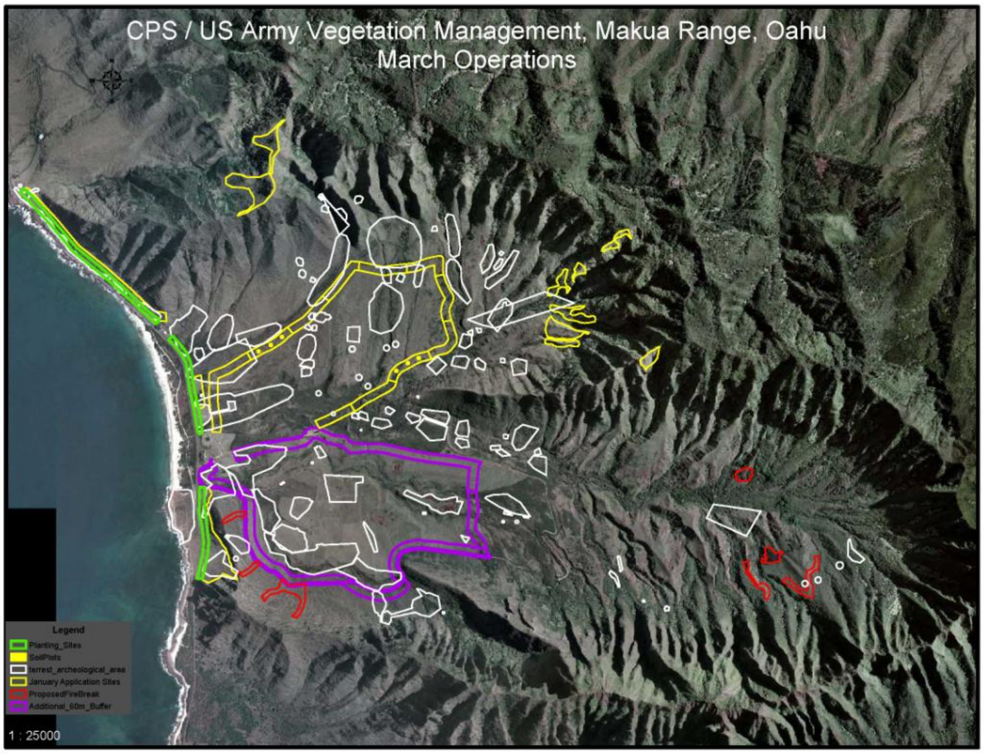
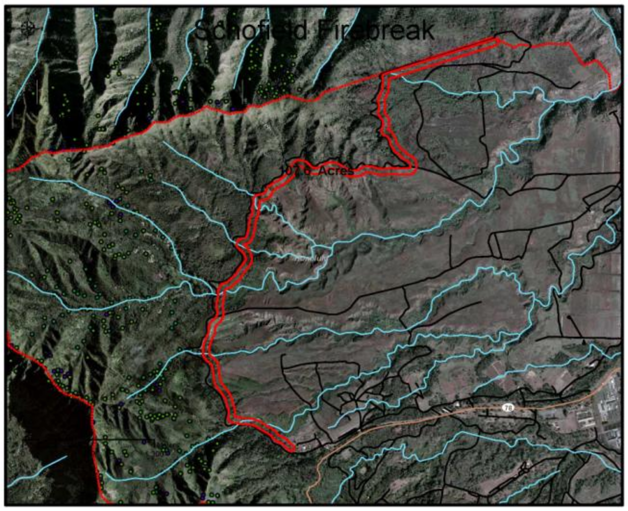


Figure 7. MMR Cultural Resources Sites (White)

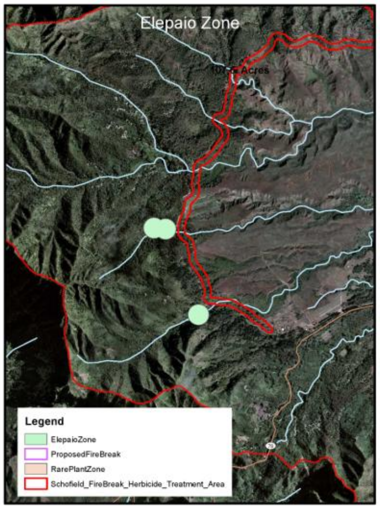
2.4.6 Marking of Test Plots and Sensitive Sites

USAG-HI provided Team CALIBRE with GIS polygons that identified application sites and sensitive sites. Sensitive sites that were identified included defined archeological sites shown in Figure 7 above, threatened and endangered (T&E) species locations, and native plant locations (Figure 8). In order to ensure sensitive sites were avoided during herbicide applications, Team CALIBRE added these polygons to planning maps and the helicopter GPS guidance system used during applications. Pre-spray maps were created and provided to USAG-HI ENV for review prior to uploading into the helicopter guidance system. All sensitive area data provided by USAG-HI to Team CALIBRE were buffered by at least 100 feet to ensure drift was not an issue. Team CALIBRE relied on USAG-HI ENV or RD to indicate whether or not sensitive sites were already buffered when data were provided.

MMR T&E Species Locations



SBMR T&E Species Locations



SBMR Elepaio Buffer Zones

Figure 8. Threatened and Endangered Species and Sensitive Areas Associated with MMR, SBMR.

In order to accurately treat designated test plots and avoid sensitive sites, the helicopter pilot used the data entered into the GIS navigation system aboard the helicopter. The pilot entered the unique identifier assigned to the specific test plot into the helicopter GIS navigation system, which displayed the plot polygon and provided navigation guidance to permit the pilot to fly to the site. Sensitive area data were displayed whenever they were near to the treatment site. The pilot applied the herbicide solution to the designated site using the GIS screen. The GIS screen depicted the treatment site and surrounding area and illustrated the exact area where the application was applied by showing a green swath on the GIS screen. The application area was highlighted on the GIS screen when the application boom was activated and then discontinued when the application boom was shut off. The green highlighting on the GIS navigation screen enabled the pilot to see exactly where the application boom was activated over the ground and avoid application skips, over-sprays and direct applications to properly marked sensitive sites.

2.4.7 Vegetation Data Collection

Measurement of vegetation conditions was conducted through visual surveys and photos. A vegetation data collection schedule identified in October 2010 was initiated in January 2011 to define the pre-treatment population condition (immediately prior to or at treatment) and establish a baseline to help measure treatment efficacy post-application at the following intervals:

- 2 weeks after treatment,
- 6 weeks after treatment,
- 12 weeks after treatment,
- 24 weeks after treatment, and
- Continuing at 12 week intervals until vegetation populations reach stable composition and density, or further treatments are conducted.

A total of 19 test plots were established (see Figure 2 in Section 2.3 Identification of Specific Trial Areas). Each test plot included three vegetation sample sites (Figure 9). The number of subsequent survey plots was determined by the coefficient of variability between all of the survey plots within each treatment plot and to provide reasonable sample distribution throughout the plot.

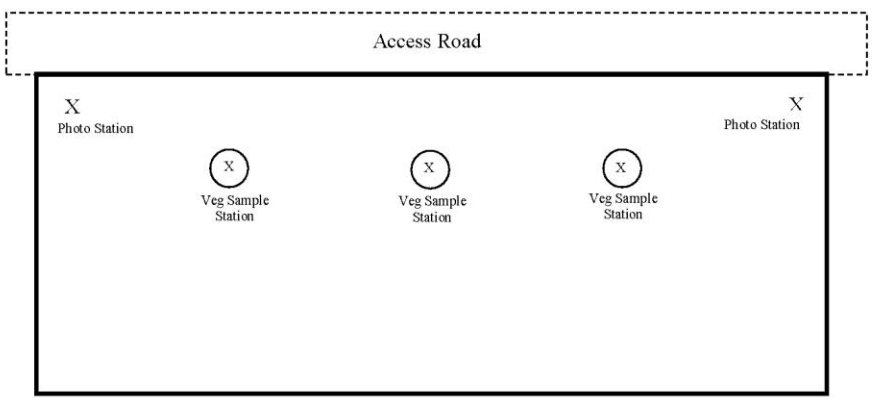


Figure 9. Vegetation Survey Plot Layout, USAG-HI, 2011.

To provide consistency and remove bias, vegetation sample sites were located 250 feet from each end of the plot and 100 feet from the front boundary. The third survey plot was located in the measured center of the treatment plot. The center of each vegetation sample site is marked with a flagged stake.

Each vegetation sample site was round and included 1/10 of an acre measured as a radius of 33 feet from the staked center point. Data collection was conducted visually using the

Braun-Blanquet method of vegetation measurement recommended by the US Forest Service.[9] Braun-Blanquet is a system that was used successfully by CPS and Arbor Global during previous vegetation community monitoring research projects, and was used extensively by Dr. William C. Bramble, Professor of Forestry (ret.), Pennsylvania State College, to measure and analyze vegetation community conditions and eco-system changes resulting from various vegetation management treatments.[10] Braun-Blanquet is a method of describing the characteristics of a vegetation community. It was devised by J. Braun-Blanquet in 1927 to survey large areas very quickly. Two scales are used. One consists of values from 1 to 5 that define the proportion of the area covered by the subject species. The second scale defines species sociability, or grouping. Data were collected within defined plot areas. The review and estimation of the percent coverage and sociability of vegetation within each survey plot is recorded.

Two photo stations were established for each treatment plot to provide a general comparative overview of vegetation conditions. Each photo station was located at a distance of 50 feet from the front and 50 feet from the end of the treatment plot. Photo stations were marked with a flagged stake. Photos were recorded while standing on the photo station location and shooting in a direction toward the plot corner on the opposite side and furthest diagonal corner of the treatment plot to capture a view as broad as possible of the vegetation condition in each plot (Figure 9). The field of view within the photo frame was aligned to capture the best rendition of vegetation conditions. To standardize photos, the upper border of the frame was aligned and centered with the opposite side and furthest corner of the treatment plot. The photographer made all reasonable effort to standardize the field of view across successive photos.

2.4.8 Soil Sampling

Measurement of the fate and mobility of the herbicide hexazinone was conducted through analysis of soil samples at various soil depths and time progression according to Arbor Global and CPS's extensive experience testing the fate and mobility of field applications of herbicides and according to sampling protocols used by Dr. Norton Nickerson[11]. Hexazinone was selected for measurement because it is the most persistent and mobile herbicide applied. The research team believed that if hexazinone did not move significantly, then other herbicides with lower environmental fate and mobility would not persist or move off-site.

A recent pesticide leaching study, performed by Chittaranjan Ray, et al. at the University of Hawaii Water Resource Research Center[12], described four agricultural herbicides, including

---

[9] General Technical Report PSW-GTR-144-Web. United States Department of Agriculture Forest Service, Pacific Southwest Research Station.
[10] Yahner, Richard H. and Hutnik, Russell J. Integrated Vegetation Management on an Electric Transmission Right-of-way in Pennsylvania. U.S. Journal of Arboriculture 30(5): September 2004.
[11] Nickerson, Norton H. Impacts of Vegetation Management Techniques on Wetlands in Utility Rights-of-Way in Massachusetts. Journal of Arboriculture 18(2). March 1992.
[12] Ray, Chittaranjan, et. al. Leaching of Selected Pesticides in Hawaii Soils as Influenced by Soil Properties and Hydrologic Conditions: Field and Laboratory Evaluations. Water Resource Research Center, University of Hawaii. July 2007.69pp.

sulfometuron methyl, as having the potential to leach given the volcanic ash soils present on Hawaii. Ray et al. did not test the influence of heavy vegetation cover, comparable with that found with Guinea grass populations at USAG-HI, on leaching potential. Rates of sulfometuron methyl that were applied by Team CALIBRE were lower than Ray et al used. Further, Team CALIBRE believes that if its testing shows that hexazinone does not leach in these conditions, then sulfometuron methyl would be less likely to leach based on the Ray et al. results.

Approval for sub-surface soil sampling and other work that requires excavation requires completion of the Section 106 National Historic Preservation Act consultation process. Since approval from USAG-HI CR was not received at the time this report was finalized, no sub-surface samples were collected for analysis.

Surface soil samples were collected from three vegetation sample sites within each plot where the higher rates of hexazinone were applied and mixed to form one sample for each soil depth. These sites were located at the same location as the vegetation data collection sites shown in Figure 3. Data were initially collected during herbicide applications using surface-mounted collection materials as recommended by the Pesticide Branch of the Plant Industry Division of the Hawaii Department of Agriculture. Initial data were collected using 16 collection units placed on the soil surface at each defined soil sample site. Collection units were arranged on the ground in a systematic pattern with one unit placed at each of the cardinal and intermediate compass points at a distance of three feet from the staked center of the sample plot. The next row of units was placed at each of the cardinal and intermediate compass points at a distance of six feet from the staked center of the sample plot. Samples were removed immediately after application, bagged, and sent to the Analytical Pesticide Technology Laboratories, Inc. in Reading, Pennsylvania for analysis.

Team CALIBRE strongly recommends sub-surface sampling be completed upon receiving USAG-HI CR to complete fate and mobility research. The first samples should be collected at the soil surface in a location just under the litter layer, and at a depth of six inches. Subsequent samples should be collected at the soil surface, just under the litter layer, and at depths of six and 12 inches. We recommend deeper samples be collected if significant amounts of hexazinone are found at the 12 inch sample. Significant amounts are defined as exceeding established detectable thresholds as defined by the State of Hawaii and/or US Environmental Protection Agency (EPA). To avoid contamination of each sample from previous excavations, test pits should be separated. This technique will eliminate the risk of false readings within previous test pits where soil was disturbed by digging for sample collection and excess soil from current testing is disposed. We recommend test pits be dug a measured distance of three feet to the west of the sample site center at 12 weeks, and three feet to the east of the sample site center at 24 weeks. Samples should then be taken three feet to north of the sample site center and then three feet to the south of the sample site center. Subsequent samples, if required, may be taken following this same pattern, but at distances of six feet from the sample site center.

3. Results

Team CALIBRE's review of existing literature, evaluation of site conditions at SBMR and MMR, and personal communications with subject matter experts led to the following results:

1. Fire has been a significant management factor at both MMR and SBMR for decades. Due to the presence of T&E species, sensitive habitats, cultural sites and personnel, fire prevention is key to protecting these resources as specified in the INRMP 2010-2014, Island of O'ahu. The richness of the soils, the repeated range fires, the steep terrain, and the past management history have encouraged the establishment of tall growing invasive grasses (Guinea grass) and brush. The spread of the invasive plants, enhanced by uncontrolled fires, continues to diminish the T&E habitat both surrounding and within the ranges.

2. Management of Guinea grass has been accomplished using several control methodologies. The two most common techniques are mechanical mowing and periodic broadcast aerial herbicide applications. Both are temporary solutions (efficacy lasting 6 months or less) that allow for military training to continue until the grasses re-vegetate the range. Herbicide application with a follow-up prescribed burn has been used extensively at SBMR. This combination results in creation of bare ground, which increases erosion of these volcanic soils and creates a negative aesthetic response from the general public. Several issues with the past application techniques have also been found and corrected. Biological control through grazing has been successful; however, cultural and logistic restrictions prevent employing this technique as a primary management alternative (personal communication with Michelle Mansker).

In order to fill gaps in research and better lay a foundation for the IVMP, Team CALIBRE initiated preliminary testing of herbicides known to control Guinea grass and other problematic invasive plants in January, March and May of 2011. Preliminary results indicate varied results ranging from poor to promising based on the products and combinations applied. Continued testing is essential to determine whether rates of herbicide applied or height and biomass of the target species were related to the variation in results. Past herbicide research has shown that treatments are more efficacious when plants are young and growing (personal communication with Edison Hidalgo, DuPont). Further testing involving an earlier application or a combination of mowing and herbicide would be beneficial.

3.1. Analysis of Existing Data and Current Conditions

Interviews of key individuals and an analysis of existing data and site conditions, led Team CALIBRE to several conclusions regarding the current state of vegetation at SBMR and MMR and the desired end state.

3.1.1 Topography and Soils

The SBMR WR is located within the central plateau of Oahu, on the eastern slopes of the Waianae mountain range and encompasses approximately 2,200 acres. The SBMR WR is characterized by folded terrain with deep gullies cutting the area into several compartments. The topography transitions from relatively flat terrain gradually increasing in slope to the base of the steeper elevations of the Waianae Range.

The United States Soil Conservation Service (SCS)[13] indicated there were two primary soil associations within the SBMR WR. These included the Tropohumults-Dystrandepts (T-D) and Helemano -Wahiawa (H-W) soil types. The SCS described the T-D soils as "gently sloping to very steep, well-drained soils that are underlain by soft weathered rock, volcanic ash, or colluvium; on narrow ridges and side slopes." The SCS described the H-W soils as "deep, nearly level to moderately sloping, well-drained soils that have a fine-textured subsoil: on uplands." The "Integrated Natural Resources Management Plan 2010-2014, Island of O'ahu"[14] further defines primary soil types within the treatment impact area as Helemano silty clay, Kolekole silty clay and Kunia silty clay with characteristics comparable to that described within SCS 1972 (Figure 10).

[13] Site List and Terrain Analysis for the Identification of Public Access Priorities, Makua Military Reservation, Oahu, Hawaii, February 2009.
[14] Integrated Natural Resources Management Plan 2010-2014 Island of O'ahu U.S. Army Garrison Hawai'i.
Center for Environmental Management of Military Lands, Colorado State University, Fort Collins, Colorado. Figure 2.3.f, page 87.

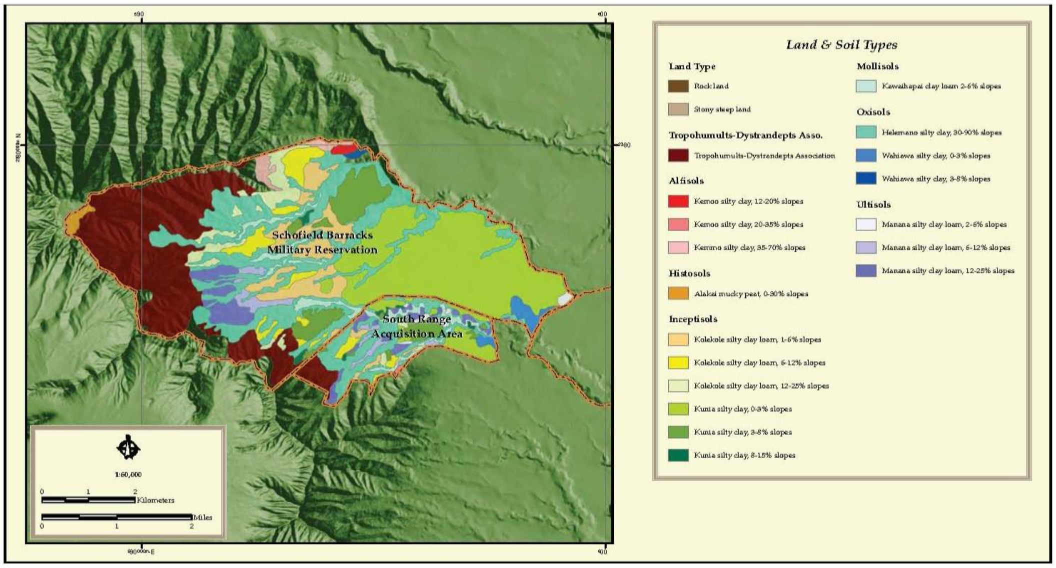


Figure 2.3.f

Figure 10. SBMR WR Soils Map (source: "Integrated Natural Resources Management Plan 2010-2014 Island of O'ahu")

MMR, situated on the western slopes of the Waianae mountain range, covers 4,856 acres. The Range is bordered by steep cliffs, which begin at Farrington Highway near the southwest corner of the property, and surround the impact area.

The SCS 1972 study suggested there were two primary soil associations within the MMR. These include the Lualualei-Fill land-Ewa (L-E) and Rocky land - Stony steep land (R-S) soil associations. The L-E association encompassed the valley where the primary test plots for this study are located. The SCS described the L-E soils as "deep, nearly level to moderately sloping, well-drained soils that have a fine-textured or moderately fine textured subsoil or underlying material, and areas of fill land; on coastal plains." The SCS described the R-S soils as "steep to precipitous, well-drained to excessively drained, rocky and stony land." This assessment was also supported by the Land and Soil Types description within the "Integrated Natural Resources Management Plan 2010-2014 Island of O'ahu" (Figure 11).

