IMPLEMENTATION PLAN

PŌHAKULOA TRAINING AREA ISLAND OF HAWAI‘I

Prepared by:
United States Army Garrison, Hawai‘i
Directorate of Public Works, Environmental Division
Pōhakuloa Natural Resources Office
P.O Box 4607 Hilo, Hawai‘i 96720

Silene hawaiiensis

October 2010

EXECUTIVE SUMMARY

Pursuant to the December 2003 Biological Opinion issued to Pohakuloa Training Area by the US FWS, this document was prepared to guide conservation efforts at PTA for 14 endangered plant species, 1 threatened plant species, 3 endangered bird species, 1 endangered mammal species, and Palila Critical Habitat, that occur at PTA. In 2003, the Army initiated formal consultation under Section 7 of the Endangered Species Act (16U.S.C. 1531 et seq.) to determine if routine military training and Transformation of the 2nd Brigade, 25th Infantry Division (Light) would jeopardize the continued existence of federally protected species and habitat at PTA. The consultation established an Action Area (AA, area potentially affected by military training) that duplicates the legally defined boundaries of PTA, including the Keamuku Maneuver Area.

In December 2003, the US FWS issued a Biological Opinion (BO) that concluded that routine military training and Transformation-related activities, mitigated by the conservation measures identified by the Army in the Biological Assessment (BA), would not jeopardize the continued existence of the threatened and endangered species found within the AA or adversely modify designated critical habitat. The conclusion of "No Jeopardy" was based on certain restrictions to military training, implementation of the PTA Iintegrated Wildland Fire Management Plan (2003), implementation of management actions identified in the BA, and preparation and implementation of the Pōhakuloa Implementation Plan (PIP). The Army was required by US FWS to create an Implementation Team (IT) to assist the Army in preparing the PIP. The IT is comprised of technical experts representing the Army, US FWS, State of Hawai‘i, USGS, Biolgical Resources Divison, Hawai‘i Volcanoes National Park, and other subject matter experts for Big Island ecosystem functions.

The PIP identifies a variety of natural resource management actions for the preservation and enhancement of protected species and habitat at PTA, and monitoring protocols for each species to evaluate success of management actions. Major management actions identified in the PIP include propagation and outplanting, non-native plant control, survey protocols for flora and fauna, rodent control, ungulate control, large-scale fencing, invasive invertebrate control, and an incipient weed program. The majority of actions are planned on Army lands.

Implementation Plan actions will benefit species and habitat through management of Areas of Species Recovery (ASRs). An ASR is defined operationally by a 100 m buffer around all known individuals for plants at sites selected for management. To assess the success of the management actions, the monitoring program in the PIP allows for an assessment of species and habitat status over time relative to achieving the PIP goals and short, mid and long-term objectives. The long term goal of the program (10-year time frame) is to reliably and defensibly quantify and predict trends in managed plant populations, and to assess trends for the surrounding plant community. The IT will conduct an annual assessment of the results of the management actions through a review of the monitoring data, to determine the Army's progress toward achieving the conservation measures in the 2003 BO, and any additional actions as outlined in the PIP. This annual assessment will allow for modification of the PIP strategies as needed, using an adaptive management approach.

The PIP also includes a twenty-year budget projection (see Section 5.0). Full implementation of the PIP is estimated to cost **$4.51 million for the first year** and up to **$9.19 million for the twentieth year** (annual increase 4.5%). Estimated total cost is **$136 million over 20 years.**

Cost figures are subject to change depending on timing of implementation of actions. It should be noted that the PIP is subject to the availability of funds and nothing in this plan should be interpreted to violate the Anti-deficiency Act. The Army intends to fund the program through its operating funds each year.

Implementation of the PIP is planned over 20 years, during which all of the management actions identified in the BO and PIP should be initiated and/or in the process of being implemented. The actions are phased based on species' rarity and risk to continued population viability. Due to the inherent variability of complex natural systems, which are exacerbated by the introduction of invasive species, climate change, wildfires, etc., there is no targeted "end phase" for this implementation plan.

Progress on the successful implementation of the PIP ensures that the Army will be in compliance with the Endangered Species Act, while maintaining training capacity at Pōhakuloa. By taking an active role to determine the best available practices and the highest priority threat management needs, the Army's conservation efforts at Pōhakuloa are intended to be in the forefront of species conservation in Hawai'i.