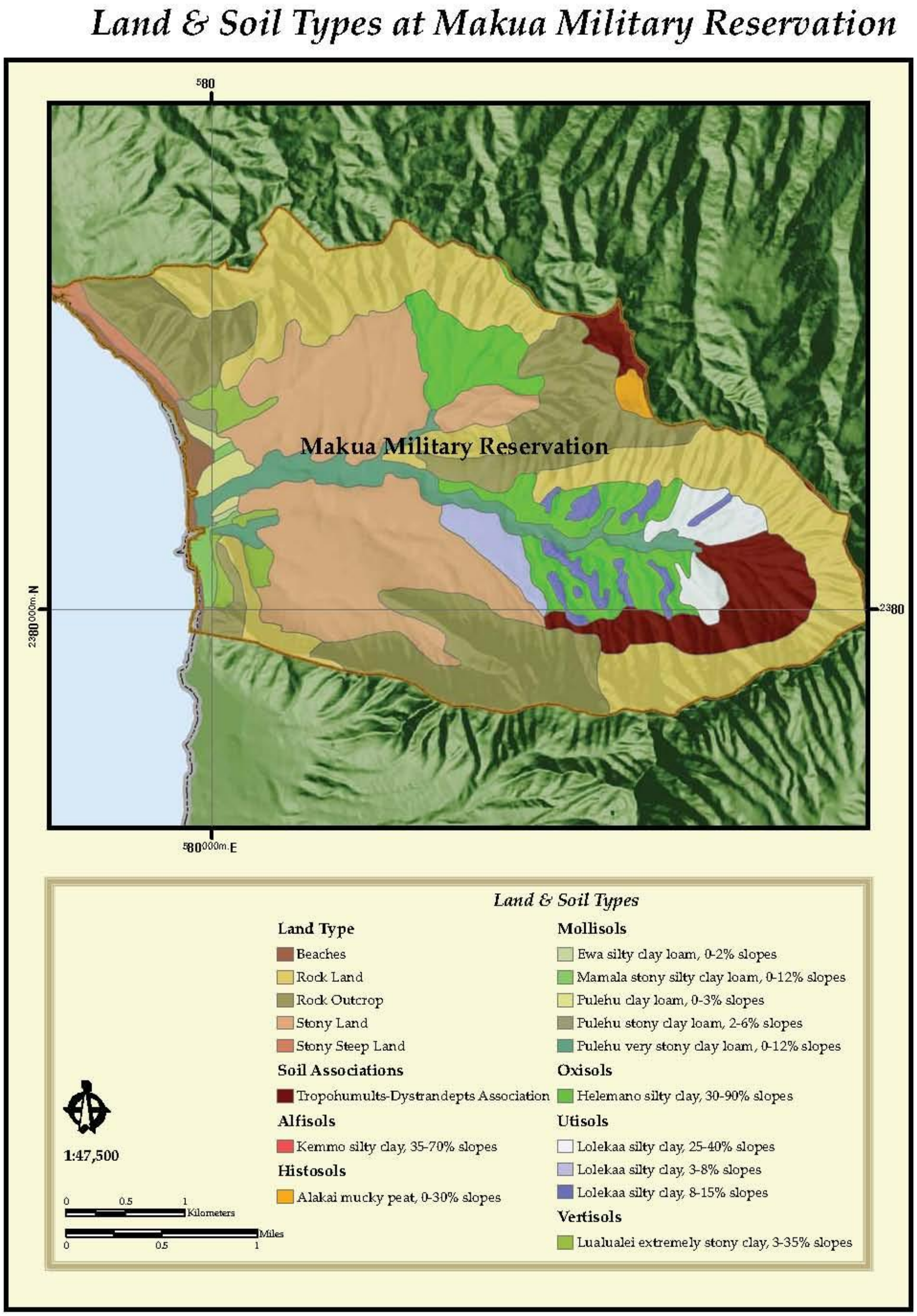


Figure 2.8.f

Figure 11. MMR Soils Map (Source: "Integrated Natural Resources Management Plan 2010-2014 Island of O'ahu")

Vic Garo, Chief Operations Officer, RD, informed Team CALIBRE that RD practices erosion control measures as necessary to stabilize and minimize soil erosion.

3.1.2 USAG-HI RD Vegetation Treatment Methods

Prevention of unplanned fires and control of the spread of fires is critical to protect people, property and natural resources. Wildfires and their suppression pose significant risks to personnel, property, cultural resources, and T&E species and their habitat[15].

Fires were a relatively common occurrence at MMR prior to the 1998[16]. Since 2004, when the MMR was closed to live fire training, there were few recorded fires[17]. The most significant fires within the past 10 years include:

- July 24 -25, 2010. Initiated by arson and burned approximately 486 acres[18].
- July 22, 2003. Initiated by a prescribed burn escape and burned approximately 2,100 acres[19].

Fires at SBMR WR are relatively common due to the frequent live-fire training conducted. These fires are most commonly ignited by ammunition. Range management staff on-hand during live fire exercises control fires as quickly as possible.[20] Sizes of fires vary from less than one acre to over 300 acres, but most are less than 1 acre.[21] Prescribed burning on the SBMR WR impact area occurs annually following the spring herbicide treatment.

Ignition and spread of fires is primarily facilitated by fuels created by tall growing grasses and brush.[22] After fires are established, they burn larger brush and trees and travel with wind to off-site locations that contain native habitat, including threatened and endangered species.[23] The steep terrain and poor access caused by UXO and topography restrict the ability to most effectively contain and control fires.[24]

Analysis of the herbicide-burn-herbicide vegetation management method used by USAG-HI at SBMR indicated the approach was aggressive and costly and failed to provide a long-term solution[25] as demonstrated by observations of SBMR application results by Team CALIBRE from 2007 through the present and communications with Vic Garo, Chief Operations Officer, RD and Allen Teshima, DuPont. This methodology provided an

---

[15] Beavers, Andrew M.; Burgan, Robert; Fujioka, Francis; Laven, Richard D.; Omi, Philip N. Analysis of Fire Management Concerns at Makua Military Reservation. Center for Ecological Management of Military Lands, Colorado State University. Fort Collins, CO. December 1999. Page 4.

[16] Personal communication. Vic Garo, Chief Operations Officer, RD; Michelle Mansker, Natural Resource Manager, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV; Jane Beachy, Ecosystem Restoration Program Manager, ENV.

[17] Personal communication. Michelle Mansker, Natural Resource Manager, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV.

[18] Memorandum For Record. SUBJECT: North Makua Fire July 24-25, 2010. IMPC-HI-PWA. 29 July 2010.

[19] Memorandum For Record. SUBJECT: Makua Military Reservation Natural Resource Post Fire Assessment APVG-GWV (200-3). 30 July 2003.

[20] Personal communication. Vic Garo, Chief Operations Officer, RD.

[21] Beavers, Andrew M.; Burgan, Robert. Wildland Fire Risk and Management on West and South Ranges, Schofield Barracks, Oahu. Center for Ecological Management of Military Lands, Colorado State University. Fort Collins, CO. March 2001. Page 8.

[22] Beavers, Andrew M.; Burgan, Robert. Wildland Fire Risk and Management on West and South Ranges, Schofield Barracks, Oahu. Center for Ecological Management of Military Lands, Colorado State University. Fort Collins, CO. March 2001. Page 2.

[23] Personal communication. Vic Garo, Chief Operations Officer, RD; Michelle Mansker, Natural Resource Manager, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV.

[24] Beavers, Andrew M.; Burgan, Robert. Wildland Fire Risk and Management on West and South Ranges, Schofield Barracks, Oahu. Center for Ecological Management of Military Lands, Colorado State University. Fort Collins, CO. March 2001. Page 35.

[25] O„ahu Integrated Natural Resource Management Plan. Section 1.10.1. Page 54.

immediate solution, but only short-term reduction in fuels. Within six months, Team CALIBRE and Allen Teshima observed target species, primarily Guinea grass (*P. maximum*), reestablished and increased fire fuels. Herbicide solutions were applied by aerial applications and were reported to be glyphosate and sulfometuron methyl. However, limited funds, tools, materials and practices significantly affected the ability of USAG-HI RD to efficiently control vegetation issues within SBMR. In addition, a growing season that extends for 12 months with periods of limited rainfall tended to exacerbate the vegetation and fire control issues on SBMR.

Additionally, installations are constrained to work within the three 2004 Measures of Merit (MOM) for Pesticide Management.[26] The MOM requires the creation of an installation pest management plan, certification of all applicators, and encourages the reduction of the lbs per acre of active ingredient applied annually since 1993. Any effective control strategy with a reduction in active ingredient usage will be beneficial to maintaining an effective and acceptable vegetation management program.

In 2008, CPS found evidence of procedures that could lead to low efficacy associated with herbicide mixing and applications. Ron Lemin of CPS worked as a batching employee during the 2008 summer application to the SBMR impact area. The mixing and application equipment and practices that had been used previously were employed during this 2008 application. During the mixing process, Mr. Lemin used a conductivity meter to measure the alkalinity (indication that the herbicides were mixed uniformly within the batch tank) of the herbicide within the solution that was applied. Mixing of the herbicide solution was performed only by agitation with the water fill hose (the batching system did not have mechanical or pump agitation). The conductivity readings showed that all of the herbicide was concentrated on the bottom of the batch tank with very little at the top. The result was that applications of the solution from the top of the mix tank did not contain adequate herbicide while solution from the bottom of the tank contained excessive herbicide concentrates. This would result in inadequate control in some areas and adequate control in other areas. This system therefore had proven to be inadequate for applications conducted by Team CALIBRE on any sites under contract with the DOD.

A batching system with effective agitation and circulation is essential in providing uniform mixing of both the amine formulation of glyphosate and the water dispersed granules of the sulfometuron methyl. For the 2010-2011 treatments conducted under this study, a new system was built by Team CALIBRE to facilitate in the application process.

Mr. Lemin also installed a hand held GPS unit in the helicopter to document application coverage. The historic practice to direct the helicopter in its field applications was for the pilot to use ground-based visual cues from a large paper map provided by USAG-HI RD. The GPS readings showed that this system results in significant gaps in ground coverage in many areas with excessive overspray of other areas that are treated multiple times. Additionally, it was impossible to determine where the heavy rates and the weaker rates were applied on the impact area.

[26] Goodman, Sherri,W.:Deputy Under Secretary of Defense, Memorandum for Defense Environmental Council. May 16, 1995.

Creating a bare ground habitat, as is the current management protocol, reduces the risk of fire, but is only a temporary solution. The first plants to reestablish on the area are aggressive invasive species, usually Guinea grass (*P. maximum*). In the meantime, the exposed ground promotes runoff that can result in water quality problems. The unattractive, brown, bare site is also visible to the public as they travel the roads adjacent to SBMR. On several occasions pictures of the SBMR impact area following herbicide treatments or prescribed burning have appeared in the Honolulu paper.

Although it has not been scientifically determined, there may be a glyphosate resistance issue that has built up on the SBMR WR impact area.[27] Repeated applications of glyphosate (2 per year) over the last decade might lead to a resistant phenotype of Guinea grass that would create a different problem. Glyphosate resistance is a known phenomenon in many areas of vegetation management, but it would only be a theory without further testing.

3.1.3 Vegetation Conditions (SBMR WR)

During site visits of SBMR WR, Team CALIBRE found that the majority of the target area is covered with grass. Deep gullies are covered with grass, low shrubs and small trees. Guinea grass (*P. maximum*) is the primary vegetative cover on SBMR WR. Within the SBMR WR firebreak system, the primary invasive species include Guinea grass (*P. maximum*), haole-koa (*L. leucocephala*), Christmas berry (*S. terebinthefolia*), albizia (*Falcataria moluccana*), Cook-pine (*Araucaria columnaris*), lemon-scented gum (*Eucalyptus citriodora*), and silk oak (*Grevillea robusta*). Many other invasive species are present within the firebreak; however, the species listed above are the most common. Native plant species are found within the SBMR WR, but were not present in any significant numbers. Most native species were found outside the firebreak on the surrounding slopes.

3.1.4 Vegetation Conditions (MMR)

During site visits of MMR, Team CALIBRE found that the majority of the target area is covered with grass, low shrubs and scattered clumps of trees. Guinea grass (*P. maximum*) is the primary vegetative cover on the lower elevation areas and many sites that have burned on the slopes, outside of the firebreak system. Within the firebreak, populations of haole-koa (*L. leucocephala*) and klu (*Acacia farnesiana*) are also common within the primary test plot area. Primary invasive species found on cliffs, in the upper valley, and on ridge tops include Guinea grass (*P. maximum*), molasses grass (*Melinis minutiflora*), haole-koa (*Leucaena leucocephala*), China berry (*Melia azedarach*), albizia (*Falcataria moluccana*), ironwood (*Casuarina equisetifolia*), silk oak (*Grevillea robusta*), eucalyptus (*Eucalyptus robusta*), kukui (*Aleurites moluccana*), and African tulip (*Spathodea campanlulata*). Other invasive species are present, but those listed above are the most common.

Native plant species were also found within MMR, and were present in significant numbers within actively protected sites, outside of the firebreak system. These include populations of akoko *(Chamaesyce celastroides var. kaenana),* a'alili *(Dodonaea viscosa),* wiliwili

[27] Personal communication with Jeffery Phillips, Monsanto and "Facts About Glyphosate – Resistant Weeds" Chris Boerboom, University of Wisconsin; Micheal Owen, Iowa State University, published by Cooperative Extension Service, Purdue University.

(Erythrina sandwichensis), and maʻo hau hele *(Hibiscus brackenridgei).* Other native and T&E species are also present and are primarily found on upper elevations, outside of the firebreak system. Species lists are maintained and populations monitored and protected by USAG-HI as required under The "Integrated Natural Resources Management Plan (INRMP) 2010-2014 Island of O"ahu".

3.1.5 Vegetation Conditions (Kahuku Training Area)

In cooperation with ENV, Team CALIBRE conducted special treatments at the Kahuku Training Area (KTA) to test effectiveness of various herbicide solutions on challenging species. Vegetation condition assessments were not conducted by Team CALIBRE. ENV team members identified test sites and individual trees for treatment. Species treated included *Chromolaena odorata, Falcataria moluccana, Cupressus lusitanica, Toona ciliata, Ficus microcarpa, Spathodea companulata, Trema orientalis, Syzigium cumini, Falcataria moluccana,* and *Grevillea robusta*.

3.1.6 Vegetation Conditions Summary

Guinea grass (*P. maximum*) is the most common and noxious of the invasive, fire spreading species found on MMR and SBMR. This species is fast growing and capable of maximum growth rates of six inches to one foot per week with a maximum height of approximately 10 feet. Guinea grass is hard to control, and creates a substantial fuel load, measured at 4 to 9 tons per acre in MMR and 2 to almost 12 tons per acre in SBMR[28]. This grass will grow on or near any open section of bare ground and is normally the first species to re-emerge after herbicide treatments and prescribed or wildfire burns. Guinea grass grows well in dry, sunny areas and invades and disrupts the function of firebreaks, as well as interferes with the use of a vast majority of the training and Range areas.

Off-site areas surrounding SBMR and MMR include T&E species and desirable native plants.[29] Fire breaks and fuels management areas were established to protect these species and habitat adjacent to the Ranges. Because of vegetation challenges associated with invasive species, it is not uncommon for fire to jump firebreaks or circumvent the fuel management areas and burn into the protected zone.[30] Due to the presence of Guinea grass, the Bureau of Land Management (BLM) Fire Rating in the impact area in the dry season increases and, consequently, the range is closed to critical live fire training with incendiary munitions.[31]

3.2. Preliminary Trials of Herbicide Application

Mr. Edison Hidalgo at the DuPont Stine-Haskel Research Center[32] performed extensive research (Figure 12 and 13) both in the field and in greenhouse studies on control of

[28] Ellsworth, Lisa and Litton, Creighton. "Using Soil Moisture and Weather Variables to Predict Live and Dead Fuel Moisture in Guinea grasslands (*Urochloa maxima*) on Oahu, Hawaii". University of Hawaii at Manoa. Natural Resources and Environmental Management.

[29] Observations of Team CALIBRE and Personal communications with Michelle Mansker, Chief, Natural Resource, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV.

[30] Observations of Team CALIBRE and Personal communications with Vic Garo, Chief Operations Officer, RD; Michelle Mansker, Chief, Natural Resource, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV.

[31] Personal communications with Vic Garo, Chief Operations Officer, RD.

[32] Edison Hidalgo, 2006, Internal DuPont research, Stine_Haskel Research Center, Newark DE.

Guinea grass with DuPont chemistries (Weestar, Oust XP, Oustar, and Velpar) and found that 1-4 oz of sulfometuron methyl (Oust XP) to be efficacious on Guinea grass. The best results occur when the grass is young and actively growing.[33]

Guineagrass Study
***Panicum maximum* (PANMA) @ 28 DAT**

SP-2006-040
Application Date: 9/22/06
Rating Date: 10/20/06 28DAT

Treatments and Rates:

		PANMA % of Control			
Treatment	ozai/A	A	b	c	AVG
Oustar	2.9	30	30	20	26.7
Oustar	5.7	40	50	50	46.7
Oustar	11.4	70	60	60	63.3
Oustar	14.3	70	80	100	83.3
Westar	2.9	30	30	30	30.0
Westar	5.7	60	50	40	50.0
Westar	11.4	100	70	40	70.0
Westar	14.3	75	80	85	80.0
OUST	0.5	60	60	50	56.7
OUST	1.0	70	75	70	71.7
OUST	2.0	80	85	80	81.7
OUST	4.0	85	80	98	87.7
Velpar-K +OUST	17+0.5	30	30	30	30.0
Velpar-K +OUST	17+1.0	50	40	40	43.3
Velpar-K +OUST	17+2.0	60	60	70	63.3
Check		0	0	0	0

Figure 12. Guinea grass Control Prescriptions and 28 Day Results Tested by Edison Hidalgo at DuPont's Stine-Haskel Research Center in 2006.

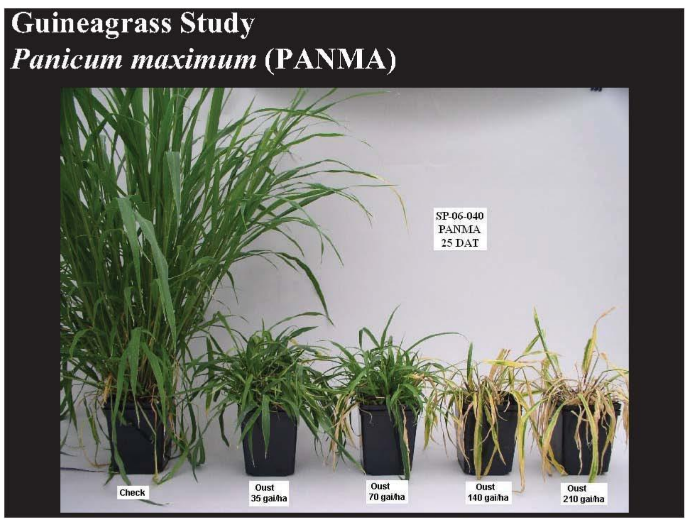


Figure 13. Guinea grass Control 28 Days Post Treatment With, 1, 2, 3, and 4 Ounces of Oust XP.

In January 2011, Team CALIBRE began conducting preliminary testing of combinations of herbicides (Figure 14) that are proven to be effective on the primary target species present, which are Guinea grass, haole-koa and Christmas berry. Chemical formulations were applied at various rates within various solutions to test efficacy. Initial applications were based on the extensive experience of Team CALIBRE and Edison Hidalgo of DuPont.

[33] Personal communications with Edison Hidalgo supported by unpublished, greenhouse research data conducted by Mr. Hidalgo.

Prescription Name	Chemical	Amount
Standard Solution	Glyphosate (Roundup ProMAX)	44.5 oz.
	Sulfometuron Methyl (Oust XP)	4 oz.
	Methylated seed oil (MSO)	13 oz. (1%)
Test 1	Hexazinone (Velpar DF)	.5lbs
	Sulfometuron Methyl (Oust XP)	1.6 oz.
	MSO	13 oz. (1%)
Test 2	Hexazinone (Velpar DF)	.74lbs
	Sulfometuron Methyl (Oust XP)	2.2 oz.
	MSO	13 oz. (1%)
Test 3	Hexazinone (Velpar DF)	.95lbs
	Sulfometuron Methyl (Oust XP)	2.8 oz.
	MSO	13 oz. (1%)
Test 4	Hexazinone (Velpar DF)	1.16 lbs
	Sulfometuron Methyl (Oust XP)	3.4 oz.
	MSO	13 oz. (1%)
Test 5	Hexazinone (Velpar DF)	1.6 lbs
	Sulfometuron Methyl (Oust XP)	4 oz.
	MSO	13 oz. (1%)
Test 6	Hexazinone (Velpar DF)	.5 lbs
	Sulfometuron Methyl (Oust XP)	4 oz.
	MSO	13 oz. (1%)
Test 7	Hexazinone (Velpar DF)	.5 lbs
	Sulfometuron Methyl (Oust XP)	4 oz.
	Metsulfuron Methyl (Escort)	1.5 oz.
	MSO	13 oz. (1%)
Test 8	Hexazinone (Velpar DF)	.5 lbs
	Lineage Prep	20 oz.
	4.1 oz. Sulfometuron Methyl (Oust XP)	
	1.4 oz. Metsulfuron Methyl (Escort)	
	43.6 oz. Imazapyr (Arsenal)	
	MSO	13 oz. (1%)
Test 9	Glyphosate (Roundup ProMAX)	44.5 oz.
	Lineage Prep	20 oz.
	4.1 oz.Sulfometuron Methyl (Oust XP)	
	1.4 oz. Metsulfuron Methyl (Escort)	
	43.6 oz. Imazapyr (Arsenal)	
	MSO	13 oz. (1%)
Test 10	Lineage Prep	30 oz.
	6.1 oz. Sulfometuron Methyl (Oust XP)	
	2 oz. Metsulfuron Methyl (Escort)	
	65.4 oz. Imazapyr (Arsenal)	
	MSO	20 oz. (1.5%)
Test 11	Glyphosate (Roundup ProMAX)	44.5 oz.
	Sulfometuron Methyl (Oust XP)	4 oz.
	Triclopyr (Garlon 4)	80 oz.
	MSO	13 oz. (1%)

Figure 14. Herbicide prescriptions identified for preliminary testing by Team CALIBRE at SBMR and MMR, January-March 2011.

The basic prescription applied within the majority of the sites within SBMR WR and MMR was 44.5 oz of Roundup ProMAX (glyphosate), 4 oz of Oust XP and 1% MSO (methylated seed oil) via helicopter application at a 10 gallon per acre rate. This prescription was selected based on research by Mr. Hidalgo and because it showed some success in past SBMR treatments. However, adequate data on results was not collected, nor was GPS-guided application conducted. This application was also commonly followed by a prescribed burn after the grass began to die, thus results on application and long term efficacy were not available.