Table ES-1 Contributors to Implementation Plan Development

Affiliation	Contributors
US Army Garrison, Hawaii	• Peter Peshut, PTA Biologist • Michelle Mansker, Chief, Natural Resources • Eric Moller, PTA Fire Chief • Kapua Kawelo, Oahu Biologist • Darryl York, PTA Biologist (former)
Center for Environmental Management of Military Lands (CEMML), Colorado State University	• Lena Schnell, Implementation Plan Manager • Steve Evans, Botanical Program Manager • Nikhil Narahari, Monitoring Coordinator • Kathy Kawakami, Horticulturist • Jefferson Jacobs, Natural Resources Specialist • Erin Foley, Natural Resources Specialist • Sarah Knox, Natural Resources Specialist • Ken Spencer, Fencing Coordinator • Brian Tucker, Natural Resources Specialist • Mike Bresell, Weed Crew Leader
US Forest Service, Pacific Research Station	• Susan Cordell
US Fish and Wildlife Service	• Patrice Ashfield • Donna Ball • Jeff Zimpfer • Dawn Greenley
USGS, Biological Resources Division	• Paul Banko • Frank Bonaccorso • Steve Hess • Jim Jacobi
State of Hawaii, DoFAW	• Lyman Perry • Joan Yoshioka
University of Hawaii, RCUH	• Tom Belfield • Marcos Gorreson
Consultants	• Reginald David, Rana Productions
Lyon Arboretum	• Alvin Yoshinaga • Nellie Sugii
Amy Greenwell Botanical Garden	• Brain Kiyabu
Volcano Rare Plant Facility	• Patty Moriyasu

ACKNOWLEDGEMENTS

The preparers thank the United States Army and the Commanders of Pōhakuloa Training Area for their continued support of the Natural Resources Office. Technical assistance for this project was made in large measure by the fine staff from CEMML, in particular Steven Evans, Lena Schnell, and Robert Borzka. We gratefully acknowledge the contributions of the Implementation Team members; this plan would not be possible without their expertise, advice and reviews. The Pohakuloa Cultural Resources Office provided technical expertise for matters of lava tubes and other areas of potential archaeological significance. Nearly everybody typed or contributed to graphics.

TABLE OF CONTENTS

Executive Summary ii

Acknowledgements v

List of Tables viii

List of Figures ix

Acronyms xi

1.0 Introduction 1

1.1 Scope and Purpose 7

1.2 Principal Program Areas 7

1.2.1 Botanical 7

1.2.2 Wildlife 8

1.2.3 Fencing 8

1.3 Management Units and Areas of Species Recovery 9

1.4 PTA Natural Resource Office Organization 14

1.5 Implementation Team 15

2.0 Botanical Program 17

2.1 Rare Plant Monitoring Protocols 18

2.1.1 Monitoring Methods 26

2.2 Rare Plant Propagation and Outplanting Protocols 32

2.2.1 Species Specific Propagation and Outplanting Protocols 45

2.3 Invasive Plant Management and Control Techniques 64

2.3.1 Incipient Weed Monitoring 78

2.4 Fire Break System 87

3.0 Endangered Birds/Mammals, Rodents, and Invasive ArthropoD Protocols 94

3.1 ‘Io Survey Protocol 95

3.2 Nēnē Survey Protocol 98

3.3 ‘Ua‘u Survey Protocol 113

3.3.1 Detection Probability for Endangered Birds at PTA 117

3.4 Hawaiian Hoary Bat Management Protocol 118

3.4.1 HHB Survey Protocols 123

3.5 Rodent Control Protocol 132

3.6 Invasive Invertebrate Monitoring and Control Protocol 138

3.6.1 Ants 138

3.6.2 *Vespula pensylvanica* monitoring and control 141
4.0 Large-Scale Fencing, Fire Break System, and Ungulate Removal 143
4.1 Introduction 143
4.2 Large-scale Fence Unit Construction 147
4.3 Feral Ungulate Removal and Monitoring 151
5.0 Summary of Implementation Schedule and Budgets (20 Years) 152
5.1 Total Expenditures for twenty-year life of the PIP: 152
5.2 Annual Schedules 157
6.0 Literature Cited 164
7.0 Personal Communications 172
8.0 Appendices 173
8.1 Hawai‘i Rare Plant Recovery Group Collecting and Handling Protocol 173
8.2 Plant Propagule Collection Protocols; developed by the Makua Implantation Team and abridged and modified for the PTA Implementation Plan: 177
1.1 Inputs 180
1.2 Evaluation Cycle 180
1.3 Final Collection Size 180
8.3 Lyon Arboretum Seed Storage Summary 196
8.4 HRPRG Reintroduction Guidelines 198
8.5 Phytosanitation Standards and Guidelines - Pōhakuloa Implementation Team 204
8.6 Pōhakuloa Training Area Seed/Plant Distribution List 227
8.7 Nene Survey Protocol for KMA 228