Mr. Hidalgo's research found that the most effective product for Guinea grass is hexazinone (Velpar), which performed well, and does an outstanding job controlling and preventing the spread of Guinea grass. However, due to its extensive use in pineapple production within Hawaii and the restricted use label, Velpar use diminished over the last ten years. High rates and repeated uses of hexazinone led to ground water contamination in agricultural areas within some parts of Hawaii. Since then, Mr. Hidalgo tested the product Oust XP (sulfometuron methyl) as a possible alternative control scenario for Guinea grass. Research shows that Oust XP works well as a growth regulator in stunting the growth of Guinea grass at an application rate of one oz/acre, and does a better job at controlling Guinea grass at a higher application rate of 4 oz/acre (Stine-Haskel Research Study, 2006).[34]

With the success of both Velpar and Oust on Guinea grass, Mr. Hidalgo recommended Team CALIBRE apply a product called Oustar, which is a combination of hexazinone and sulfometuron methyl, which he found to be somewhat effective solution for Guinea grass control in DuPont greenhouse studies. To best understand the range of efficacy within this environment and minimize the risk of off-target damage, Mr. Hidalgo suggested initial Oustar test rates of 10 oz, 14 oz, 18 oz, and 22 oz per acre. Oustar is not yet a registered product in Hawaii and thus requires a mix of Velpar DF and Oust XP in the appropriate combinations to get the same active ingredient applied. Based on this recommendation, applications were applied at these rates on the North Lobe fire break at MMR in January 2011. Since Velpar DF is a restricted use product, this research required obtaining an aerial permit from the Hawaii Department of Agriculture, Pesticide Branch.

Many of the sites within SBMR WR and MMR include broad-leaf vegetation that is difficult to control with the standard mix of glyphosate and sulfometuron methyl. In these sites, Team CALIBRE included Garlon 4 – Ultra (triclopyr) with the Roundup ProMAX and Oust XP. This prescription was used along the fire break at SBMR WR and along the Farrington Highway at MMR in January 2011. The combined use of Garlon 4 Ultra and Roundup ProMAX are based on efficacy results on industrial utility ROW treatments over the last decade in Hawaii.

Prescriptions applied during the March 2011 test applications at MMR included the use of Lineage Prep, and a combination of Lineage Prep and Roundup ProMAX. Lineage Prep is a combination of imazapyr, sulfometuron methyl, and metsulfuron methyl; their equivalent,

[34] Personal communication with Edison Hidalgo, DuPont.

respective amounts are represented in italics in the table above. These formulations provide four chemistries working on different plant functions, and may provide better and longer control of target species at lower rates. Trials completed by the USFS on kikuyu grass for koa regeneration on the Big Island have shown that imazapyr provided good results on targeted grass species.[35] Metsulfuron methyl is labeled as an effective woody and herbaceous control product that can control grasses at higher rates. Their addition may prove advantageous in increasing control of target species on MMR.

Team CALIBRE's findings from preliminary herbicide testing are presented in Appendices A and B of this report.

4. Control Method Recommendations

General control methods considered by the Gap Analysis team included biological (i.e., pests or pathogens of target species), mechanical control (i.e., plant and/or facilitate and maintain desirable ground cover), and chemical applications (i.e., herbicides). Each of these methods was selected or eliminated from recommendation for additional research based on projected, potential efficacy against the target plants, projected cost, operational practicality, and potential for off-target environmental risks.

4.1. Biological Control

Biological control mechanisms (i.e., pests or pathogens of target species) are often considered by the public to be the optimum control mechanism due to their natural actions. Biological controls include pathogens (bacteria, virus, fungus, and mycoplasma–like organisms), pests (insects, mites, bugs, nematodes and similar), animals and parasitic plants. Considerable evidence exists to demonstrate that biological controls can result in significant adverse impacts when they do not behave as expected and damage desirable plants or property. There are numerous examples in Hawaii of alien species introduced for biological control that resulted in a far larger problem than the solution they provided. Examples include the mongoose *(Helogale parvula)* and cane toad (*Bufo marinus*).

Most of the plants commonly encountered in Hawaii are alien species and many of these are invasive. Extensive research into potential controls of invasive plants and testing on that potential control's impact on desirable plants must be conducted before considering release. Identification and testing is an exhaustive process. Because of the extensive time and resources that would be required to identify and pre-test most biological methods, Team CALIBRE recommends that pathogens, pests and parasitic plants not be considered for testing as a long-term vegetation control method.[36]

[35] Personal communications with Mike Donoho, PuuWaawaa Ahupuaa Coordinator, Department of Forestry and Wildlife during 2008 field visit and test plot observations by Team CALIBRE"s Ron Lemin.
[36] Smith, Clifford W. Technical Report 45- The prospects for biological control of nonnative plants in Hawaiian National Parks. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa, Department of Botany. October 1982.

Grazing by animals, specifically large herbivores, such as cows, horses, goats and sheep, has been demonstrated to be an effective technique for maintaining vegetation at low heights in some areas. USAG-HI[37] and the Marine Corps Base Hawaii at Kaneohe[38] conducted grazing research using cattle and other herbivores. Given the extensive cost and logistics of conducting this research, and the ready availability of published research at USAG-HI on grazing efficacy, further research is not needed; however, grazing could be considered as a technique for long-term vegetation management.

4.2. Mechanical Control

Mechanical applications using mowing machines are currently applied extensively on USAG-HI ranges. Mowing is accomplished through the use of string-trimmers or large mowing machines transported by tractors. This method removes the upper portion of target vegetation, but does not control the roots and stump. This method provides fast control of target species and facilitates removal of fuel from the site. Most vegetation, including the undesirable vegetation targeted within this study, rapidly re-sprouts. Given that this method is a common practice and the response of vegetation is well understood, this method is not recommended for further testing for inclusion in long-term management. However, research studies by Edison Hidalgo (Dupont) have shown that efficacy is increased on Guinea grass when it is shorter and actively growing.[39] Therefore, a study to combine mechanical mowing with a glyphosate, sulfometuron prescription could provide useful results for the Guinea grass problem occurring on the fire breaks. The long-term IVMP will address the combination of effective management scenarios such as combining both mowing and chemical as desirable solutions to Guinea grass control.

4.3. Cultural Management of Vegetation

Cultural Management of undesirable vegetation includes disrupting the site by breaking the soil, planting competitive crops/vegetation, and modification of site conditions.

Breaking the soil and modifying site conditions with plows, bulldozers, explosives or other physically disruptive techniques can be effective in the short term. However, this technique was eliminated from consideration due to UXO challenges, aesthetic considerations and the knowledge that invasive plants would reestablish quickly.

Modifying site conditions through soil additives or physical site changes was eliminated from consideration for the same reasons as breaking the soil and due to potential for long-term environmental impacts from any additives that may be applied.

---

[37] Steven D. Warren, Stephen A. Sherman, and James A. Zeidler. Assessment of Livestock Grazing Impacts on Fuels and Cultural Resources at Mākua Military Reservation (MMR), Island of O„ahu, Hawai„i Center for Ecological Management of Military Lands, Colorado State University. Fort Collins, CO. November 2007.

[38] Personal communications with Dr. Diane Drigot, MCBH.

[39] Personal communications with Edison Hidalgo supported by unpublished internal DuPont greenhouse research data conducted by Mr. Hidalgo.

A separate project funded by AEC with the help of Antonio Palazzo, Research Agronomist for the US Army Corps of Engineers, tested the application of salt spray, glyphosate, and sulfometuron methyl to control Guinea grass.[40] Following control, Mr. Palazzo used a specialized "seed ball" technique to re-vegetate the site. The "seed ball" has been tested using perennial rye grasses, root stolons, and cool season grass seeds. The results are pending, but the "seed ball" might become viable means to re-vegetate the firebreaks following removal of the Guinea grass. Team CALIBRE will monitor this study to coordinate review and consideration of the results for incorporation into the IVMP.

Removal of undesirable vegetation followed by installation of desirable plants is sometimes effectively used to manage undesirable vegetation. Management practices and site conditions must be conducive to enabling desirable plants to effectively compete against undesirable plants for space, nutrients and water. Techniques to remove undesirable plants include cultivation (primarily plowing), or herbicide applications. Undesirable plants are often aggressive, invasive plants. To maintain communities of desirable plants, regular management is required. If not regularly managed, undesirable plants may reestablish and out-compete desirable plants, destroying the plant community.

Team CALIBRE recommends three methods of cultural control to be tested for possible inclusion in a long-term IVMP:

- Selective removal of undesirable plants using herbicide to promote desirable vegetation communities,
- Planting of medium-sized, dense foliage trees to shade out undesirable plants, and
- Installation of low-growing ground-covers (green strips) using a hydro-seeding process, or possibly the "seed ball" technology developed by Mr Palazzo.

These techniques were selected based on their historical success as described in numerous publications and in the extensive experience of Team CALIBRE, and the projected, potential cost-effectiveness of each technique. They are also listed as suggested fire break management scenarios within the Integrated Natural Resources Management Plan 2010-2014 Island of Oʻahu (page 33). The promotion of desirable vegetation communities through selective herbicide treatments was successfully demonstrated in Hawaii by Hawaiian Electric Company in managing vegetation on its rights-of-way.

Team CALIBRE plans to plant medium-sized, dense foliage trees to shade out undesirable plants and provide a firebreak that will prevent the propagation and spread of fire, pending

[40] Personal communication with Antonio Palazzo, Research Agronomist, US Army Corps of Engineers..

approval of ground disturbance from USAG-HI Cultural Resources. These trees, primarily native species, are proposed for planting in an area adjacent to the fence that extends along Farrington Highway. Species currently being proposed include kou (*Cordia subcordata*), true kamani (*Calophyllum inophyllum*), milo (*Thespesia populnea*), hala (*Pandanus tectorius*), and mango (*Mangifera indica*). The initial test planting is currently projected to cover an area approximately 1.6 acres in size.

If additional funds are obtained, Team CALIBRE recommends planting five hundred (500) trees throughout the test plot, excluding any archeological sites that are identified by USAG-HI CR who we recommend accompany the planting team. Plantings should be contiguous and provide a dense canopy ground cover to effectively shade and prevent undesirable grass species from establishing in populations that can propagate and spread fire. Installation of these plantings would be most beneficial if completed in November 2011, at the beginning of the rainy season, to facilitate establishment. Three sizes of trees are recommended for planting: 1 gallon, 5 gallon and 25 gallon. Each of these size classes should be divided into two groups. One group should be irrigated until established and the other group should be left with only natural water. Team CALIBRE recommends mulch be applied to one-half of each subgroup to test for increased growth and establishment. Growth and monitoring of these trees is recommended for at least three years, and perhaps longer, depending on unpredictable weather patterns.

4.4. Chemical Applications

Chemical applications of herbicides or plant growth regulators are commonly conducted to control undesirable vegetation. The Gap Analysis Team agreed that combinations of various herbicide formulations work effectively. Combinations permit lower application rates for each formulation while often increasing the efficacy of control as compared to one formulation. These combinations can result in lower cost for the application solution and increased control efficacy. Increased control efficacy can further reduce costs by reducing the frequency of applications.

Team CALIBRE recommends TimberMark be used to visually define treatment areas including sensitive areas and habitat prior to aerial herbicide applications. Marking is conducted with a blue, water-based latex paint that is easily viewed from the air. The marked perimeters consist of an equally spaced intermittent line with each paint mark identified with a corresponding GPS coordinate. GIS data, provided either by USAG-HI or Team CALIBRE (with approval from USAG-HI), would be uploaded into the helicopter navigation system to mark sensitive areas and habitats. Boundaries marked with paint provide confirmation of treatment and sensitive area locations prior to herbicide application and provide a visual aid to the helicopter pilot during application.

Team CALIBRE recommends preliminary testing of combinations of herbicides in March 2011 and May 2011 continue with increased replications. Review of the early results of January applications within the North Lobe showed lower than anticipated control (Figure 15); these sites require further monitoring. Reviews of the early results of applications within the South Lobe showed mixed results and also require further monitoring. Summaries of the preliminary observations are located in Appendix A, North Lobe Test Plot Preliminary Findings and Appendix B, South Lobe Test Plot Preliminary Findings.

Figure 15. Examples of Typical Test Plot Before (left), Then 2 Weeks (center) and 12 Weeks (right) After Treatment showing the regrowth of Guinea grass and resprouting of haole-koa.

Preliminary results and further analysis will permit Team CALIBRE to modify solutions in an attempt to identify the optimum solution that will provide the desired control at the lowest rate/cost. Pending funding, additional formulations and solutions will be tested as soon as final results from the preliminary tests are collected and analyzed, and additional formulations are identified and registered. Based on these preliminary tests, recommendations for additional research may be warranted to support long-term vegetation management.

Team CALIBRE recommends other herbicide formulations that are currently in development or being registered for application (personal communication with Edison Hidalgo, DuPont) also be tested to determine their efficacy on the target species individually and then within solutions. Based on results, these formulations may be considered in long-term vegetation management based on efficacy and cost effectiveness.

A separate project using salt to modify site conditions is being conducted currently. Team CALIBRE will monitor this study to coordinate review and consideration of the results for incorporation into the IVMP.

5. Conclusion

Based on our review of available publications and interviews with key USAG-HI personnel and subject matter experts, current and past USAG-HI technical vegetation management practices are inadequate to support the military mission and protect sensitive natural and cultural resources by stabilizing the vegetative community and reducing threats of wildland fires. Our evaluation of existing conditions indicate Guinea grass and invasive plants continue to dominate the MMR and SBMR range landscape, threatening T&E species through habitat depletion and fire danger.

Cost-effective and successful vegetation management practices must be developed and implemented at USAG-HI to better manage vegetation, reduce costly wildland fires, and permit military training as required. Management of fire breaks and fuel management areas, especially when associated with a significant slope and high winds, is a key consideration in managing undesirable vegetation. Elimination of fire danger species, such as Guinea grass, within and near these fire control areas would be a significant deterrent to uncontrolled fires. Additional testing is needed to determine if timing of the herbicide application can improve Guinea grass efficacy or analyze the timing of the prescribed burn following application to determine whether it may be decreasing overall efficacy.

The USAG-HI IVMP must involve the creation of green strip fire breaks or plantings of vegetation to deter the spread of wild fires (INRMP 2010-2014, Island of O'ahu). This will require additional testing and research beyond the research performed to date. Long term control strategies need to be employed to obtain results beyond a 6 month period. Combining mechanical, biological and chemical control methods could be advantageous. Further testing is required.

Development of cost-effective solutions at USAG-HI is challenged by multiple environmental, administrative, cultural, and public issues. In order to identify and implement the most cost-effective, environmentally sound control methods, constant diligence and research on developing tools, techniques and herbicides will be required. Herbicide tests that have been completed have demonstrated strengths and weaknesses and should be expanded to develop the most effective formulations that will best address vegetation conditions throughout USAG-HI. Management of target species more cost-effectively than previous methods to achieve USAG-HI goals can be accomplished, but requires extensive research and application of various control methods appropriate for site conditions. Continued funding and support will be essential to complete the necessary testing to create a valid and effective IVMP.

The following actions are recommended for continued research and testing within the next two years for development of the IVMP:

- Selective removal of undesirable plants using herbicide to promote desirable vegetation communities,
- Planting of medium-sized, dense foliage trees to shade out undesirable plants,

- Installation of low-growing ground-covers using a hydro-seeding process,
- Continued testing of herbicide formulations,
- Testing of new herbicide formulas,
- Continued soils and vegetation monitoring

Team CALIBRE thanks USAG-HI for the opportunity to conduct a gap analysis and initiate preliminary research using state-of-the-art tools, techniques, and materials. Team CALIBRE recommends USAG-HI implement recommendations presented in this plan, and fund, as able, an additional two years of research and monitoring in support of developing a long-term, cost effective IVMP.

Appendix A: North Lobe Test Plots

General condition of plants throughout the test site during initial review and assessment:

- Guinea grass (*Panicum maximus*): Generally healthy. Some basal brown stems, flushing growth and seed formation observed.
- Haole koa (*Leucaena leucocephala*): Emerging small brightly-colored healthy leaves and active normal seed fall observed.
- Klu (*Acacia farnesiana*): New growth emerging with bright green sprouts and leaves. Few dried seed pods present.
- Guava (*Psidium guajava*): Dark green leaves and immature, small green fruits.
- Java plum (*Syzygium cumini*): Stunted growth with good form, likely due to dry area. Immature fruits observed.
- Sandalwood (*Santalum ellipticum*): One individual found on 107 2-C. Healthy individual.
- Morning glory (*Ipomaea ochrocea)*: One individual found on 101 1-S, healthy and climbing on a haole koa.

Plot # 101 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO

Haole koa

- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall were observed. Cover (i.e., the estimated portion of the sample site comprised of the target plant canopy) at 50%. Sociability medium to large clumps.
- First Post-Treatment Observation (PTO) – Complete leaf drop, dying stems and brittle ends.
- Second PTO – Average 35% regrowth. Epicormic resprouts along main stems observed on all trees. No releaf along branches or tips.
- Third PTO – Average 40% regrowth. Flowering and new leaves observed on one sample site.

Guinea grass

- Baseline Vegetation Conditions – Flushing growth and seed formation observed. Grass 9-12 feet in height. Coverage 95%. Sociability medium to large clumps.
- First PTO – 100% brown foliage. Grass height declining to 6 feet tall, with mottled leaves, yellow and brown patches.
- Second PTO – Average 35% regrowth. Grass regrowth observed from inside clumps with brown low, green six feet high.
- Third PTO – Average 35% regrowth. Clumps to 8 feet in height.

Klu

- Baseline Vegetation Conditions – Only found in portions of plot. Where found, cover 20%, sociability small clumps.
- First PTO – Complete leaf drop, dying stems.
- Second PTO – Average 30% regrowth.
- Third PTO – Average 30% regrowth.

Java plum

- Baseline Vegetation Conditions – Cover restricted to one healthy specimen. Sociability was one individual.
- First PTO – Unaffected.
- Second PTO – Control (i.e., the percent of green, live growth relative to the entire target plants on the sample site) at 20% with only small branch dieback.
- Third PTO – Control increased to 60%.

<u>Morning glory</u>

- Baseline Vegetation Conditions – Cover was restricted to one healthy specimen climbing on a haole-koa. Sociability was one individual.
- First PTO – Control at 50%.
- Second PTO – Control increased to 100%.
- Third PTO – Control remained at 100%.

<u>Sandalwood</u>

- Baseline Vegetation Conditions – Cover was restricted to one healthy specimen. Sociability was one individual.
- First PTO – Control at 70%.
- Second PTO – 10% leaves remaining. Control increased to 100%.
- Third PTO – Control remained at 100%.

<u>Plot #102Treatment Solution 6: 0.5lbs Velpar, 4 oz Oust XP, 13 oz MSO</u>

<u>Haole koa</u>

- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall observed. An average of 75% Cover observed.
- First PTO – Control increased to 100%.
- Second PTO – Average 20% regrowth
- Third PTO – Average 40% regrowth.

<u>Guinea grass</u>

- Baseline Vegetation Conditions: From four to seven feet in height. Cover 95%. Sociability large clumps.
- First PTO – Control increased to 100%.
- Second PTO – Control decreased to 95%.
- Third PTO – Control decreased to 20%.

<u>Plot #103Treatment Solution 3: 0.95lbs Velpar, 2.8 oz Oust XP, 13 oz MSO</u>

<u>Haole koa</u>

- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall were observed. Cover 15% and sociability small clumps.
- First PTO – Control increased to 100%.
- Second PTO – Control decreased to 70%.
- Third PTO – Control decreased to 60%.

<u>Guinea grass</u>

- Baseline Vegetation Conditions – Cover 100%. Sociability pure stands. Eight to ten foot height.
- First PTO – Control at 100%. Stems and clumps lying down, browning, yellowing.
- Second PTO – Control decreased to 85%. Clumps sprouting new green.
- Third PTO – Control decreased to 40%. Resprouts within original clumps with very few outside old clumps.

<u>Klu</u>

- Baseline Vegetation Conditions – Bright green leaves. Cover 60%. Sociability medium to large clumps.
- First PTO – Control at 100%.
- Second PTO – Average 35% regrowth.
- Third PTO – Average 75% regrowth. Flowering observed.

<u>Plot #104 Treatment Solution 2: 0.74lbs Velpar, 2.2 oz Oust XP, 13 oz MSO</u>

<u>Haole koa</u>

- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall observed. Cover 70%. Sociability medium to large clumps.
- First PTO – Control at 100%.
- Second PTO – 40% resprouting
- Third PTO – Control decreased to 75%.

<u>Guinea grass</u>

- Baseline Vegetation Conditions – Cover 100%. Sociability pure stands. Heights were over eight feet.
- First PTO – Control at 100%.
- Second PTO – 30% resprouting from clumps.
- Third PTO – 40% resprouting from clumps.

<u>Klu</u>

- Baseline Vegetation Conditions – Cover 10%. Sociability individuals. Trees leafing out.
- First PTO – Control increased to 70%.
- Second PTO – Resprouting, Control decreased to 50%.
- Third PTO – Resprouting, Control decreased to 10%.

<u>Plot# 105 Treatment Solution 6: 0.5lbs Velpar, 4 oz Oust XP, 13 oz MSO</u>

<u>Haole koa</u>

- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored healthy leaves and active normal seed fall observed. Cover 25%. Sociability large clumps.
- The first PTO – Control at 100%
- Second PTO – Control decreased to 85%.

- Third PTO – Control remained at 85%.

Klu

- Baseline Vegetation Conditions – Small, densely-packed stands. Bright green leaves emerging. Five feet height.
- First PTO – Control at 100%.
- Second PTO – Resprouting, Control decreased to 75%.
- Third PTO – Resprouting, Control decreased to 35%.