LIST OF TABLES

Table ES-1 Contributors to Implementation Plan Development iv
Table 1.0-1. Threatened and endangered plant species in the PIP.. 6
Table 1.3-1. Summary of management actions conducted in each ASR. 12
Table 1.5-1. Pōhakuloa Implementation Team members.. 16
Table 2.1-1. Random Paces and Bearing table to be used for monitoring unit location selection. 23
Table 2.1-2. Codes used to record herbivory.. 25
Table 2.2-1. Priority Species for Seed Collection... 34
Table 2.2-2. Priority Species for Outplanting.. 36
Table 2.2-3. Current Outplanting Sites off PTA.. 37
Table 2.2-4. Current and Candidate Outplanting Sites at PTA. 40
Table 2.2-5. Current and Proposed Outplanting Sites for *H. haplostachya*. 48
Table 2.2-6. Current and Proposed Outplanting Sites for *H. coriacea*. 49
Table 2.2-7. Proposed Outplanting Sites for *I. hosakae*.. 51
Table 2.2-8. Proposed Outplanting Sites for *M. venosa*.. 52
Table 2.2-9. Current and Proposed Outplanting Sites for *N. ovata*. 53
Table 2.2-10. Current and Proposed Outplanting Sites for *S. lanceolata*. 56
Table 2.2-11. Current and Proposed Outplanting Sites for *S. incompletum*............................... 57
Table 2.2-12. Current and Proposed Outplanting Sites for *S. angustifolia*. 59
Table 2.2-13. Current and Proposed Outplanting Sites for *T. arenarium*. 60
Table 2.2-14. Current and Proposed Outplanting Sites for *V. o-wahuensis*. 61
Table 2.2-15. Current and Proposed Outplanting Sites for *Z. hawaiiense*. 63
Table 2.3-1. Weed Priority Ranking developed by PTA NRO.. 66
Table 2.3-2. Ground Cover Classes Used for Pole-intercept Understory Monitoring................. 75
Table 2.3-3. Stem Length Classes for Pole-intercept Understory Cover and Woody Species Counts.. 75
Table 2.3-4. Stem Length Classes for Pole-intercept Understory Cover and Woody Species Counts.. 76
Table 2.3-5 .Incipient Invasive Species at PTA... 81
Table 2.3-6. Most WANTED Invasive Species... 81
Table 2.3-7. List Priority Survey Areas for Incipient Weeds 83
Table 2.3-8. Incipient Weed Control Method Scores.. 86
Table 2.3-9. Incipient Weed Priority Control Rankings... 86
Table 2.4-1. Progress on the Fuel Break System for PTA and KMA. 92
Table 3.4-1. Five general habitat classes for HHB habitat selection sampling. 125
Table 3.4-2: Regular weekly sampling schedule by survey point, dates given for Pre-pregnancy and Breeding seasons 2009.. 129
Table 4.2-1. Summary of regulatory and construction issues related to large-scale fence units. 149
Table 5.0-1. Summary – Pōhakuloa Implementation Plan Estimated Personnel and Program Support Costs (20 Years) 153
Table 5.2-1. Annual Schedule for Wildlife and Botanical Programs....................................... 157
Table 5.2-2 Annual Schedule for Vegetation Control... 163

LIST OF FIGURES

Figure 1.0-1. PTA Cantonment as seen from TA 23 1
Figure 1.0-2. PTA and Surrounding Land Ownership. 3
Figure 1.1-1. Small-scale fencing at ASR 8. 9
Figure 1.3-1. ASRs within Completed and Planned Fence Units. 11
Figure 2.0-1. *H. haplostachya* in bloomin Kīpuka Kālawamauna 17
Figure 2.1-1. *H. haplostachya* monitoring plots. 18
Figure 2.1-2. Flow diagram depicting an adaptive management strategy. 19
Figure 2.1-3. Layout of 10 x 25 meter monitoring plot with three transects. 21
Figure 2.1-4. Layout of 10 x 25 meter monitoring plot with three transects and fourteen 2 x 2 meter subplots. 22
Figure 2.1-5. Tagging format for base and end stakes. 23
Figure 2.1-6. Data sheet used to record monitoring data 24
Figure 2.1-7. Format for plant tags. 24
Figure 2.1-8. Diagram illustrating plant points within a monitoring unit. 26
Figure 2.1-9. Telling the difference between small *T. arenarium* and *Dubautia* species 28
Figure 2.2-1. PTA Interpretive Garden 32
Figure 2.2-2. PTA Off-Site4 Outplanting Locations 39
Figure 2.2-3. Current and Candidate Outplanting Sites at PTA 41
Figure 2.2-4. Current and Candidate Outplanting Sites in KMA 42
Figure 2.2-5. PTA RRPF 45
Figure 2.3-1. Weed Crew working in Kīpuka Kālawamauna 64
Figure 2.3-2. Boundaries for *S. kali* control in northern PTA. 73
Figure 2.3-3. Herbicide application for non-native plants 78
Figure 2.3-4. Incipient Plant Inventory Form 80
Figure 2.3-5. Incipient Weed Prioritized Control Areas 84
Figure 2.3-6 85
Figure 2.4-1. FB at Pu‘u Pāpapa in KMA 87
Figure 2.4-2. Status of Fuel Break System in Western PTA. 89
Figure 2.4-3. Status of Pu'u Nohona o Hae Fuel Break in KMA 90
Figure 2.4-4. Planned Pu'u Pāpapa Fuel Break in KMA. 91
Figure 3.0-1. Nēnē at Range 1. 94
Figure 3.1-1. Hawaiian Hawk 95
Figure 3.1-2. Map of ‘Io Survey Transects at PTA 97
Figure 3.2-1. Nēnē at Range 1. 98
Figure 3.2-2. Source Populations for Nēnē on PTA. 100
Figure 3.2-3. Nēnē distribution at PTA. 101
Figure 3.2-4. Range One Nēnē habitat restoration area and range surface danger zones (SDZ) 107
Figure 3.2-5. Nēnē survey buffers and priority areas in the Ke‘āmuku Maneuver Area. 111
Figure 3.3-1. Hawaiian Petrel 113
Figure 3.3-2. Hawaiian Petrel survey locations. 116
Figure 3.4-1. Hawaiian Hoary Bat 118

LIST OF FIGURES

Figure 3.4-2. HBB occupancy sampling frame, locations and habitat type. 126
Figure 3.4-3. HHB Automated Detector with Weather-proof Housing Design 128
Figure 3.4-4. HHB KMA 2009 survey locations 131
Figure 3.5-1. Replacing bait within the redent control area. 132
Figure 3.5-2. Current Rodent Control Sites 134
Figure 3.5-3. Location of *Z. hawaiiense* in West PTA. 136
Figure 3.6-1. Argentine ants infesting a *S. lanceolata* infloresence 138
Figure 4.0-1. Fence Crew clipping wire mesh to posts. 143
Figure 4.2-1. Drilling post-holes in rock. 147
Figure 4.2-2. Fence Crew aligning and setting posts. 148
Figure 4.2-3. Status of the construction of large-scale fence units at PTA. 150
Figure 4.3-1. Goats at PTA. 151
Figure 5.0-1. Mauna Kea at sunset 152

ACRONYMS

AA	Action Area
ac	acres
ANOVA	Analysis of Variance
ARU	Autonomous Recording Units
ASR	Area of Species Recovery
BA	Biological Assessment
BAX	Battle Area Complex
BIISC	Big Island Invasive Species Committee
BO	Biological Opinion
DOFAW	Division of Forestry and Wildlife
FB	Fuel Break
GIS	Geographical Information System
GPS	Global Positioning System
ha	Hectares
HVNP	Hawai‘i Volcanoes National Park
HDOA	Hawai‘i Department of Agriculture
HHB	Hawaiian Hoary Bat
HPPRCC	The Hawai‘i and Pacific Plants Recovery Coordinating Committee
HRPRG	Hawai‘i Rare Plant Restoration Group
IMU	Intensive Management Unit
IT	Implementation Team
IWFMP	Integrated Wildland Fire Management Plan
KMA	Ke‘āmuku Maneuver Area
m	Meters
MP	Management Project
MU	Monitoring Unit
NPS	National Park Service
NRO	Natural Resources Office
NTGB	National Tropical Botanical Garden
PCH	Palila Critical Habitat
pers. comm.	Personal communication
PIER	Pacific Island Ecosystems at Risk
PIP	Pōhakuloa Implementation Plan