Guinea grass

- Baseline Vegetation Conditions – Cover 90%. Sociability large clumps. Heights over 8 feet.
- First PTO – Control at 100%. Heights up to 5".
- Second PTO – Resprouts from clumps, control decreased to 70%.
- Third PTO – Resprouts from clumps and seedlings, control decreased to 50%.

Plot #106 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO

Haole koa

- Baseline Vegetation Conditions – Healthy, emerging, small brightly-colored healthy leaves and active normal seed fall observed. Cover 20%. Sociability small clumps.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 80%. Unopened, stunted leaves and open leaves on stems.
- Third PTO – Control decreased to 75%.

Guinea grass

- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Luxuriant growth, dominant height 10 feet.
- First PTO – Control at 100%.
- Second PTO – Resprouts from clumps, control decreased to 85%.
- Third PTO – Resprouts from clumps, control decreased to 75%.

Klu

- Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Leaves were freshly emerged.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 85%, resprouts.
- Third PTO – Control decreased to 10%, resprouts.

Plot 107 Treatment Solution 7: 0.5 Velpar, 4 oz Oust XP, 1.5 oz Escort, 13 oz MSO

Haole koa

- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored healthy leaves and active normal seed fall observed. Cover 40% on only one site. Sociability large clumps.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 90%.
- Third PTO – Control increased to 100%.

Guinea grass
- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Luxuriant growth, dominant height 10 feet.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 90%, resprouting from clumps.
- Third PTO – Control decreased to 70%, resprouting from clumps.

Guava
- Baseline Vegetation Conditions – Healthy condition, immature fruit. Cover 5%. Sociability medium to large clumps.
- First PTO – Control at 80%, leaves yellowing.
- Second PTO – Control decreased to 65%, resprouts.
- Third PTO – Control remained at 65%, resprouts.

Sandalwood
- Baseline Vegetation Conditions – Healthy. Cover <1%. Sociability was one specimen.
- First PTO – Control at 100%.
- Second PTO – Control remained at 100%.
- Third PTO – Control remained at 100%.

Plot 108 Treatment Solution 1: 0.5lbs Velpar, 1.6 oz Oust XP, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored healthy leaves and active normal seed fall observed.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 95%.
- Third PTO – Control decreased to 70%, resprout along stems.

Guinea grass
- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Luxuriant growth, dominant height ten feet.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 90%.
- Third PTO – Control decreased to 60%, regrowth from clumps.

Klu

- Baseline Vegetation Conditions – Cover 25% in one sample site. Sociability medium to large clumps. Leaves were freshly emerged.
- First PTO – Control at 100%.
- Second PTO – Control remained at 100%.
- Third PTO – Control decreased to 80%.

Guava
- Baseline Vegetation Conditions – Green, mature leaves. Cover 20%. Sociability small clumps and individuals.
- First PTO – Control at 100%, yellow leaves.
- Second PTO – Control decreased to 90%.
- Third PTO – Control increased to 95%.

Plot #109 Treatment Solution 1: 0.5lbs Velpar, 1.6 oz Oust XP, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored healthy leaves and active normal seed fall observed. Cover 15%. Sociability individuals and small clumps.
- First PTO – Control at 75%.
- Second PTO – Control remained at 75%.
- Third PTO – Control decreased to 60%, resprouts along stems.

Guinea grass
- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Luxuriant growth, dominant height 10 feet.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 75%.
- Third PTO – Control increased to 90%.

Klu
- Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Leaves freshly emerged.
- First PTO – Control at 75%.
- Second PTO – Control remained at 75%.
- Third PTO – Control increased to 80%.

Plot #110 Treatment Solution 3: 0.95lbs Velpar, 2.8 oz Oust XP, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Healthy, emerging, small brightly-colored healthy leaves and active normal seed fall observed. Cover 20% on one site. Sociability small clumps.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 70%, resprouts along stems.

- Third PTO – Control decreased to 40%, resprouts along stems.

Klu
- Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Leaves were freshly emerged.
- First PTO – Control at 85%.
- Second PTO – Control decreased to 75%.
- Third PTO – Control decreased to 20%, resprouts.

Guinea grass
- Baseline Vegetation Conditions – Cover 65%. Sociability medium to large clumps. Luxuriant growth, dominant height8 feet.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 95%.
- Third PTO – Control decreased to 40%, resprouting from clumps.

Plot #111 Treatment Solution 7: 0.5 Velpar, 4 oz Oust XP, 1.5 oz Escort, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Healthy, emerging, small brightly-colored healthy leaves and active normal seed fall observed.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 80%.
- Third PTO – Control decreased to 80%.

Klu
- Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Leaves were freshly emerged.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 90%.
- Third PTO – Control decreased to 20%, resprouting.

Guinea grass
- Baseline Vegetation Conditions – Cover 50%. Sociability medium large clumps. Luxuriant growth, dominant height 8 feet.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 80%.
- Third PTO – Control decreased to 55%, resprouting from clumps.

Plot #112 Treatment Solution 2: 0.74lbs Velpar, 2.2 oz Oust XP, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Healthy, emerging, small brightly-colored healthy leaves and active normal seed fall observed.
- First PTO – Control at 100%.

- Second PTO – Control decreased to 60%.
- Third PTO – Control remained at 60%.

<u>Guinea grass</u>

- Baseline Vegetation Conditions – Cover 80%. Sociability medium large clumps. Luxuriant growth, 6 feet.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 60%.
- Third PTO – Control decreased to 50%, resprouting from clumps.

<u>Klu</u>

- Baseline Vegetation Conditions – Cover 25%. Sociability medium clumps. Leaves were freshly emerged.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 20%.
- Third PTO – Control remained at 20%.

<u>Preliminary Conclusions:</u>
Control of all major target species was initially good, as shown through extensive brown foliage; however, all species recovered during the review period. Control appeared to be limited to foliage exposed and did not control the root system of the plants. Heavy ground Cover of Guinea grass restricts ground contact of herbicide solution as demonstrated through the very small detection of hexazione during the initial soil tests. Herbicide rates applied appeared to inadequately provide penetration and satisfactory control of target species.

Appendix B: South Lobe Test Plot Observations

General condition of plants throughout the test site during initial review and assessment:

- Guinea grass (*Panicum maximus*): Low levels of basal brown stems, flushing growth and seed drop.
- Haole koa (*Leucaena leucocephala):* Large brightly-colored healthy leaves and active, normal seed fall.
- Klu (*Acacia farnesiana*): Small, developing, bright green woody growth and leaves.
- Guava (*Psidium guajava*): Dark green leaves and yellow fruits.
- Java plum (*Syzygium cumini*): Trees form small, likely due to dry site, and well developed with immature fruit.

Additional plants were found only in small numbers or as individuals. These plants were generally in good health and normal condition and included the following species:

- Morning glory (*Ipomaea ochrocea)*
- Carpetgrass (*Axonopus fissifolius*)
- Sensitive plant (*Mimosa pudica*)
- Cocklebur (*Xanthium strumarium)*
- Fireweed (*Senecio madagascariensis*)
- Coat buttons (*Tridax procumbens*)
- Dandelion (*Taraxacum officinale*)
- Plantain grass (*Plantago lanceolata*)
- White daisy (*Bidens alba*)

Plot #200 Treatment Solution 9: 44.5 oz Roundup Pro MAX, 20 oz Lineage Prep, 13 oz MSO

Haole koa

- Baseline Vegetation Conditions – Healthy, emerging small bright leaves and active normal seed fall were observed. Cover 25%. Sociability medium large clumps.
- First Post-Treatment Observation (PTO) – Control at 45%. Dieback, spotty yellowing of leaf, dying stems found.
- Second PTO – Control increased to 60%. Epicormic resprouts along main stems observed on some trees. No releaf along branches or tips.
- Third PTO – Control increased to 70%. Flowering and new leaves observed on dying plants in 10% of instances.

Guinea grass

- Baseline Vegetation Conditions – Tall grass-from 7-8 feet in height. Cover 95%. Sociability almost pure stands.
- First PTO – Control at 60%. Grass lying down to 4 feet, browning, with mottled leaves, yellow and brown patches.
- Second PTO – Control increased to 80%.
- Third PTO – Control increased to 85%. Significant brown. Green at bases only.

Klu

- Baseline Vegetation Conditions – Small population in only one sample site. Cover 20%, Sociability small clumps.
- First PTO – Control at 35%.
- Second PTO – Control increased to 45%.
- Third PTO – Control increased to 80%.

<u>Plot #201 Treatment Solution 9: 44.5 oz Roundup Pro MAX, 20 oz Lineage Prep, 13 oz MSO</u>

<u>Guinea grass</u>
- Baseline Vegetation Conditions – Cover 25%. Sociability small and large clumps. Heights over 6 feet.
- First PTO – Control at 35%.
- Second PTO – Control increased to 55%.
- Third PTO – Control increased to 75%.

<u>Carpetgrass</u>
- Baseline Vegetation Conditions – Cover 50%. Sociability medium large clumps.
- First PTO – Control at 85%.
- Second PTO – Control increased to 90%.
- Third PTO – Control decreased to 80%.

<u>Sensitive plant</u>
- Baseline Vegetation Conditions – Cover 5%. Sociability individuals.
- First PTO – Control at 10%.
- Second PTO – Control remained at 10%.
- Third PTO – Control increased to 80%.

<u>Fireweed</u>
- Baseline Vegetation Conditions – Cover less than 1%. Sociability individuals.
- First PTO – Control at 50%.
- Second PTO – Control decreased to 40%.
- Third PTO – Control decreased to 30%.

<u>Plot #202 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO</u>

<u>Guinea grass</u>
- Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Eight to 10 foot height.
- First PTO – Control at 65%. Stems still green but lying over.
- Second PTO – Control decreased to 60%. Clumps sprouting new green.
- Third PTO – Control increased to 75%. Resprouting within original clumps.

<u>Carpetgrass</u>

- Baseline Vegetation Conditions – Cover 75%. Sociability small and large clumps. Seeds opening.
- First PTO – Control at 80%.
- Second PTO – Control decreased to 75%.
- Third PTO – Control remained at 75%.

<u>Morning glory</u>

- Baseline Vegetation Conditions – Cover 5%. Sociability individuals.
- First PTO – Control at 60%.
- Second PTO – Control decreased to 10%.
- Third PTO – No data. Area was mowed.

<u>Sensitive Plant/Mimosa grass</u>

- Baseline Vegetation Conditions – Cover less than 1%. Sociability individual.
- First PTO – Control at 35%.
- Second PTO – Control decreased to 10%.
- Third PTO – No data. Area was mowed.

<u>Plot #203 Treatment Solution 10: 30 oz Lineage Prep, 20 oz MSO</u>

<u>Haole koa</u>

- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall observed. Cover 35%. Sociability medium to large clumps.
- First PTO – Control at 45%.
- Second PTO – Control remained at 45%.
- Third PTO – Control increased to 55%.

<u>Guinea grass</u>

- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Heights 6 to 8 feet.
- First PTO – Control at 30%. Grass falling over.
- Second PTO – Control increased to 55%.
- Third PTO – Control decreased to 45%.

<u>Carpetgrass</u>

- Baseline Vegetation Conditions – Cover 75%. Sociability large clumps.
- First PTO – Control at 80%.
- Second PTO – Control remained at 80%.
- Third PTO – Control decreased to 20%. Mowed.

<u>Fireweed</u>

- Baseline Vegetation Conditions – Cover <1%. Sociability individuals.
- First PTO – Control at 10%.

- Second PTO – Control remained at 10%.
- Third PTO – Control increased to 20%.

Morning glory
- Baseline Vegetation Conditions – Cover <1%. Sociability individuals. Growing on Haole koa.
- First PTO – Control at 20%.
- Second PTO – Control remained at 20%.
- Third PTO – Control remained at 20%.

Java plum
- Baseline Vegetation Conditions – Cover <1%. Sociability individuals.
- First PTO – Control at 20%.
- Second PTO – Control remained at 20%.
- Third PTO – Control increased to 30%.

Plot #206 Treatment Solution 10: 30 oz Lineage Prep, 20 oz MSO

Guinea grass
- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Heights were 4 to 10 feet.
- First PTO – Control at 75%.
- Second PTO – Control remained at 75%.
- Third PTO – Control increased to 95%. No re-sprout. Dead grass still stands 4 to 10 feet high.

Haole koa
- Baseline Vegetation Conditions – Cover <1%. Sociability small to medium clumps.
- First PTO – Control at 70%.
- Second PTO – Control remained at 70%.
- Third PTO – Control decreased to 30%. Resprouting along main stem.

Klu
- Baseline Vegetation Conditions – Cover 25%. Sociability is small clumps. 5 to 6 feet in height.
- First PTO – Control at 35%.
- Second PTO – Control remained at 35%.
- Third PTO – Control increased to 85%.

Java plum
- Baseline Vegetation Conditions – Cover <1%. Sociability individual. One individual found.
- First PTO – Control at 30%.

- Second PTO – Control remained at 30%.
- Third PTO – Control increased to 90%.

Plot #207 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Cover 10%. Sociability individuals.
- First PTO – Control at 80%.
- Second PTO – Control remained at 80%.
- Third PTO – Control remained at 80%.

Klu
- Baseline Vegetation Conditions – Cover 15%. Sociability small to medium clumps.
- First PTO – Control at 35%.
- Second PTO – Control increased to 60%.
- Third PTO – Control increased to 65%.

Guinea grass
- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Up to 9 feet in height.
- First PTO – Control at 95%.
- Second PTO – Control decreased to 85%.
- Third PTO – Control increased to 95%.

Plot #208 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall observed. Cover 20%. Sociability medium large clumps.
- First PTO – Control at 90%.
- Second PTO – Control remained at 90%.
- Third PTO – Control increased to 100%.

Guinea grass
- Baseline Vegetation Conditions – Height 4 to 5 feet. Cover 45%. Sociability large clumps to nearly pure stands.
- First PTO – Control at 40%.
- Second PTO – Control remained at 40%.
- Third PTO – Control increased to 65%.

Klu
- Baseline Vegetation Conditions – Bright green leaves. Cover 5%. Sociability individuals and small clumps.

- First PTO – Control at 80%. Leaves fallen, brittle ends found. No resprouting.
- Second PTO – Control remained at 80%. Resprouting observed.
- Third PTO – Control decreased to 70%. Releafing.

Carpetgrass
- Baseline Vegetation Conditions – Cover 25%. Sociability, small clumps and individuals. Seeds opening.
- First PTO – Control at 60%.
- Second PTO – Control remained at 60%.
- Third PTO – Control increased to 80%.

Plaintain grass
- Baseline Vegetation Conditions – Cover <1%. Sociability individuals.
- First PTO – Control at 10%. Leaf margins browning.
- Second PTO – Control increased to 20%.
- Third PTO – Control decreased to 10%. Site mowed.

Fireweed
- Baseline Vegetation Conditions – Cover <1%. Sociability individuals.
- First PTO – Control at 20%.
- Second PTO – Control remained at 20%.
- Third PTO – No data. Area was mowed.

Preliminary Conclusions:

Control of all major target species was initially good, and remained satisfactory as indicated by extensive brown foliage. Guinea grass maintained satisfactory Control in all instances except Plot 203. Most other species showed some signs of recovery in certain areas during the review period. Further monitoring of these plots is recommended through January 2012 to measure response of this vegetative community.

CALIBRE Integrated Vegetation Management Plan
OANRP Discussion

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

The IVMP project ended up focusing on firebreak creation/maintenance via herbicide spraying, and spot treatment of select weeds. They received one year of funding. Recently, IVMP staff contacted OANRP to say they may be able to secure additional funding. If they are successful, they may return as early as 2012 to continue project implementation. Work was conducted on three training ranges: Schofield Barracks West Range (SBW), Makua Military Reservation (MMR), and Kahuku Training Area (KTA)

A full report of the IVMP project was written by the IVMP team, and is on file with OANRP (see Appendix 1-4)

IVMP Staff

Name	Affiliation
Heather La Rowe	CALIBRE – senior program manager
Kevin Eckert	Arbor Global – vegetation specialist
John ?	Arbor Global – field staff
Ron Lemin	Crop Production Services – operations specialist
Franklin Leavitt	Crop Production Services – GIS analyst
Wayne ?	Crop Production Services? – pilot, logistics
Tom Haupman	Pacific Helicopter – pilot, Long Ranger, Hughes 500
Kenny ?	Pacific Helicopter – ground crew
Guy ?	Pacific Helicopter – pilot, Hughes 500 (January only)
Frank Raby	Schofield Range Division –

OANRP staff involved with the IVMP project include: Jane Beachy (JB; Ecosystem Restoration Program Manager), Joby Rohrer (JR; Senior Natural Resource Management Coordinator), Kapua Kawelo (KK; Federal Biologist), and Kaleo Wong (KWo; Natural Resources Management Coordinator).

Equipment

Batch Mixing tank
IVMP had a batch mix-tank custom made for the project. This allowed mixes of 500 gallons to be made and used to quickly refill the tank on the ship. The system was mounted on a trailer and has an efficient pump system that can also be used to reticulate the mix in the tank.

Batch mix-tank

Refilling the helicopter tanks

Aerial Boom Sprayer

The aerial sprayer was provided by Windward Aviation. The IVMP retrofitted Windward's system with large-droplet nozzles. These nozzles lived up to their name, creating large droplets which resisted drifting. The nozzles previously used by Windward created fine droplets, which mist and drift, increasing the likelihood of non-target effects. The large-droplet nozzles created a rain-like treatment.

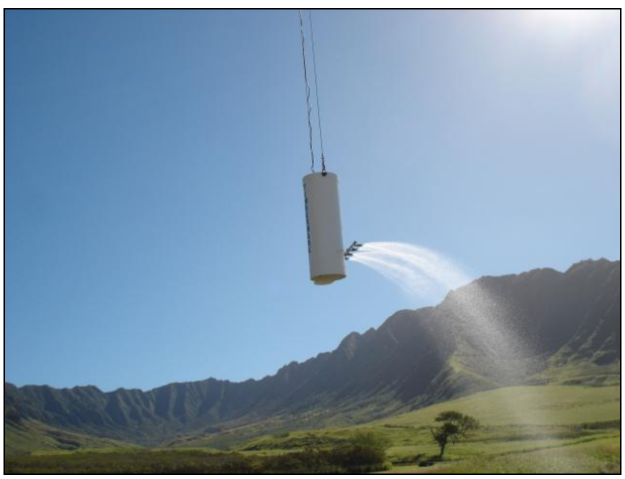
Boom sprayer, with large-droplet nozzles; spraying in Makua

The boom sprayer trigger was operated by the pilot, and was connected to an onboard GPS. Once the pilot depressed the trigger, the GPS unit began recording a track of the spray area. This track was assigned a width, according to the reach of the boom. The pilot could then 'paint' the area to be sprayed, noting gaps on the GPS screen.

Onboard GPS set-up


Large-droplet nozzle

TimberMark™ Aerial Sprayer
The TimberMark aerial sprayer was provided by Crop Production Services. It is similar to spray balls used by other agencies in the State (National Parks, MISC), but differs in having the spray tank located at the end of the longline, with the sprayer. Theoretically, the dosage can also be calibrated such that each time the pilot triggers the system, a measured amount is applied; there were problems with this feature during Kahuku operations. Also, the sprayer is powered by compressed air, not gravity. Multiple nozzle arrangements are possible with the TimberMark system, including nozzles facing directly down and nozzles arranged into a mini-boom.


TimberMark mini-boom


TimberMark spot sprayer

As with the boom sprayer, the Timbermark trigger was operated by the pilot, and was connected to an onboard GPS. Again, this allowed the pilot to track where exactly he was spraying. The GPS component of this system was not working during IVMP operations. The TimberMark sprayer was attached to the helicopter by two cables, including one electrical cable.

Two-cable attachment required for TimberMark

On-board GPS

For all spray operations, GIS shapefiles for each spray area, or job, were loaded onto the onboard GPS/computer. The pilot used the shapefiles to navigate to each spray location and ensure that the entire spray location was treated. After completing one job, the pilot would load the next job. At the end of the flight, all GPS information was downloaded, providing a record of the actual areas sprayed, as well as a flight track.

Onboard GPS system, with spray ‘job’ loaded

Field Operations

The IVMP staff conducted field operations in January, March, and May of 2011. OANRP assisted with part of each of these operations. The following is a summary of the projects which occurred at the various training ranges, and OANRP's involvement with each project. The summary does not include all of the IVMP field activities, as OANRP was not involved with many of them

Summary of IVMP Field Operations

Location	Activity	Date	Description	OANRP Involvement
SBW	Firebreak	January	Sprayed along the inside of the firebreak road	Provided IVMP team with shapefiles of rare taxa locations (elepaio), and 'no spray' buffers around these locations.
SBW	Firebreak	May	Sprayed the inside of the SBW impact area	Provided IVMP team with updated, expanded 'no spray' buffers.
SBW	HedGar Spot Tx	May	Treated about 6 HedGar spots with TimberMark system	JB, KK, KWo selected specific target patches for trial. KK rode in helicopter to assist in directing pilot during treatment.
MMR	Firebreak	January	Firebreak Roads: Sprayed along the firebreak road. Installed herbicide plots.	Provided IVMP team with shapefiles of rare taxa locations, and 'no spray' buffers around these locations. IVMP team installed plots and monitored.
MMR	Firebreak	January	Farrington Hwy: sprayed fuel break along Farrington Hwy,	Provided IVMP team with shapefiles detailing the approved remote fuel break zones.
MMR	Firebreak	January	Makua Cave: sprayed fuel break between Farrington Hwy and ridge top	Provided IVMP team with shapefiles detailing the approved remote fuel break zones.
MMR	Remote Fuelbreak	January, May	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.
MMR	Remote Fuelbreak	January	Kahanahaiki: sprayed fuel break zones (6)	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 .
MMR	Remote Fuelbreak	March	Lower Makua: 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 .
MMR	Remote Fuelbreak	March	Lower Ohikilolo: 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 .
MMR	Alien Weed Spot Tx	January	Treated 4 alien tree species with TimberMark system	JB, JR identified TimberMark targets, and passed on site info to IVMP staff. Could not ride in helicopter to direct pilot (not OAS), so briefed Kevin Eckert on locations, and he rode with pilot.
MMR	CasSpp Spot Tx	March, May	Treated two CasEqu stands with boom sprayer	JB, JR identified CasEqu patches for control, provided map to IVMP staff. The patches were treated for the first time in March, and follow up treatment was conducted on both in May.