ACRONYMS

PTA	Pōhakuloa Training Area
PVA	Population Viability Analysis
RPPF	Rare Plant Propagation Facility
SBCT	Stryker Brigade Combat Team
SERDP	Strategic Environmental Research and Development Program
TA	Training Area
US Army	Army
US ACOE	US Army Corps of Engineers
USDA NRCS	US Department of Agriculture Natural Resources Conservation Service
USFS	US Forest Service
US FWS	US Fish and Wild Life Service
USGS-BRD	US Geological Survey, Biological Resources Division

1.0 INTRODUCTION

Figure 1.0-1. PTA Cantonment as seen from TA 23.

The PTA AA includes all of PTA training areas including the KMA (Figure 1.0-1). The geographic scope of the PIP includes the entire AA. All sites for the PIP actions are specifically described and mapped in the PIP, with the majority of actions planned for Army owned or controlled land.

PTA Region

PTA is located in a saddle between the volcanoes of Mauna Kea and Mauna Loa approximately 40 kilometers (27 miles) south of Waimea and approximately 58 kilometers (36 miles) west of Hilo. The United States first used the lands in this area in 1942 for military maneuvers during World War II. During the next several decades, PTA grew into the largest US Army holding in the State of Hawaiʻi consisting of approximately 44,030 ha (108,801 ac). The majority of the land or 34,324 ha (84,815 ac) was acquired through both Governor and Presidential Executive Orders. Another 9,303 ha (22,988 ac) were added through a 65-year lease with the State of Hawaiʻi, which expires in 2029, and another 9 ha (23 ac) are held through a variety of sources (ACOE 2003). Figure 1.0-1 depicts the boundaries and 23 training areas that comprise PTA and illustrates land ownership on and adjacent to PTA. Hawaiʻi State lands border PTA to the north (including Mauna Kea State Park), east and south, Hawaiian Home Lands to the Northeast, and Bishop Estate (Kamehameha School) lands plus state lands along the western edge of PTA. The

Army recently purchased 23,978 acres of Parker Ranch Land (the KMA) to the west of the installation making the training area a total of approximately 132,814 acres. In this report, the lands that previously comprised PTA will be referred to as PTA and the new land acquisition area will be referred to as the KMA.

PTA consists primarily of a sub-alpine tropical dryland ecosystem with upper montane to alpine elevations of 1,228 to 2,637 meters (4,029 to 8,652 feet). The cool-tropical climate is characterized by a 12.8 degree Celsius (55 degree Fahrenheit) average annual high temperature and a 10.6 degree Celsius (51 degree Fahrenheit) average annual low temperature. PTA experiences a greater diurnal temperature fluctuation than a seasonal fluctuation. The soil consists of approximately 80% lightly weathered pāhoehoe and ʻaʻā lava and about 20 percent volcanic ash derived soils. There are no surface streams, lakes or bodies of water within PTA due to low rainfall and porous substrates. Rainfall, fog drip and occasional frost are the main sources of water that sustain the plants and animals in the dryland habitat of PTA (US Army, Hawaiʻi 2002). In addition to barren lava, disturbed areas and areas consisting of fountain grass (*Pennisetum setaceum*) grassland on PTA, vegetation is a complex mosaic of 21 native Hawaiian plant communities.