Location	Activity	Date	Description	OANRP Involvement
KTA	Alien Weed Spot TX	May	Treated 9 alien taxa with TimberMark system	JB and KK selected species and sites for trial. KK rode in helicopter to assist in directing pilot during treatment.
KTA	ChrOdo Spot Tx	May	Treated ChrOdo core with boom spray system	JB mapped *C. odorata* hotspot for control. KK rode in helicopter to assist in directing pilot during treatment.

The IVMP is preparing a full project report detailing the results of the 2011 treatments. OANRP has only recently received a copy of this report. It focuses on the result of the fuel break sprays.

Discussion

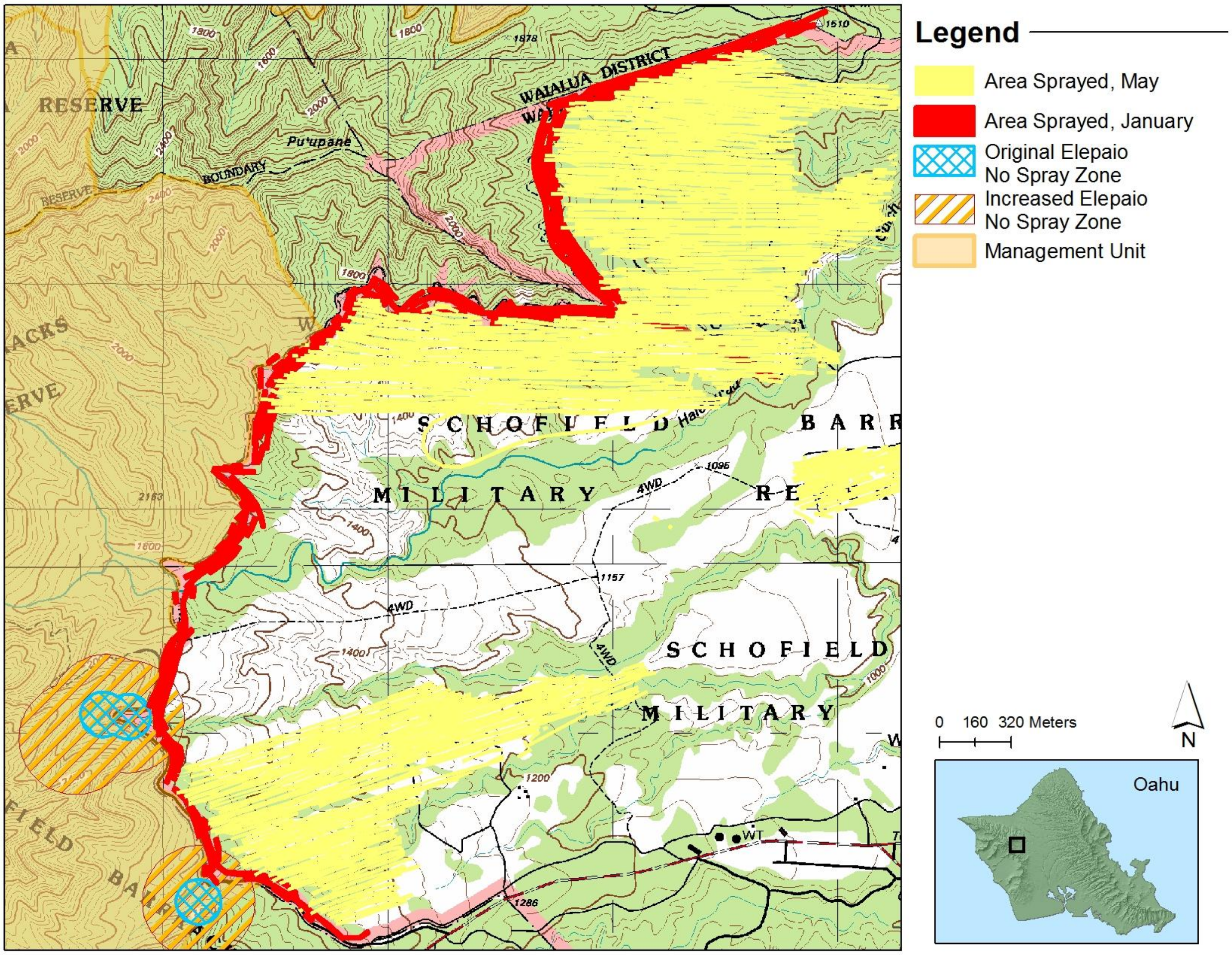
Schofield: Firebreak

The firebreak road was sprayed in January. OANRP staff were minimally involved in this spray effort, and primarily assisted IVMP staff by providing them with shapefiles of rare taxa in the area and 'no-spray' buffers around the elepaio closest to the spray zone. Despite this, OARNP staff later found that the aerial boom spray had crossed into the 'no spray' buffers drawn around the lowest elevation elepaio habitat. This incident is written up in full in Appendix 4-1 The overspray was not discovered right away. There is a time lag between when the pilot depresses the sprayer trigger, and when the on board GPS begins recording the spray zone. The GPS data from the spray did not overlap the buffer; however at the site, it did. Also, the rare taxa shapefile used to create the 'no-spray' buffer was out of date.

The interior of the firebreak road, in the impact area, was sprayed in May. Again, OANRP staff were minimally involved in this effort. OANRP did, however, provide IVMP staff with updated buffers around known elepaio. The 'no-spray' buffer was also increased from 100m to 200m. Both January and May sprays appeared to be quite effective, creating strips of dead grass. The boom sprayer appeared to have minimal drift. Trees sprayed appear to be recovering (*Falcataria chinensis)*.

Aerial view of part of the SBW fuel break ~~boom~~ spray

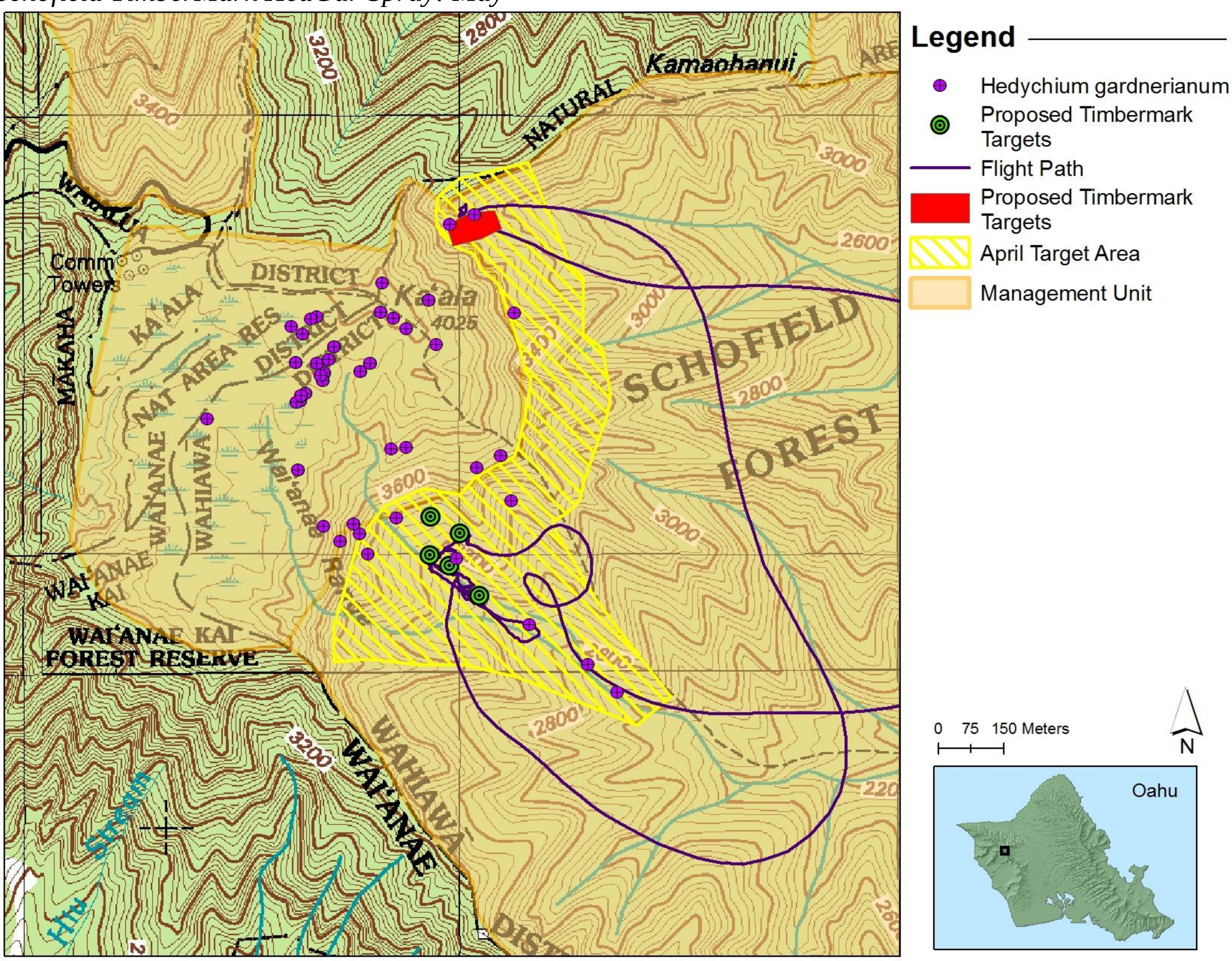
Schofield Firebreak Spray: January and May



<u>Schofield: HedGar Spot Treatment</u>
The back of Haleauau, below the cliffs of Kaala, has many large patches of mature *Hedychium gardnerianum* (HedGar). JB, KK, and KWo conducted an aerial survey of the area, and selected six locations (five points and one polygon) where the HedGar was found in patches at least 5x5m in size, at least partially surrounded by other weeds. KK rode with the pilot to assist in directing the treatment of these patches. While it was difficult to ensure that the exact same patches were treated, patches in the right (scoped) zones were treated. The HedGar patches were treated with 15 gallons of solution (water, 1% Escort, MSO as an adjuvant). During the spray operation, KK noted that flying with the TimberMark set up in windy conditions was difficult.

Left: TimberMark sprayer, with HedGar circled in red. Native uluhe to the left of the ginger
Right: TimberMark sprayer, with HedGar circled in red. *Psidium cattleianum* is visible between the ginger and the sprayer. *Begonia folisa*, another weed, is the reddish vegetation in the bottom left of the photo.

Schofield TimberMark HedGar Spray: May



The HedGar sprays were monitored during an aerial survey 21 September 2011, almost five months after treatment. The sprayed areas were very visible; the HedGar leaves were yellowing and browning, although the plants did not appear to be dead. Escort typically takes a long time to completely kill HedGar, so this wasn't unexpected. It was difficult to evaluate non-target effects from the air. In some areas, it seemed that the line of treated foliage ended along the line of a HedGar patch, while in other areas there was a buffer of brown vegetation around the HedGar. Both native and alien taxa (*Psidium cattleianum, Buddleia asiatica*) were burned by the spray. This control technique seems to be effective, but would only be used in degraded areas dominated by alien species. It is not precise enough to use in high-quality native habitat. OARNP staff felt that it would be worthwhile to see the spray ball set-up used by MISC/National Parks.

Area treated with TimberMark. Red circles note live HedGar patches.
Yellow circles note treated, dying HedGar patches.

<u>MMR: Firebreak; Firebreak Roads</u>
The IVMP team installed herbicide trial plots along the firebreak road. They conducted vegetation monitoring in the plots prior and post spraying. The boom sprayer was used to treat these areas. OANRP involvement was limited to observing vegetation monitoring technique.

Above: spraying the north lobe of the firebreak road.
Below: the sprayed portion of the south firebreak road directly across of the Lower Ohikilolo *Chamaesyce celastroides* fuelbreaks.

South lobe of the firebreak road. The red arrows point to the sprayed area.

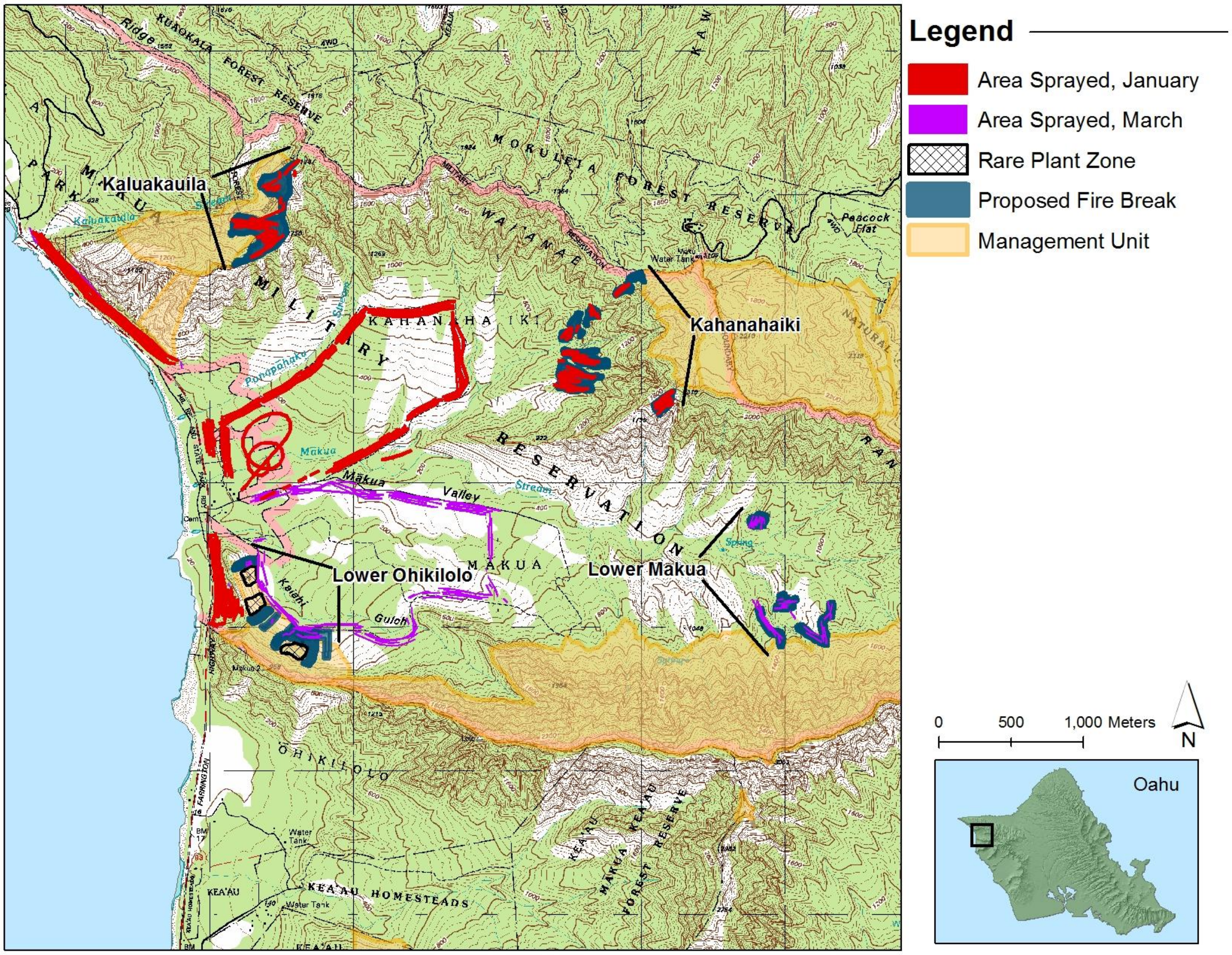
MMR: Firebreak; Farrington Highway

The area along the highway, north of Range Control was sprayed. The sprays were effective in controlling grass, but were also highly visible and provoked a negative response from the public. In addition, the area sprayed crossed over on to State land at the extreme north end of the spray zone. Woody weeds in the spray area, particularly *Leucaena leucocephala* and *Prosopsis pallida*, appeared to be recovering from the spray by April. *Dodonea viscosa* in the spray zone appeared to be dead as of April.

MMR: Firebreak; Makua Cave

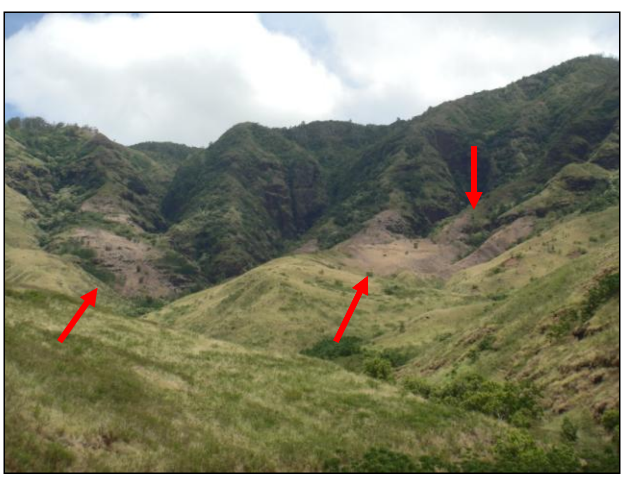
The area along Farrington Highway, between Range Control and Makua Cave and directly makai of the Lower Ohikilolo MU, was sprayed. The spray was effective in controlling alien grasses. This area

MMR Spray Locations: January and March



<u>MMR: Remote Fuel Breaks</u>

The IVMP sprayed several remote fuel breaks. All were identified and selected by OANRP, based on the Makua Biological Opinion. All remote fuel break sprays were directed at grass control.



Remote fuel break below Kahanahaiki

Fuel break north of Kahanahaiki, Kuaokala rd

MMR Remote Fuel Break Treatment Results

Area	Notes
Kahanahaiki	Six discrete locations were sprayed makai of the Kahanahaiki MU in January. These areas were monitored in April, and all had dead, brown grass. This treatment was effective. These areas were somewhat challenging to spray, due to terrain. The pilot was asked to avoid forested areas, and minimal non-target effects were observed to trees in the area. (See photos below)
Kaluakauila	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. (See photos below)
Lower Ohikilolo	Buffers to the northwest and northeast of the Lower Ohikilolo MU were sprayed in March. They were scoped first by staff. These breaks were sprayed with Fusilade and Oust. The sprays themselves went well, with a minimum of drift, but the weather was not great, and the sprays had to be timed for calm periods. The Fusilade was not effective, with very little dieback observed in April. (No photos presented as treatment ineffective.)
Lower Makua	Two locations were sprayed along the forest line in the back of Makua in March. Both were sprayed with Fusilade. When monitored aerially in April, there was some dieback visible at both sites, but results were not dramatic. (See photos below)

Remote fuel break at C-ridge

Kaluakauila remote fuel break

Lower Makua Fusilade treatment area

MMR: Alien Weed Spot Treatment

Several species were treated with TimberMark in MMR in January. They include *Melia azederach* (MelAze), *Falcataria mollucana* (FalMol), *Grevillea robusta* (GreRob), and *Spathodea campulata* (SpaCam). Multiple individuals were treated of each species. In April, these trees were monitored from the ground and from the air. The MelAze, SpaCam, and GreRob observed were all resprouting, with the exception of maybe one GreRob. Of the seven FalMol treated, four appeared to be dead from the air, while the rest still were partially foliated. Results of this Timbermark trial indicated that while the timbermark system might give good coverage, the herbicide mix used was not effective at controlling all the target species.

Spathodea campulata re-sprouting

Grevillea robusta re-sprouting

Falcataria mollucana defoliated canopies

MMR: CasSpp Spot Treatment

Two large patches of *Casuarina* species (CasSpp) in the back of MMR were sprayed with the boom sprayer. These patches have distinct edges, and are very easy targets. They were first treated in March, and by April appeared to be almost completely brown. JR and JB scoped the patches during an aerial survey in April, and identified some live trees that could be re-treated. All re-treatment took place in May.

Treated *Casuarina* patch after March spray. Some trees were missed on the edges of the plot (still green).

KTA: Alien Weed Spot Treatment

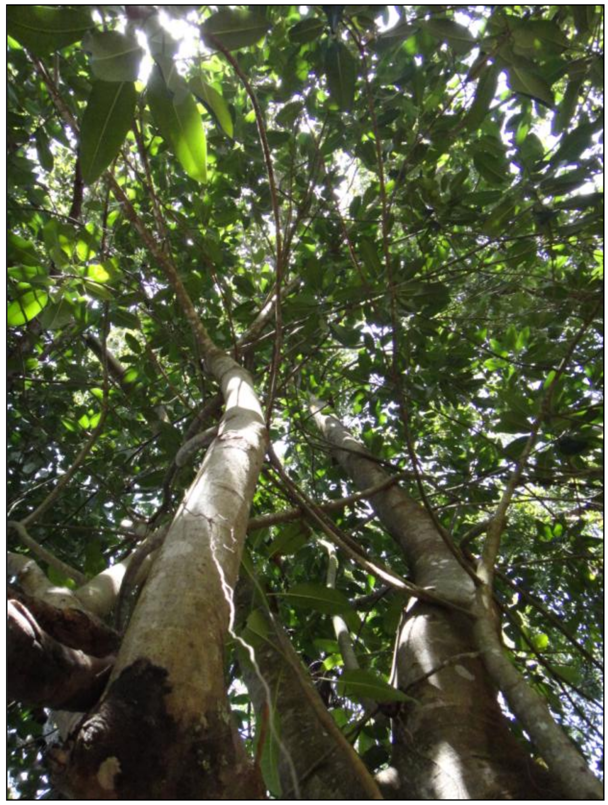
Nine species were chosen to test the TimberMark treatment technique. KK and JB selected all the trial trees, tagged them, GPSed them, and took notes on surrounding vegetation. KK rode with the pilot to assist in locating the target points during treatment. All were treated with the same herbicide mix. Most of the targets were large trees which were relatively easy to pick out (although it was difficult to ensure that the trees which had been tagged were the same ones sprayed). One of the targets, *Chromolaena odorata* (ChrOdo), a shrub, was difficult to identify from the air. KK recommends installing large flagging markers on the treatment sites, or having a spotter intimately familiar with the area ride with the pilot when treating ChrOdo.

KTA TimberMark Treatment Results

Species	# of Treated Individuals	Results
Spathodea campanulata	6	Some trees almost totally defoliated, others not. All had green cambium. Incomplete control
Ficus sp.	5	Very little effect, most plants looked healthy.
Toona ciliata	3	Most trees defoliated, some resprouting, most with green cambium. Incomplete control.
Cupressus lusitanica	5	None of the trees treated were defoliated. Most had brown leaves on the top, where they were sprayed, and green leaves below. The dense foliage of this taxa seems to have prevented the spray from penetrating even to the level of the lower branches. Incomplete control
Trema orientalis	4	All of the treated trees were partially defoliated, but appeared to be flushing with healthy new growth. Incomplete control
Falcataria mollucana	6	Several of the treated trees were almost completely defoliated, while one or two others were only partially defoliated. All had green cambium. Incomplete control
Syzigium cumini	5	Half the treated trees were bulldozed after spraying, and could not be monitored. The treated trees still left were defoliated, but all had green cambium. Incomplete control.
Grevillea robusta	5	The treated trees were all or partially defoliated. Only one had a brown, dead cambium. Incomplete control
Chromolaena odorata	4	Three treatment sites monitored. At two sites, all the plants treated were dead, as well as all the surrounding vegetation. Some Chrodo on the edges of the treatment area persisted. At the third and largest site, some ChrOdo were resprouting, but most were completely dead. This area was the first to be sprayed, and the pilot was working out kinks in the treatment system; this may have contributed to the incomplete coverage.

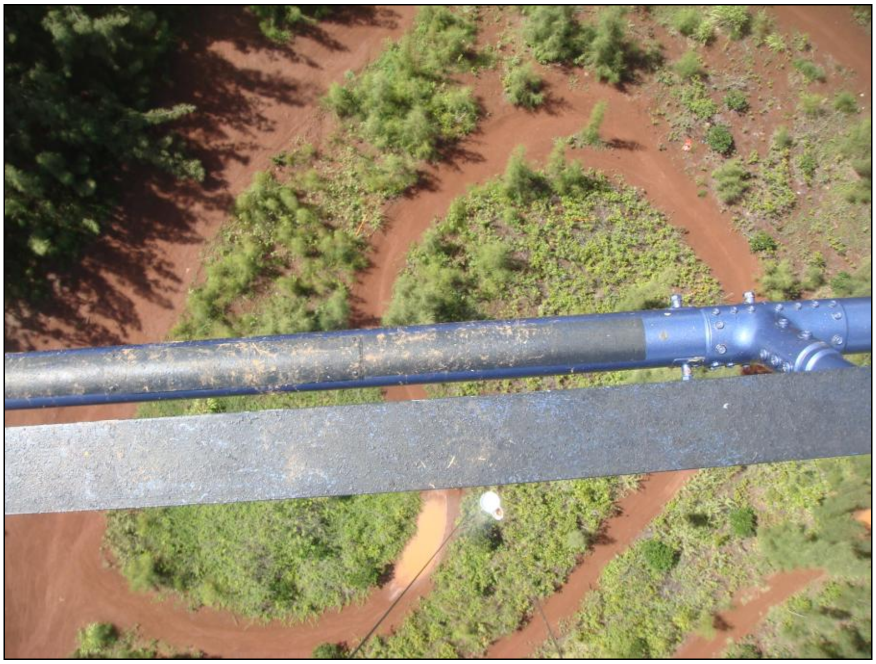
In all, the results of the trial were mixed. There were some technical problems with the spray equipment, detailed in 'Final Thoughts' below. Only one of the tree weeds treated died (GreRob). Some may still decline and die, but others may recover, as they were already showing signs of re-sprouting. The trial should be monitored once more, in another 5-6 months. Thus far, it appears that the herbicide mix was not effective in controlling the treated trees. The TimberMark sprayer was most effective on Chrodo. Non-target impacts varied. At some sites, it appeared that the dense canopy of the treated tree prevented the spray from penetrating to the understory below. At other sites, signs of spray stretched up to 15m away. KK indicated that the pilot was not told to exercise extreme precautions when spraying, and that if he had, over spray might have been a bit more limited.


Spathodea campanulata incomplete control


Ficus sp. no noticeable impact

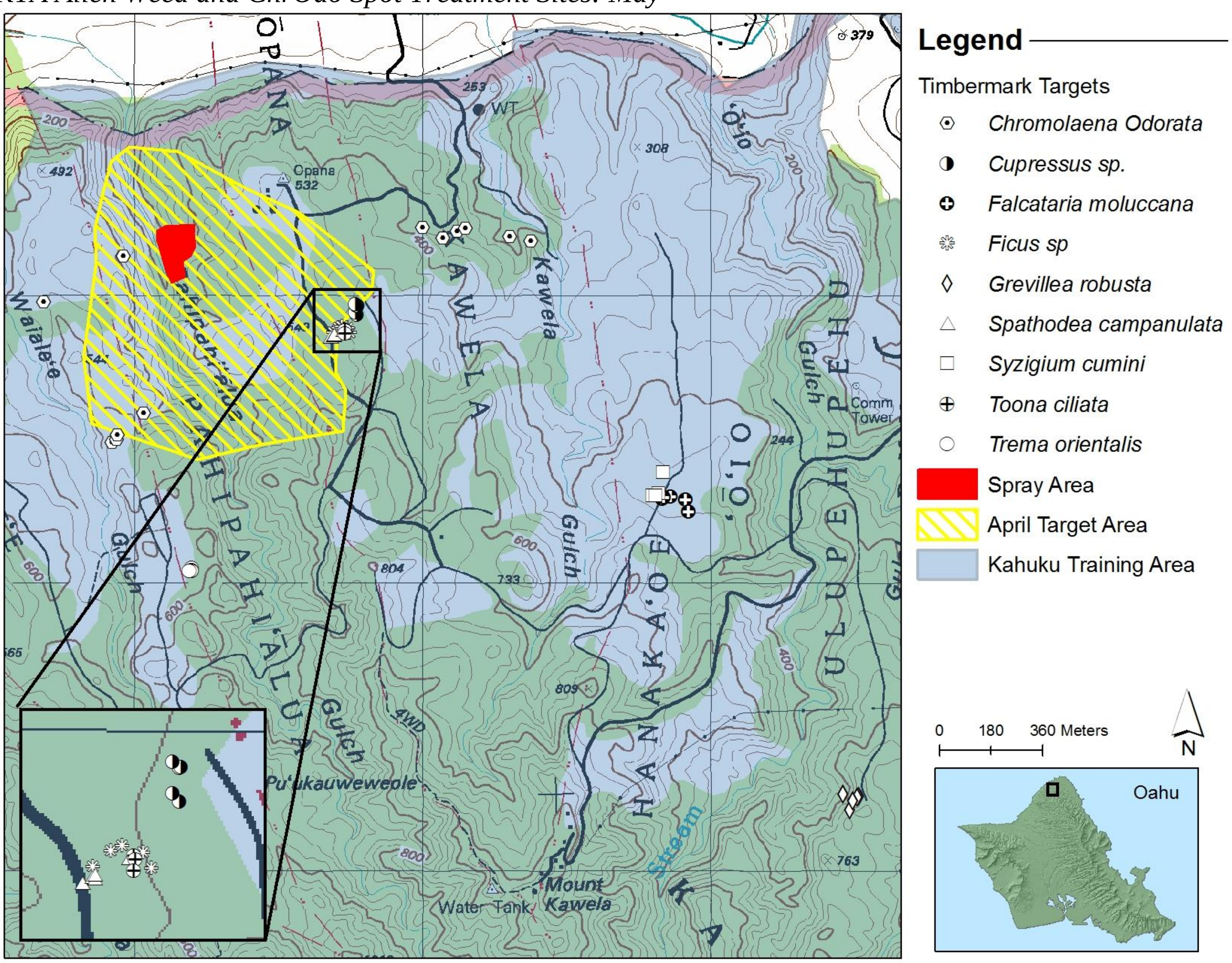

Trema orientalis re-sprouting


Cupressus lusitanica incomplete control



Spraying an outlying ChrOdo patch with TimberMark.

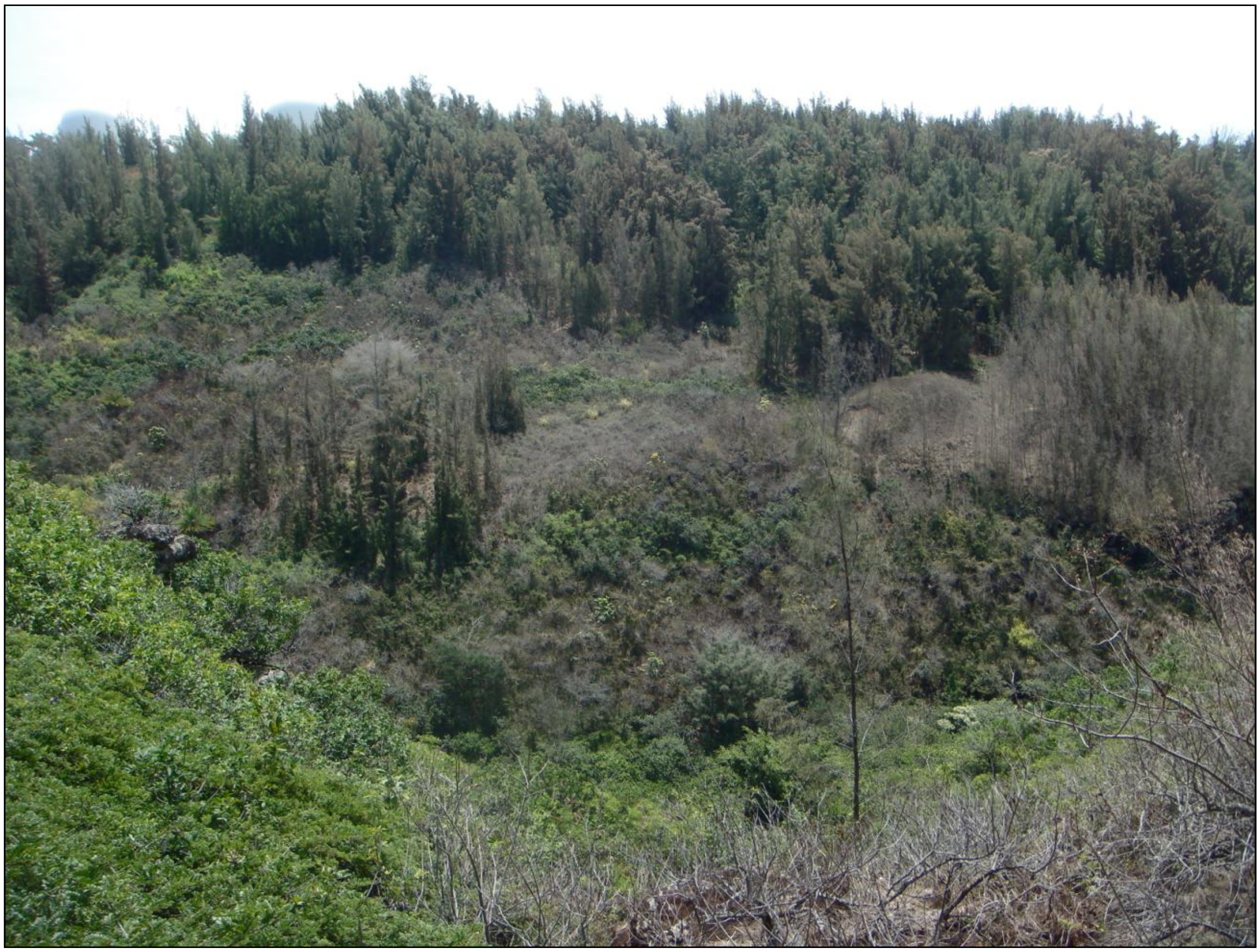
KTA Alien Weed and ChrOdo Spot Treatment Sites: May



KTA: ChrOdo Spot Treatment

The boom sprayer was used to treat the core of the Chrodo infestation. The area to be treated was identified from previous Chrodo surveys, photos, and maps. Some of the Chrodo was visible from a vantage point located across the gulch, but would have been difficult to pick out from the air. KK rode with the pilot to assist in locating the treatment area. The site was difficult to fly, due to the steep terrain and patches of tall, emergent *Casuarina*. The results of the ChrOdo treatment are detailed in the *Chromolaena odorata* Management Summary and Control Plan.

The boom sprayer was effective in treating the entire area. Photos taken from across the gulch show that the core Chrodo area is brown and burned one month after treatment. While it is unlikely that all Chrodo plants in the spray zone died, there was a serious reduction in vegetation cover.



The ChrOdo infestation core, after boom spraying.



Pilot Tom, watching the TimberMark set-up Boom spraying the ChrOdo patch

Recommendations and Final Thoughts

Boom Sprayer
The boom sprayer was an effective fuel break control tool. It provided good coverage of the CasEqu and ChrOdo patches as well. OANRP is not confident that the optimal herbicide mix for controlling both woody weeds and grasses was identified. This could prove to be a valuable tool for firebreak maintenance as well as removal of some invasive species for degraded areas.

Lessons learned:
- Boom sprayer gets good coverage
- Nozzles worked particularly well and were praised by the pilot, Tom Haupman
- Well-suited for treatment of large swaths of vegetation.
- Slopes and steep terrain add difficulty to flying and getting good coverage
- Emergent trees in the spray zone make application difficult and potentially dangerous.
- The on-board GPS provides good feedback to pilot and is very useful for staff to plan and track control. The delay between pressing the spray trigger and activation of the GPS log can be problematic.

TimberMark
The TimberMark system was a more difficult tool than the boom sprayer. Lessons learned:
- Big targets in degraded areas are best
- Targets must be well marked
- The GPS system was buggy and didn't function well
- The double connection cables are a hazard as they can snag on vegetation

- Difficult to tell how much herbicide is being applied to a target
- Difficult to tell how much herbicide left in tank as the system was designed for applying paint, a more viscous solution, therefore the gage read inaccurately

The pilot, Tom Haupman, offered some comparisons between the TimberMark system and a regular Ball Sprayer system (with which he is familiar):

TimberMark	Ball Sprayer
2 connection cables = less safe	1 connection cable = more safe
Tank holds 40 gallons	Tank holds 120 gallons
Tank must be depressurized before refilling	Tank not pressurized
No fill valve on tank; difficult for pilot to determine how much herbicide left.	Pilot can see how much spray left in tank
Herbicide weight at end of rope = less safe	Herbicide weight on ship = more safe
Nozzles dispense large droplets, minimal aeration, minimal drift = more safe	Nozzles do not dispense large droplets, solution is aerated, more drift = less safe
May deliver herbicide at faster rate	May deliver herbicide at slower rate
Spray pressure inconsistent, because powered by compressed air, system designed for paint delivery (paint is more viscous than herbicide solution). Often have to hover and wait for pressure to rebound after an application.	Spray pressure consistent, because electric pump used.
Cannot pull spray rig through tree canopy, as not ruggedized, and 2 connection cables.	Can pull spray rig through canopy, as ball is ruggedized, and only 1 connection cable.
Spray rig is heavy, easier to punch through canopy for treatment	Spray rig is light, difficult to punch through canopy for treatment.
GPS system connected to trigger	GPS system not connected to trigger
Rig not currently available in State	Rig present on Maui, used by Pacific Helicopters

Some of the good features of the TimberMark system could be added to the Ball Sprayer system, in particular changing out the spray nozzles, and connecting the spray trigger to an onboard GPS system.

<u>Future Use</u>
If the IVMP returns to Oahu with more funding:

- Consider additional treatment/maintenance of remote fuel breaks. These were the most successful IVMP operations.
- Consider treatment of Chrodo hotspots in KTA. These sprays were also successful. Since large markings on the ground are critical for the pilot/spotter, all treatment sites must be visited ahead of time. Only large and/or remote Chrodo patches are worthwhile for this action.

Spray ball operataions:

- Gain experience with other spray ball rigs in the State. Evaluate. Consider using for treating Chrodo in KTA, and possible HedGar in Haleauau.

Appendix X:

<u>Vegetation Monitoring Checklists for Kaluaa:</u>

Native Canopy:

Species Name	Percent Occurrence (out of 149 plots)
Pouteria sandwicensis	28.86%
Acacia koa	27.52%
Metrosideros polymorpha	27.52%
Psychotria mariniana	20.81%
Alyxia oliviformis	17.45%
Pisonia umbellifera	10.74%
Canavalia galeata	9.40%
Coprosma foliosa	8.72%
Pipturis albidus	8.72%
Psydrax odorata	8.72%
Diospyros hillebrandii	6.71%
Freycinetia arborea	6.71%
Morinda trimera	6.04%
Myrsine lessertiana	6.04%
Claoxylon sandwicensis	5.37%
Pisonia sandwicensis	5.37%
Antidesma platyphyllum	4.70%
Dodonaea viscosa	4.70%
Psychotria hathewayi	4.70%
Streblus pendulinus	4.70%
Cocculus orbiculatus	4.03%
Hedyotis terminalis	4.03%
Korthalsella degeneri	3.36%
Caesalpinia bonduc	2.68%
Charpentiera obovata	2.01%
Coprosma longifolia	2.01%
Labordia kaalae	2.01%
Lepisorus thungbergianus	2.01%
Melicope oahuensis	2.01%
Pisonia brunoniana	2.01%
Smilax melastomifolia	2.01%
Styphelia tameiameiae	2.01%
Diospyros sandwicensis	1.34%
Elaeocarpus bifidus	1.34%
Leptecophylla tameiameiae	1.34%
Nestegis sandwicensis	1.34%
Pteralyxia macrocarpa	1.34%
Santalum freycinetianum var. freycinetianum	1.34%
Strongylodon ruber	1.34%
Syzygium sandwicensis	1.34%
Urera glabra	1.34%
Bobea elatior	0.67%
Broussaisia arguta	0.67%
Chamaesyce multiformis	0.67%
Charpentiera tomentosa	0.67%
Clermontia persicifolia	0.67%

Species Name	Percent Occurrence (out of 149 plots)
Cyanea angustifolia	0.67%
cyrtomium caryotideum	0.67%
Dicranopteris linearis	0.67%
Ilex anomala	0.67%
Korthalsella complanata	0.67%
Microlepia strigosa	0.67%
Myrsine sandwicensis	0.67%
Nephrolepis exaltata subsp. hawaiiensis	0.67%
Neraudia melastomifolia	0.67%
Pittosporum glabrum	0.67%
Pleomele forbesii	0.67%
Sapindus oahuensis	0.67%
Scaevola gaudichaudiana	0.67%

Native Understory:

Species Name	Percent Occurrence (out of 149 plots)
Alyxia oliviformis	34.23%
Cocculus orbiculatus	33.56%
Doodia kunthiana	31.54%
Pouteria sandwicensis	28.19%
Microlepia strigosa	26.85%
Acacia koa	25.50%
Metrosideros polymorpha	22.82%
Psychotria mariniana	22.15%
Carex wahuensis	17.45%
Coprosma foliosa	16.11%
Pisonia umbellifera	14.77%
Canavalia galeata	14.09%
Chamaesyce multiformis	14.09%
Nephrolepis exaltata subsp. hawaiiensis	14.09%
Dianella sandwicensis	12.75%
Freycinetia arborea	12.08%
Dicranopteris linearis	11.41%
Lepisorus thungbergianus	11.41%
Dryopteris sandwicensis	10.74%
Hedyotis terminalis	10.74%
Pipturis albidus	10.74%
Antidesma platyphyllum	10.07%
Charpentiera obovata	10.07%
Tectaria gaudichaudii	10.07%
Carex meyenii	9.40%
Asplenium macraei	8.72%
Claoxylon sandwicensis	8.72%
Diospyros hillebrandii	7.38%
Myrsine lessertiana	7.38%
Psychotria hathewayi	7.38%
Bidens torta	6.71%
Cibotium chamissoi	6.71%
Dodonaea viscosa	6.71%
Psydrax odorata	6.71%