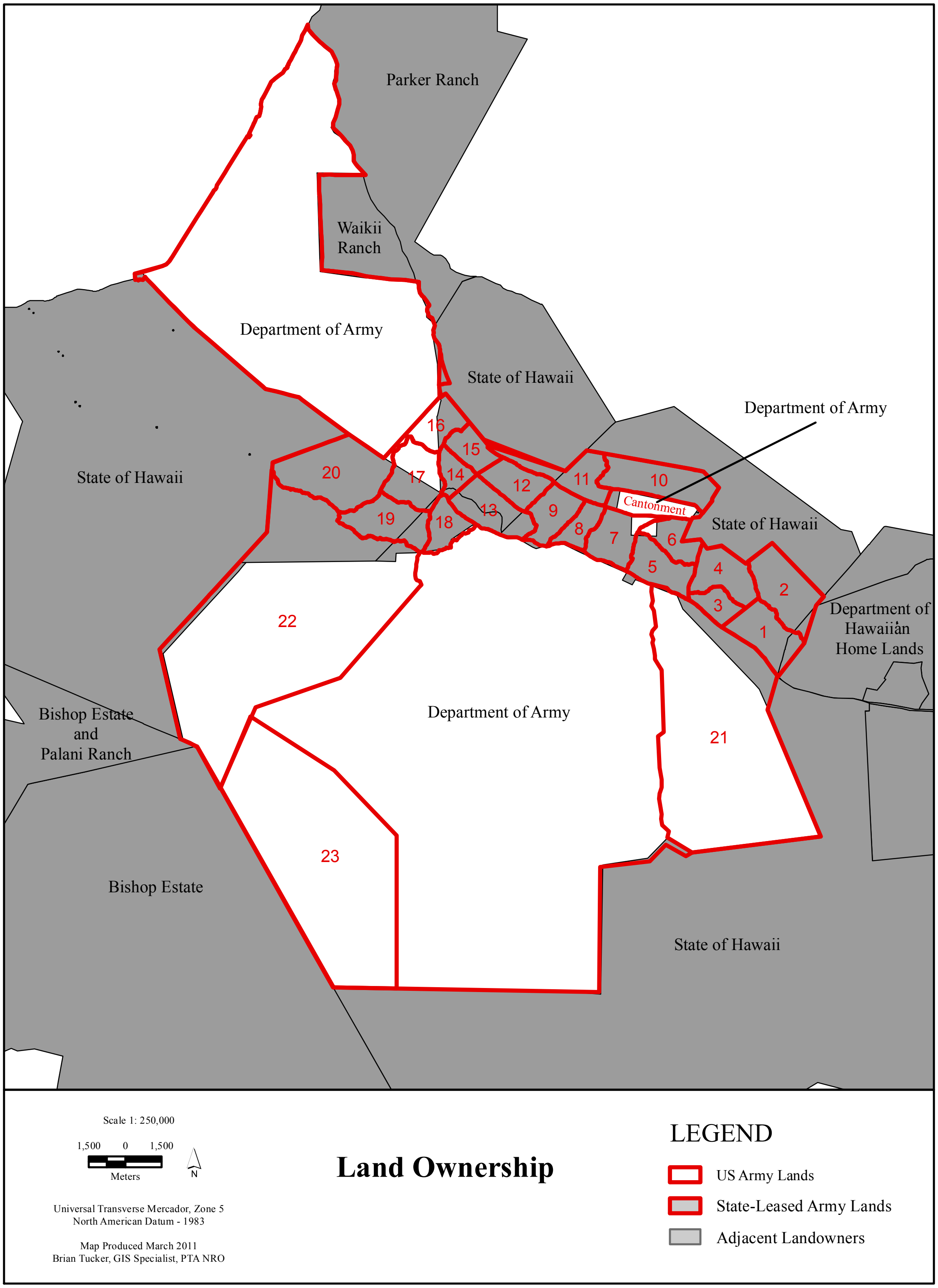


Figure 1.0-2. PTA and Surrounding Land Ownership.

PTA is the best training land resource for US military forces within the Pacific region. PTA provides high quality, realistic training land for Army, Navy, Air Force, Marine Corps, National Guard, and Reserve forces as well as for other nations. Military training use of PTA expanded rapidly from the late 1940's through the 1970's. During this time the natural resources of the area were only sparsely studied and the unique biology of the land was not fully recognized. However, a surge of fieldwork in the 1980's and 1990's revealed that PTA harbors a high density of rare and federally listed plant species living in a relatively native ecosystem. Today, many scientists consider the sub-alpine tropical dryland ecosystem as being one of the rarest on the planet (US Army, Hawai'i 2002). Recognizing a strong need to protect and enhance the natural resources of PTA, the Army now provides funding to support environmental programs.

KMA Region

KMA is located to the northwest of PTA and is bounded by Saddle Road State Highway (200) to the northeast and Māmalahoa State Highway (190) to the northwest and was purchased from Parker Ranch in 2006 by the Army for maneuver training. KMA is 23, 978 ac (9,704 ha) and dominated by non-native grasslands with limited native shrublands. Elevation at KMA ranges between 5,577 feet (1,700 meters) near the boarder with PTA to 2,461 feet (750 meters) where the western borders meets Māmalahoa Highway (190) (ACOE 2003). The annual rainfall is about 23 inches (60 cm) per year; however, annual rainfall can be highly variable (ACOE 2003). The area is usually clear and sunny in the morning with no clouds or wind until the afternoon, which can be very windy.