Species Name	Percent Occurrence (out of 149 plots)
Pisonia sandwicensis	6.04%
Asplenium horridum var. horridum	5.37%
Coprosma longifolia	5.37%
Caesalpinia bonduc	4.70%
Charpentiera tomentosa	4.70%
Scaevola gaudichaudiana	4.70%
Sphenomeris chinensis	4.70%
Streblus pendulinus	4.03%
Dryopteris glabra	3.36%
Eragrostis grandis	3.36%
Labordia kaalae	3.36%
Melicope oahuensis	3.36%
Microlepia speluncae	3.36%
Pisonia brunoniana	3.36%
Psilotum nudum	3.36%
Smilax melastomifolia	3.36%
Diplazium sandwichianum	2.68%
Nephrolepis cordifolia	2.68%
Peperomia tetraphylla	2.68%
Phyllanthus distichus	2.68%
Pteridium aquilinum	2.68%
Styphelia tameiameiae	2.68%
Cyperus hypochlorus var. hypochlorus	2.01%
Delissea waianaeensis	2.01%
Diospyros sandwicensis	2.01%
Elaphoglossum paleaceum	2.01%
Morinda trimera	2.01%
Panicum nephelophilum	2.01%
Psilotum complanatum	2.01%
Solanum sandwicense	2.01%
Strongylodon ruber	2.01%
Asplenium contiguum	1.34%
Asplenium nidus	1.34%
Cyanea pinnatifida	1.34%
Doryopteris decora	1.34%
Dryopteris fusco-atra	1.34%
Hedyotis acuminata	1.34%
Hedyotis schlechtendahliana	1.34%
Huperzia phyllantha	1.34%
Korthalsella complanata	1.34%
Korthalsella degeneri	1.34%
Leptecophylla tameiameiae	1.34%
Lobelia yuccoides	1.34%
Nestegis sandwicensis	1.34%
Peperomia sp.	1.34%
Pteralyxia macrocarpa	1.34%
Selaginella arbuscula	1.34%
Urera glabra	1.34%
Vaccinium reticulatum	1.34%
Vandenboschia cyrtotheca	1.34%
Alectryon macrococcus var. macrococcus	0.67%
Asplenium excisum	0.67%

Species Name	Percent Occurrence (out of 149 plots)
Bobea elatior	0.67%
Broussaisia arguta	0.67%
Clermontia persicifolia	0.67%
Ctenitis latifrons	0.67%
Cyanea superba subsp. superba	0.67%
cyrtomium caryotideum	0.67%
Dubautia laxa	0.67%
Elaeocarpus bifidus	0.67%
Elaphoglossum alatum	0.67%
Gahnia beecheyi	0.67%
Ilex anomala	0.67%
Lysimachia hillebrandii	0.67%
Machaerina angustifolia	0.67%
Melicope clusiifolia	0.67%
Myrsine sandwicensis	0.67%
Neraudia melastomifolia	0.67%
Pittosporum glabrum	0.67%
Pleomele forbesii	0.67%
Rumex albescens	0.67%
Sadleria cyatheoides	0.67%
Santalum freycinetianum var. freycinetianum	0.67%
Schiedea kaalae	0.67%
Syzygium sandwicensis	0.67%
Viola chamissoniana	0.67%
Wikstroemia oahuensis var. oahuensis	0.67%
Xylosma hawaiiense	0.67%
Zanthoxylum kauaense	0.67%

Alien Canopy:

Species Name	Percent Occurrence (out of 149 plots)
Schinus terebinthifolius	67.79%
Passiflora suberosa	41.61%
Psidium cattleianum	38.26%
Toona ciliata	30.87%
Aleurites moluccana	19.46%
Grevillea robusta	17.45%
Psidium guajava	12.75%
Passiflora edulis	10.07%
Lantana camara	8.05%
Phlebodium aureum	5.37%
Buddleia asiatica	4.70%
Clidemia hirta	2.68%
Ipomoea cairica	2.68%
Spathodea campanulata	1.34%
Cordyline fruticosa	0.67%
Eucalyptus sp.	0.67%
Heliocarpus popayanensis	0.67%
Musa sp.	0.67%

Alien Understory:

Species Name	Percent Occurrence (out of 149 plots)
Clidemia hirta	88.59%
Passiflora suberosa	72.48%
Schinus terebinthifolius	63.09%
Blechnum appendiculatum	50.34%
Toona ciliata	48.99%
Christella parasitica	46.98%
Psidium cattleianum	44.97%
Lantana camara	40.27%
Rubus rosifolius	28.19%
Phlebodium aureum	26.85%
Oplismenus hirtellus	16.11%
Grevillea robusta	15.44%
Psidium guajava	14.77%
Youngia japonica	14.77%
Melinis minutiflora	14.09%
Ageratina riparia	13.42%
Conyza bonariensis	13.42%
Paspalum conjugatum	12.08%
Buddleia asiatica	11.41%
Passiflora edulis	10.07%
Physalis peruviana	10.07%
Oxalis corniculata	8.72%
Aleurites moluccana	8.05%
Ageratum conyzoides	6.71%
Ipomoea cairica	5.37%
Christella dentata	4.70%
Kalanchoe pinnata	4.70%
Cordyline fruticosa	4.03%
Spathodea campanulata	3.36%
Adiantum radianum	2.68%
Crassocephalum crepidoides	2.68%
Deparia petersenii	2.68%
Nephrolepis multiflora	2.68%
Rivina humilis	2.68%
Anagallis arvensis	2.01%
Musa sp.	2.01%
Schefflera actinophylla	2.01%
Stachytarpheta dichotoma	2.01%
Andropogon virginicus	1.34%
Cheilanthes viridis	1.34%
Erichtites valerianifolia	1.34%
Heliocarpus popayanensis	1.34%
mallotus phillippenis	1.34%
Panicum maximum	1.34%
Rhynchelytrum repens	1.34%
Triumfetta semitriloba	1.34%
Adiatum hispidulum	0.67%
Arundina gramminifolia	0.67%
Drymaria cordata var. pacifica	0.67%
Emilia sonchifolia	0.67%

Species Name	Percent Occurrence (out of 149 plots)
Erigeron karvinskianus	0.67%
Eucalyptus sp.	0.67%
Hyptis pectinata	0.67%
Kyllinga brevifolia	0.67%
Leucaena leucocephala	0.67%
Melia azedarach	0.67%
Plantago lanceolata	0.67%
Salvia occidentalis	0.67%
Setaria gracilis	0.67%
Setaria palmifolia	0.67%

Hapapa Bench/Land of 10,000 Snails
Restoration/Re-vegetation Plan

Goal of Plan:
To establish a detailed restoration/revegetation strategy and associated timeline for execution for the Hapapa Bench (flat portions) and the predator exclosure.
Goal of Restoration:
Restore a diverse habitat of known host plants to provide food and shelter for *Achatinella mustelina* which will reduce temperatures, raise site humidity and provide adequate cover from daytime exposure. Restore native host plants for *Drosophila montgomeryi.*
Measures of Success:
- The revegetation goal within the Hapa snail exclosure is to obtain a 100% vegetation cover within three years. A combination of aerial and ground photopoints will be installed in order to monitor revegetation progress in areas that are currently open.
- Monitor the success of seed sowing using 1x1 meter plots via % cover of the species sown.

Background:
Management History
1950s and 1960s: Jon Obata first visited the bench area and he said the area was nearly impenetrable as it was a dense mass of ieie, papala kepau, and opuhe tangled together.
1980s and early 1990's: TNC conducts weed trials and biological surveys, notes that the extensive native bryophyte layer in the area is being destroyed by pig activity.
2000: Ken Wood finds large *Freycinetia arborea* patches with 30 snails on each piece of *F. arborea*; he names the site "Land of 10,000 Snails."
2001: Vince Costello and Mike Hadfield visit the site. Daniel Chung conducts a snail survey using transects throughout Hapapa and Waieli area.
2004: 481 *A. mustelina* snails counted in 24 person hours.
2006: 25 acre Hapapa/North Kaluaa fence completed by the Nature Conservancy (TNC), volunteers, and OANRP staff.
2009: Almost 50% less *A. mustelina* seen and 169 *E. rosea* collected. Concerns about the future health of the *A. mustelina* population grows.
2009-2010: Army Compatible Use Buffer Program purchases Honouliuli Preserve with assistance from State, and private partners primarily for endangered species management. Title transfers to the State of Hawaii for management as a forest reserve with other uses as well including recreational hiking and hunting.
2010: *A. mustelina* collected to store in the lab until the predator proof fence is completed.
2011: 142 *E. rosea* collected on the bench and killed in a 3 day period using 60 man hours
2011: Install predator-proof fence

MIP/OIP Rare Resources at Hapapa Bench/Land of 10,000 Snails:

Organism Type	Species	Pop. Ref. Code	Management Designation	Wild/ Reintroduction
Plant	*Plantago princeps* var. *princeps*	ELI-A	MFS	Reintroduction
Snail	*Achatinella mustelina*	KAL-A	MFS	Wild
Insect	*Drosophila montgomeryi*		MFS	Wild

MFS= Manage for Stability *= Populaiton Dead
GSC= Genetic Storage Collection †=Reintroduction not yet don

Other Rare Taxa at the Hapapa Bench/Land of 10,000 snails:

Organism Type	Species	Status
Plant	*Cyanea grimesiana subsp. obatae*	E
Plant	*Cyanea membranacea*	None
Plant	*Delissea waianaensis*	E
Plant	*Melicope christophersenii*	PE
Plant	*Phyllostegia mollis*	E
Plant	*Platydesma cornuta var. decurrens*	PE
Plant	*Schiedea pentandra*	SOC
Plant	*Schiedea hookeri*	E
Plant	*Schiede kaalae*	E
Plant	*Solanum sandwicense*	E
Plant	*Urera kaalae*	E
Insect	*Drosophila ambochila*	E
Snail	*Endodonta sp.*	None
Snail	*Cookeconcha sp.*	None
Snail	*Laminella sanguinea*	SOC
Snail	*Amastra micans*	SOC

SOC: Species of Concern, **C:** Candidate, **E**: Endangered, **PE:** Proposed Endangered

Hapapa Bench/Land of 10,000 snails Map

Map removed, available upon request


Southeast portion of excluder fence


NW side of proposed predator proof fence. Pisonia reintroductions in foreground, and older Pisonia habitat in the background where *A. mustelina* will be released in predator proof fence.


East portion of excluder fence

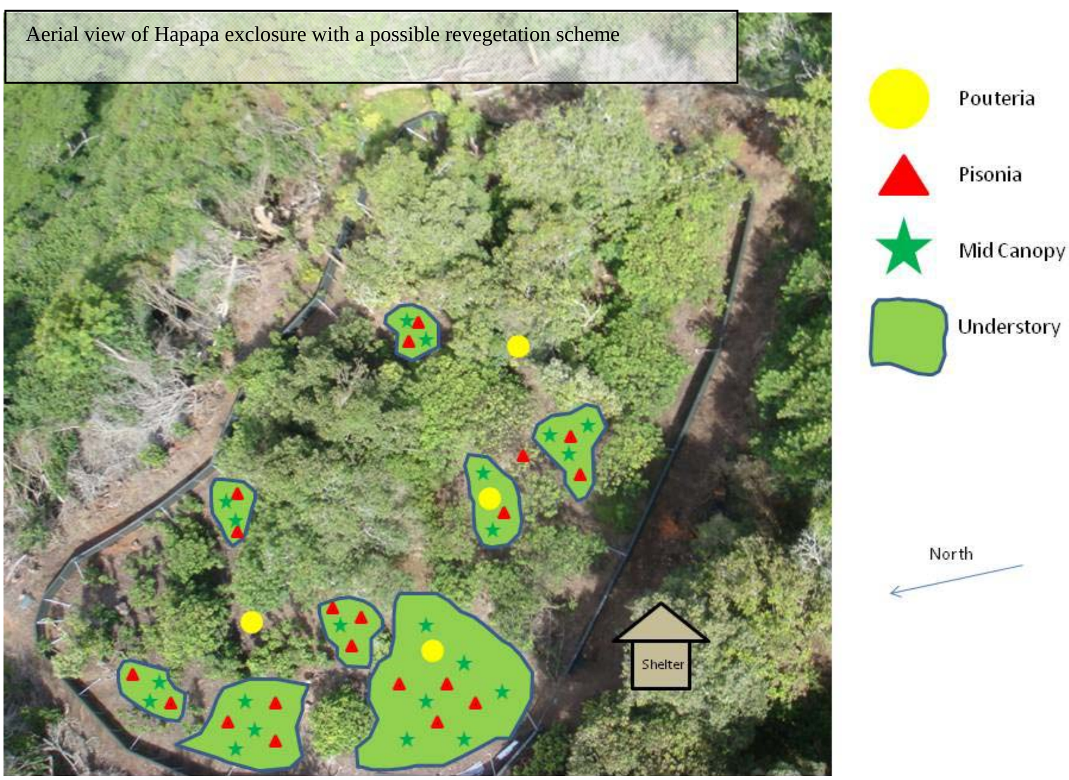

West portion of excluder fence


West side of proposed predator proof fence with A. mustelina habitat in the background on the right.


Southeast side of predator proof fence boundry with *A. mustelina* habitat in *P. sandwicensis* tree habitat in middle background.

Photo Collage of Hapapa Bench/Land of 10,000 Snails


Aerial view of Hapapa exclosure immediately following exclosure construction



Aerial view of Hapapa exclosure with a possible revegetation scheme

Predator-Proof fence Design Overview

- The *Euglandina* fence will be based off a rat/mouse proof mesh fence with added barriers. The rat/mouse proof fence must be a tested and proven design with a buried portion, a hood, tight mesh construction, and engineered fasteners and junctions. All fence materials must be stainless or heavily galvanized to ensure longevity under harsh conditions. Compatibility of materials used must be considered.
- In diverting for the typical mouse/rat fence; approximately the bottom half meter of fencing will be a solid sheet of stainless steel or comparable material
- On this sheeting additional barriers will be mounted to include some or all of the following:
    - A secondary flashing sheet mounted at 15% off the vertical wall. The flashing will be approximately 15 cm in length
    - An electric fencing tape (2-3 inches wide). This will be connected to a photovoltaic system within the fence

<u>Restoration Approaches</u>

1) seed sowing; 2) transplanting; 3) reintroduction; 4) passive recruitment

Plants For Hapapa Restoration (Species in bold to be planted in greater numbers)

PLANT TAXA **level of difficulty**	**Understory**	**Canopy**	**Prop Technique**	**Notes**	**Collection Period**
FAST GROWING					
Asplenium nidus	X		transplant		
Bidens torta *E*	X		Seed sowing		July-Aug
Cyanea membranacea *E*	X		Seed-grown outplant	Weisenberger	Aug-Oct
Hedyotis terminalis *E*	X		Sowing or transplant		
Microlepia strigosa *I*	X		In vitro/cuttings	Lynch	
Pipturus albidus *E*		X	Seed-grown outplant/ seed sowing		Continual
Pisonia brunoniana ***E***		X	Sowing or seed grown outplant	Koebele	
Pisonia sandwicensis ***E***		X	Sowing, seed grown outplant, transplant	Koebele	
Pisonia umbellifera ***E***		X	Sowing, seed grown outplant, transplant	Koebele	
Urera glabra ***E***		X	Cuttings/seed sowing	TNC	
Urera kaalae ***E***		X	Cuttings	TNC	
SLOW GROWING					

PLANT TAXA **level of difficulty**	**Understory**	**Canopy**	**Prop Technique**	**Notes**	**Collection Period**
Charpentiera sp. *E*		X	Seed grown outplant		
Freycinetia arborea *D*	X		Seed grown outplant		
Labordia kaalae *I*		X	Seed sowing		July-Sept
Metrosideros polymorpha *E*		X	Cuttings		
Myrsine lessertiana *I*		X	Seed grown outplant/seed sowing/transplant	Koebele	
Pleomele forbesii *I*		X	Seed grown outplant		
Pouteria sandwicensis *E*		X	Seed grown outplant/transplant saplings	Koebele	
Psychotria hathewayi *I*		X	Seed grown outplant	Koebele	

E=easy, I=intermediate, D=difficult

1) **Seed sowing**: Opportunistic collection of fruits/seeds of host plants. Sowing can be done at start of the wet season and also opportunistically for seeds with a longer dormancy. Sowing should be done in shallow, wide depressions to maximize soil moisture. Tamping (but avoid burying of small seeds) to ensure good seed-soil contact may help. For *Pisonia*, given how sticky the fruits are, just collect bunches of fruit and sow the whole bunch.

2) **Tr*ansplan*ting**: Transplanting to consist of digging up keikis from adjacent areas and using cutting material. Again, since some keikis are clustered together, easier sometime to just dig up the whole cluster and plant that cluster in the same spot than damage roots by separating them. Kolea, Papala kepau, mamaki are good candidates for transplanting. Larger *Pisonia umbellifera* branches can root if kept moist and thinly buried, should also be tried in a shadier location. It is very important to track and monitor these efforts in order to adapt the use of these techniques based on success rates observed.

3) **Reintroduction:** Plants can be grown on site at a field nursery as needed or more easily at our Army nurseries. One option is to grow plants in planter boxes, rather than in traditional pots. The idea behind planter boxes is to grow a bunch of host plants in a number of rectangular planter/flower boxes without regard for separating individual plants out since the goal is just to provide food and shelter for snails. This eliminates the need to individually transplant seedlings from small pots to larger ones etc. Processing of fruits should also be minimal to cut down on labor costs (e.g. basic pulp removal only for really fleshy fruit like pilo). More seeds can be added to planter boxes as collected as well to fill out areas that aren't growing well. The whole box can then be planted at the exclosure with plants allowed to thin themselves out over time. The boxes should only be about 6 inches in depth to allow tree species to root on site rather than in tree pots. Boxes should be held in the nursery for about 6-8 months or less if need be depending on size of plants. Boxes can be planted in a grid fashion or nodes to allow for easier walking, and *Euglandina* searches.

Seed flats can be substituted instead of boxes for more fast growing ground cover species like mamaki and *Bidens* as a supplement to direct sowing on site. Again, just plant the whole flat once the root mass is large enough (think lawn but with *Bidens* and mamaki together).

Species list is basically the same as list for sowing, some other slow growing species like hame, olomea, alaa, kamakahala (Labkaa). Fruit collection for these species in adjacent areas (i.e. Palikea to Kaala) is basically opportunistic. Cuttings should be made for *U. kaalae, U. glabra* and glabrous type *M. polymorpha* to be raised in the Army Nursery.

Timing of planting: Ideally in January-February for first set of boxes and thereafter every 8 months for 3 years depending on space availability on site and in the nursery.

Restoration Action Plan:

A great deal of vegetation was altered during construction of the predator proof fence at Hapapa. Numerous giant *S. terebinthifolius* were felled or heavily trimmed to make a corridor for the fence to follow. Subsequently, the habitat requires restoration to be suitable for snails. The priority at the Hapapa bench should be to restore canopy and understory where there are gaps using fast-growing, sun-loving native plants in order to maintain shade and moisture within snail habitat. Based on foundational work conducted at the site in 2006 by TNC, OANRP can develop a plan to achieve immediate cover in the short-term which also incorporates slower-growing species for long-term habitat recovery.

There are countless ways to achieve successful restoration of this habitat and the approach suggested in this plan is merely one such way. This approach will focus on seed-grown outplants and seed sowing. Other approaches that have been suggested include the use of mixed species planter boxes and field nurseries and perhaps these can be utilized in the execution phase of this action plan.

All restoration efforts should be tracked closely so that successes can be duplicated and unsuccessful techniques can be reassessed. The Ecosystem Restoration Program Manager created a common native effort tracking spreadsheet on the shared drive.

YEAR 1: Grow 100 *Urera kaalae* via cuttings, 200 *Pisonia umbelifera* and conduct *B. torta* seed sow where understory is thin.

- Collect *B. torta* and *L. kaalae* seed from Kaluaa-late summer 2011.
- Collect cuttings from all available sources of *U. kaalae* within old TNC outplantings in fall of 2011.
- Collect seed from *Pisonia umbellifera* in the fall and winter of 2011. See Koebele Papala kepau propagation tips.
- Utilize Army Greenhouse collection of U. kaalae to produce seed to sow.
- Conduct seed sow of *B. torta* as needed within exclosure to provide for vegetation connectivity.
- Use TNC propagation technique for growing *U. kaalae* from cuttings to obtain plants quickly.
- Grow taxa until they are in 4”-6”pots (ideally by Winter 2012).

YEAR 2: Plant fast growing canopy in gaps to provide continuous habitat for *A. mustelina* and make collections of slower growing *Pouteria sandwicensis*, *Myrsine lessertiana* and *Freycinetia arborea*.

- Plant 100 *U. kaalae* and 200 *P. umbelifera* in 4”-6” pots. Conduct follow-up maintenance and care during regular snail and predator control visits to area.
- Collect *P. sandwicensis* during Fall 2012 and *M. lessertiana* and *F. arborea* when available with goal to have 50 of each for planting in few years.
- Germinate above taxa in Greenhouse. See Koebele Papala kepau and Kolea propagation tips.

YEAR 3-4: Plant slow-growing taxa grown in year 2 and collect a diversity of plants from the table to increase diversity

- Collect to grow a diverse mix of ~100 plants from the table above.
- Grow plants in greenhouse and outplant
- Continue to adapt and improve restoration plans for this site based on lessons learned.

APPENDIX (OTHER RESOURCES)

Taxon summary: *Cookeconcha* sp. 1

Species/habitat description: Undescribed species, 0.5 cm maximum size. Helical with brown bands perpendicular to whorls. Thought to be extinct until re-discovered at Puu Hapapa in 2002. Probably detritivore, possibly fungus and lichen grazer as well. Found on lower limbs of Pisonia umbellifera branches clustered near branch crotches and knots. Also found on rocks and soil. Species was formally widespread throughout the preserve in soil and talus slopes of upper gulch pockets of mesic forest 2000-2900' in elevation.

Global population distribution:

Location (code)	**Est. number**	**Represented in captive prop.?**	**Notes**
Puu Hapapa (HAP-A)	300	No	Found only at two sites at Hapapa bench area. First core site contains approx. 300 (counted 2004 D. Sailer/Y. Johnston). Second site had only 2 snails (4 box area south of shelter).

Management recommendations:

- Euglandina and flatworms are the primary predators as the snails are too probably small for rats.
- Formally re-survey and census area annually during periods of extended rainfall.
- Bring 3-5 individuals into captive propagation from Puu Hapapa.
- Assist D. Chung or other malacologist with captive rearing efforts by assisting with funding search for more formal captive propagation lab.
- Conduct informal Euglandina search and removals quarterly at all locations.
- Recruit researcher assistance (Marty Meyers) for monthly Euglandina removals at Puu Hapapa and Central Kaluaa areas.

- Survey S. Ekahanui area and 4 box area again at Puu Hapapa to determine if still extant at those areas.
- Restore Pisonia habitat in core population (30 m sq. area) and minimize human traffic in area.

Taxon summary: *Endodonta* sp. 1

Species/habitat description: 0.5 cm maximum size. Undescribed species. Ground snail, probably detritivore, possibly fungus and lichen grazer. Found on rocks near Cookeconcha area in Oct. 2005, previously thought to be extinct.

Global population distribution:

Location (code)	Est. number	Represented in captive prop.?	Notes
Puu Hapapa (HAP-A)	5?	No	Found 2005, Marty Meyers near Cookeconcha area.

Management recommendations:
- Euglandina and flatworms are the primary predators as the snails are too probably small for rats.
- Formally re-survey and census area annually during periods of extended rainfall.
- Bring 3-5 individuals into captive propagation from Puu Hapapa.
- Assist D. Chung or other malacologist with captive rearing efforts by assisting with funding search for more formal captive propagation lab.
- Conduct informal Euglandina search and removals quarterly at all locations.
- Recruit researcher assistance (Marty Meyers) for monthly Euglandina removals at Puu Hapapa and Central Kaluaa areas.
- Survey other areas of Puu Hapapa to determine if still extant elsewhere.
- Restore Pisonia habitat in core population (30 m sq. area) and minimize human traffic in area.

Taxon summary: *Laminella sanguinea*

Species/habitat description: 1.5 to 2 cm maximum. Conical with black zig zags, cream to tan to brown in coloration, fading to pink with age. Usually arboreal, found climbing along *Freycinetia arborea* or trunks of other native trees (e.g. Pisonia or Xylosma). May also be found in leaf litter, appears to prefer litter of *Urera glabra*, *Pipturus albidus,* and *Freycinetia arborea*. Species seems to prefer ie ie covered soil/talus slopes in upper gulch pockets of diverse mesic forest. About 2000-2800 ft. in elevation. Lamsan are very difficult to find given habit of remaining in ie ie axils or leaf detritus and covering itself with dirt, mucus and agglutinations.

Global population distribution:

Location (code)	**Est. number**	**Represented in captive prop.?**	**Notes**
Puu Hapapa (HAP-A)	5?	Yes	Population declining at Hapapa bench area due to ie ie destruction and presumed predation by Euglandina.

Management recommendations:
- Continue rodent control at all population locations.
- Formally re-survey area annually during periods of extended rainfall.
- Bring 3-5 individuals into captive propagation from locations other than Puu Hapapa if found during surveys.
- Assist D. Chung or other malacologist with captive rearing efforts by assisting with funding search for more formal captive propagation lab.
- Conduct informal Euglandina search and removals quarterly at all locations.
- Recruit researcher assistance (Marty Meyers) for monthly Euglandina removals at Puu Hapapa.
- Minimal impact habitat restoration of known sites to increase levels of native leaf litter and re-growth of ie ie.

Drosophila

Because *Urera* has separate male and female plants and is wind-pollinated, it is susceptible to low seed set when populations become low within a small area. As a result, it may have difficulty recovering naturally even if direct threats are removed (Magnacca). In addition to the habitat alteration, *D. montgomeryi* is susceptible to predation by a variety of introduced predatory species including yellow jackets and several ant species (USFWS 2006).

The presence of such large numbers of *D. ambochila* was a good sign.., since it appears to be entirely restricted to the Honouliuli area (Magnacca).

OIP 2008: Excerpt

Threats to *Achatinella* species in general are rats (*Rattus rattus, R. norvegicus,* and *R. exulans*), predatory snails (*Euglandina rosea*), terrestrial flatworms *Geoplana septemlineata* and *Platydemis manokwari,* and the small terrestrial snail *Oxychilus alliarius*.

Threat - *Euglandina rosea:* The introduced predatory snail *E. rosea* feeds only on other snails and is the major cause of destruction of snail populations at this time.
Goal: Eliminate *E. rosea* predation via predator exclosures where possible and with dog detection teams.
Actions to Achieve Goal:
· Build exclosures around populations selected for stabilization wherever feasible. Ensure contractors adhere to design and plans for the exclosures through close monitoring of progress throughout construction.
· Toxic *E. rosea* baiting may be done much less frequently with a predator exclosure.
· Support research on dog detection of *Euglandina*.
· Support research on molluscicide for use in natural areas, and on other exclosure designs.

Threat - *Platydemis manokwari:* This flatworm is a documented predator of tree snails from other Pacific Islands and does occur from low elevations on Oahu to the top of Mount Kaala. The other two species have been found feeding on the tissue of dead Oahu tree snails, but it is not known if these two animals were the cause of death or just opportunistic feeders.
Goal: To detect and eliminate predation on *Achatinella.* Nothing is currently known about control measures for *P. manokwari*, but the electric fence on the predator exclosure may deter this flatworm.
Actions to Achieve Goal: monitoring of *Achatinella* rich areas will hopefully detect this predator if present. Research on the threat of this predator to *Achatinella* is also needed.
Monitoring: Only careful visual searching in leaf litter and under logs and rocks will reveal this flatworm. The Army will conduct searches at the same time as *E. rosea* searches.
Success: Success of detection and elimination of this species will be difficult to measure. However, populations of *Achatinella* will be monitored for growth and persistence with monitoring and research.

Appendix 1-8:
Vegetation Monitoring Checklists for Manuwai:

Native Canopy Species List	
Species Name	**Percent Occurrence (out of 231 plots)**
Diospyros sandwicensis	55.4%
Psydrax odorata	40.7%
Dodonaea viscosa	21.2%
Diospyros hillebrandii	17.3%
Alyxia oliviformis	15.6%
Metrosideros polymorpha	14.7%
Sapindus oahuensis	10.4%
Leptecophylla tameiameiae	8.7%
Wikstroemia oahuensis var. *oahuensis*	6.9%
Nestegis sandwicensis	6.1%
Pleomele halapepe	3.9%
Pouteria sandwicensis	3.9%
Psychotria hathewayi	3.5%
Lepisorus thungbergianus	3.0%
Metrosideros tremuloides	3.0%
Acacia koa	2.6%
Eugenia reinwardtiana	2.6%
Pisonia sandwicensis	2.6%
Antidesma platyphyllum	2.2%
Bobea elatior	1.7%
Canavalia galeata	1.3%
Coprosma foliosa	1.3%
Pipturis albidus	1.3%
Psychotria mariniana	1.3%
Rauvolfia sandwicensis	1.3%
Bidens torta	0.9%
Cocculus orbiculatus	0.9%
Dianella sandwicensis	0.9%
Hedyotis acuminata	0.9%
Santalum freycinetianum var. *freycinetianum*	0.9%
Strongylodon ruber	0.9%
Asplenium nidus	0.4%
Charpentiera obovata	0.4%
Cibotium chamissoi	0.4%
Coprosma longifolia	0.4%
Cyanea angustifolia	0.4%
Erythrina sandwicensis	0.4%
Hedyotis terminalis	0.4%
Perrottetia sandwicensis	0.4%
Pisonia brunoniana	0.4%
Pisonia umbellifera	0.4%
Pittosporum confertiflorum	0.4%
Pittosporum glabrum	0.4%
Reynoldsia sandwicensis	0.4%
Scaevola gaudichaudiana	0.4%
Streblus pendulinus	0.4%

Native Understory Species List	
Species Name	**Percent Occurrence (out of 231 plots)**
Diospyros sandwicensis	48.1%
Psydrax odorata	47.2%
Alyxia oliviformis	30.3%
Dodonaea viscosa	29.9%
Carex wahuensis	27.7%
Carex meyenii	24.2%
Diospyros hillebrandii	17.3%
Doodia kunthiana	16.9%
Microlepia strigosa	16.9%
Metrosideros polymorpha	14.7%
Cocculus orbiculatus	10.8%
Sapindus oahuensis	10.0%
Lepisorus thungbergianus	9.5%
Bidens torta	7.8%
Selaginella arbuscula	7.4%
Sphenomeris chinensis	7.4%
Wikstroemia oahuensis var. *oahuensis*	6.9%
Acacia koa	6.5%
Dianella sandwicensis	6.5%
Psychotria hathewayi	5.6%
Doryopteris decora	5.2%
Eugenia reinwardtiana	4.3%
Nephrolepis exaltata subsp. *hawaiiensis*	4.3%
Hedyotis acuminata	3.9%
Canavalia galeata	3.5%
Mariscus hypochlorus	3.5%
Nestegis sandwicensis	3.5%
Charpentiera obovata	3.0%
Pouteria sandwicensis	3.0%
Waltheria indica	3.0%
Leptecophylla tameiameiae	3.0%
Metrosideros tremuloides	2.6%
Peperomia blanda	2.6%
Pleomele halapepe	2.6%
Pteridium aquilinum	2.6%
Coprosma foliosa	2.2%
Eragrostis grandis	2.2%
Pisonia sandwicensis	2.2%
Dryopteris sandwicensis	1.7%
Gonocormus minutus	1.7%
Psilotum nudum	1.7%
Chamaesyce multiformis	1.3%
Coprosma longifolia	1.3%
Dicranopteris linearis	1.3%
Paspalum scrobiculatum	1.3%
Phyllostegia parviflora var. *lydgatei*	1.3%
Scaevola gaudichaudiana	1.3%

Native Understory Species List	
Species Name	**Percent Occurrence (out of 231 plots)**
Tectaria gaudichaudii	1.3%
Antidesma platyphyllum	0.9%
Boehmeria grandis	0.9%
Hedyotis schlechtendahliana	0.9%
Lythrum maritimum	0.9%
Peperomia tetraphylla	0.9%
Pipturis albidus	0.9%
Psychotria mariniana	0.9%
Rauvolfia sandwicensis	0.9%
Sida fallax	0.9%
Strongylodon ruber	0.9%
Asplenium horridum var. *horridum*	0.4%
Asplenium macraei	0.4%
Asplenium nidus	0.4%
Cibotium chamissoi	0.4%
Elaphoglossum hirtum var. *micans*	0.4%
Elaphoglossum paleaceum	0.4%
Erythrina sandwicensis	0.4%
Freycinetia arborea	0.4%
Hedyotis terminalis	0.4%
Labordia kaalae	0.4%
Lysimachia hillebrandii	0.4%
Melicope oahuensis	0.4%
Microlepia speluncae	0.4%
Morinda trimera	0.4%
Myrsine sandwicensis	0.4%
Osteomeles anthyllidifolia	0.4%
Peperomia membranacea	0.4%
Peperomia oahuensis	0.4%
Peperomia sp.	0.4%
Perrottetia sandwicensis	0.4%
Phyllanthus distichus	0.4%
Pisonia brunoniana	0.4%
Pisonia umbellifera	0.4%
Pittosporum glabrum	0.4%
Plectranthus parviflorus	0.4%
Santalum freycinetianum var. *freycinetianum*	0.4%
Scaevola mollis	0.4%

Alien Canopy Species List	
Species Name	**Percent Occurrence (out of 231 plots)**
Psidium cattleianum	64.1%
Syzygium cumini	49.4%
Toona ciliata	44.2%
Schinus terebinthifolius	33.3%
Aleurites moluccana	30.7%
Grevillea robusta	26.8%
Psidium guajava	10.0%
Passiflora edulis	5.6%
Coffea arabica	4.8%
Spathodea campanulata	4.3%
Lantana camara	2.2%
Melia azedarach	2.2%
Buddleia asiatica	1.3%
Passiflora suberosa	1.3%
Phlebodium aureum	1.3%
Leucaena leucocephala	0.9%
Acacia confusa	0.4%
Cupressus lusitanica	0.4%
Panicum maximum	0.4%
Pluchea carolinensis	0.4%
Trema orientalis	0.4%

Alien Understory Species List	
Species Name	**Percent Occurrence (out of 231 plots)**
Psidium cattleianum	74.5%
Blechnum appendiculatum	71.0%
Clidemia hirta	66.2%
Toona ciliata	48.1%
Syzygium cumini	34.6%
Schinus terebinthifolius	32.0%
Christella parasitica	28.6%
Adiatum hispidulum	26.4%
Oplismenus hirtellus	23.8%
Lantana camara	22.1%
Grevillea robusta	19.0%
Ageratina riparia	17.3%
Panicum maximum	13.4%
Kalanchoe pinnata	12.6%
Psidium guajava	12.1%
Melinis minutiflora	11.3%
Coffea arabica	10.4%
Rubus rosifolius	9.1%
Leucaena leucocephala	8.7%
Spathodea campanulata	8.2%
Aleurites moluccana	7.8%
Ageratina adenophora	7.4%
Conyza bonariensis	7.4%

Alien Understory Species List	
Species Name	**Percent Occurrence (out of 231 plots)**
Setaria gracilis	7.4%
Andropogon virginicus	6.9%
Hyptis pectinata	6.9%
Passiflora suberosa	6.5%
Stachytarpheta dichotoma	6.1%
Cordyline fruticosa	5.2%
Passiflora edulis	5.2%
Adiantum radianum	4.3%
Buddleia asiatica	4.3%
Cheilanthes viridis	4.3%
Youngia japonica	4.3%
Chamaecrista nictitans	3.9%
Oxalis corniculata	3.9%
Paspalum conjugatum	3.0%
Schefflera actinophylla	3.0%
Cupressus lusitanica	2.6%
Pennisetum polystachion	2.2%
Plantago lanceolata	2.2%
Begonia Hirtella	1.7%
Christella dentata	1.7%
Rhynchelytrum repens	1.7%
Ageratum conyzoides	1.3%
Emilia sonchifolia	1.3%
Phlebodium aureum	1.3%
Triumfetta semitriloba	1.3%
Chrysopogon aciculatus	0.9%
Cuphea carthagenesis	0.9%
Desmodium incanum	0.9%
Digitaria setigera	0.9%
Nephrolepis multiflora	0.9%
Pluchea carolinensis	0.9%
Rubus argutus	0.9%
Acacia confusa	0.4%
Axonopus fissifolius	0.4%
Castilleja arvensis	0.4%
Centella asiatica	0.4%
Crotalaria pallida	0.4%
Deparia petersenii	0.4%
Digitaria ciliaris	0.4%
Drymaria cordata var. *pacifica*	0.4%
Oxalis corymbosa	0.4%
Pityrogramma austroamericana	0.4%
Sida rhombifolia	0.4%
Spathoglottis plicata	0.4%
Trema orientalis	0.4%
Vernonia cinerea	0.4%

DEPARTMENT OF THE ARMY
US ARMY INSTALLATION MANAGEMENT COMMAND, PACIFIC REGION
HEADQUARTERS, UNITED STATES ARMY GARRISON, HAWAII
851 WRIGHT AVENUE, WHEELER ARMY AIRFIELD
SCHOFIELD BARRACKS, HAWAII 96857-5000

REPLY TO
ATTENTION OF:

25 APR 2011

Office of the Garrison Commander

Mr. Loyal Merhoff
Field Supervisor
US Fish and Wildlife Service
300 Ala Moana Blvd., Room 3-122
Honolulu, Hawaii 96850

Dear Mr. Merhoff:

The purpose of this letter is to report a take of a single Oahu Elepaio (*Chasiempis sandwichensis ibidis*) territory as authorized by the 2003 Oahu Biological Opinion. During late February, 2011, Army Natural Resource Staff (NRS) observed die-off of the only Elepaio territory below the Schofield Barracks West Range firebreak road in Banana Gulch. A map showing the location and photos of the damage are enclosed.

After further investigation, it has been determined that take of the territory occurred in January 2011 while a contractor was conducting routine herbicide spray operations in preparation for a prescribed burn. Normally, preparatory sprays of the range do not get close enough to the firebreak road to have the potential to impact this Elepaio territory. In this instance, the contractor was trying out a fairly new spray technology used on the mainland. The plan was to spray the large trees along the inside of the firebreak to help with maintenance of the road to the 10/20/30 standard. This technology is much more precise and results in less drift of herbicides than the typical application from a helicopter would.

To prepare for spraying directly along the inside of the firebreak road, NRS provided the contractor with a GPS location and map of the Elepaio territory with an additional 100 meter buffer on the territory shape file. The contractors were told that this area needed to be avoided and the Army was assured the information would be entered into the helicopter GPS system for use during spray operations.

It is believed that some of the spray of the Elepaio habitat was due in part to the windy conditions and resulting herbicide drift. It is also thought that the steep and complicated terrain along the firebreak road confused the pilot, who was not able to tell when he was flying over the Elepaio habitat. The NRS will continue to work closely with contractors applying herbicides on Oahu ranges to ensure avoidance of endangered species and their habitat. Instead of a 100 foot buffer, spray operations will completely avoid the area in the future.

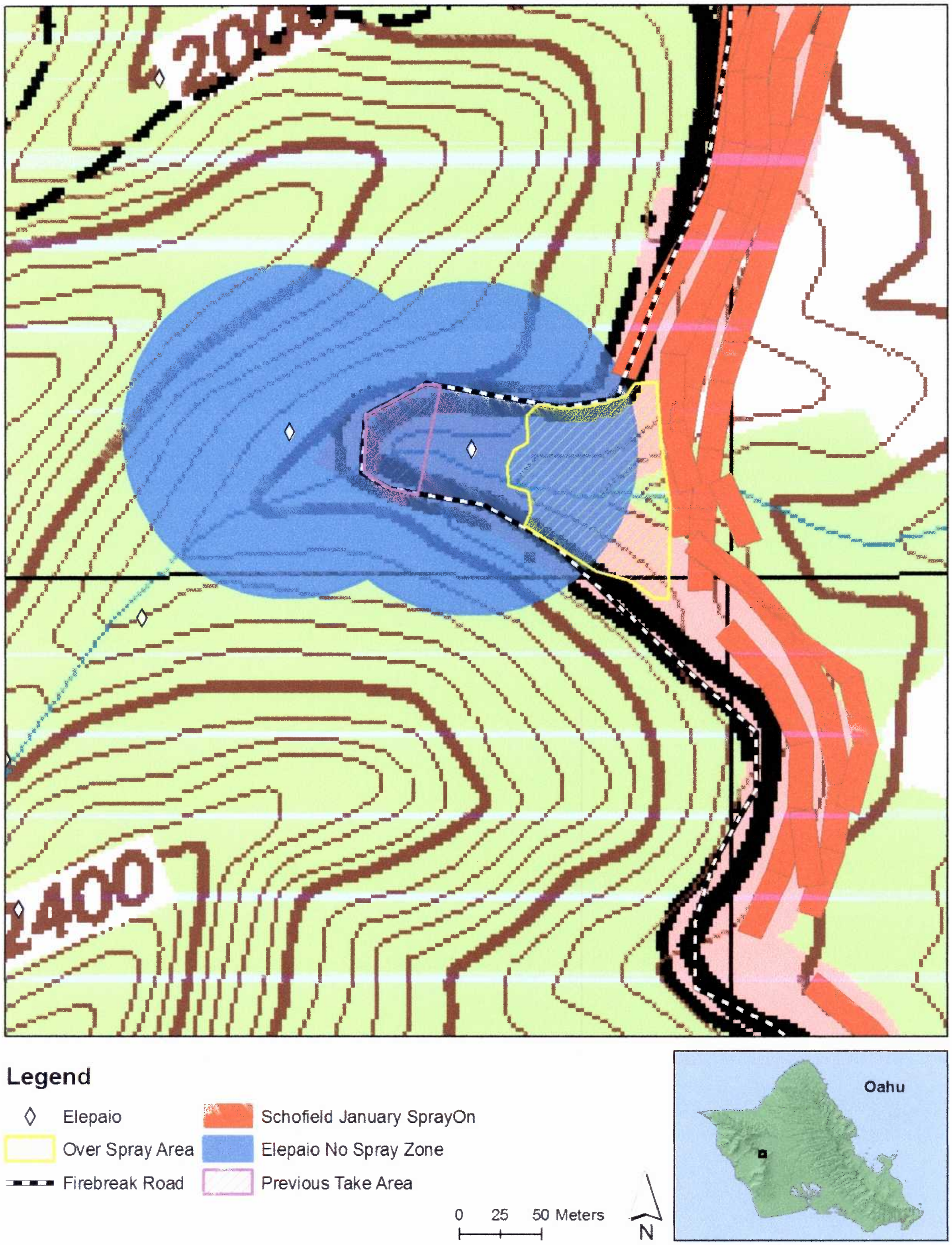
Prior to the spray operation, the territory was known to contain a Elepaio pair that had not yet nested this season. NRS have monitored the territory over the past six weeks and have not been able to relocate the pair. At this point, NRS considers this a take of this territory for this year. Hopefully, the pair relocated upslope of the firebreak road into one of the many areas containing unoccupied Elepaio habitat.

A copy of this letter has also been provided to the Director of the Mission Support Element who overseas use and operation of the ranges (i.e. Range Control). Please contact Michelle Mansker, Natural Resource Program Manager, Environmental Division, Directorate of Public Works, 655-9189, if you have any questions or concerns regarding this information.

Sincerely,

Douglas S. Mulbury
Colonel, US Army
Commanding

Enclosures



Map showing Elepaio territory taken in 2011 in yellow hatched area and 2004 in pink

Enclosure 4

3 March, 2001 photo of dead vegetation in the Banana Gulch Elepaio territory, looking South

Enclosure 1

3 March, 2001 photo of dead vegetation in the Banana Gulch Elepaio territory, looking straight on

Enclosure 2

3 March, 2011 photo of dead vegetation in the Banana Gulch Elepaio territory, looking North

Enclosure 3