Other Lands

While the majority of PIP actions take place on Army Lands, some actions are conducted on Hawai'i State Lands. There are five sites where the State allows the Army to plant some of the threatened and endangered species. The Army applies for an annual permit from the State of Hawai'i to conduct planting and non-native plant control around the plantings. These sites represent variations in elevation, substrates, moisture regimes and community types. All are located in areas designated by the State for long term conservation. For further discussion see Chapter 2.2.

On occasion, the Army also leases additional properties for training. These lands are discussed in the draft Legacy and Transformation BAs (US Army 2002; USACOE 2003). The following is a quick synopsis of the occasional use lands.

- Pu'u Pā is 13,296 acres of rolling hilly terrain are available for lease from June to October from Parker Ranch. Authorized uses include unit bivouac, tactical maneuver, and air assault operations. This area is capable of supporting a battalion performing maneuver training.
- Humu'ula is 20,377 acres, which is located directly east of TA 1 and 2 at PTA. The land is leased by Parker Ranch from the Department of Hawaiian Home Lands and sublet to the Army. Authorized uses previously included unit bivouac, tactical maneuvers, and air assault, and air operations. The Army has not been allowed to use this area for the past several years.
- 'Ūpolu Point is an airstrip located in Kohala (northern tip of the Big Island). The Army leases the 89 acres to stage aircraft for tactical flight operations at PTA.

Since there are no threatened or endangered species concerns on these lands, no management requirements were identified in the BO (USFWS 2003). At this time, NPR does not manage for natural resource on these lands.

Listed species addressed in the PIP

This PTA PIP has been developed strictly from a biological perspective. Although primarily species based, an emphasis on habitat restoration and ecosystem processes is recognized, focusing on: 1) the intrinsic value of *in situ* biological webs in designated sensitive/special areas, 2) building on habitat restoration and threat removal/control, 3) stabilizing habitat and allowing for natural recovery, and 4) utilizing augmentation and reintroduction of species as needed. The decisions on the specific management actions and the locations of these actions are based primarily on the known biological needs of the species occurring on PTA. Therefore, the action priorities in the PIP are fully justified on biological grounds.

The Army recognizes that intensive management efforts at species and habitat levels can have negative effects on other listed species and sensitive species, as well as native ecosystems if not properly implemented. In addition to proposing actions beneficial to the listed species, the avoidance of negative affects of proposed actions ("do no harm") is an important guiding principle of the Army's NRO. Following this principle, the PIP incorporates protocols designed to minimize negative effects of human activities in native ecosystems such as inadvertent introduction of alien weeds, introduction of pathogens, trampling of vegetation, opening of trails, increased fire risk, and genetic contamination via inappropriate outplantings. These protocols protect not only the listed species, but also other sensitive rare and endangered species known to occupy PTA. Careful testing of techniques before large-scale implementation and monitoring for the consequences of management actions also reflect this principle.

All of the species addressed in the PIP are federally threatened or endangered species and are endemic to the Hawaiian Islands. Nine of the 19 listed species addressed in the PIP are only found on the Island of Hawaiʻi and a significant proportion of these only remain within the AA (Table 1.0-1).

There are no reliable population estimates for PTA for the three endangered bird species (Nēnē, ʻIo and ʻUaʻu) and the HHB that also occurs on PTA and are included in this PIP. It is believed that the ʻIo and ʻUaʻu are only transients on PTA whereas the Nēnē utilize limited portions of PTA and KMA year round. The bat is a year round resident. However, as described later in this document solitary tree roosting bat species are notoriously difficult to obtain population estimates on.

Table 1.0-1**.** Threatened and endangered plant species in the PIP

	Plants Recorded since 2003 BO	**Currently Known Plants**	**PTA Population Units**
Asplenium peruvianum var. insulare	18	552-902	20-25
Haplostachys haplostachya	1,738-1,986	20,830-23,494	4-5
Hedyotis coriacea	7	174	5-6
Isodendrion hosakae	0	871	2
Melanthera venosa	0	3,345	1*
Neraudia ovata	4	224	2
Portulaca sclerocarpa	0	41	5
Silene hawaiiensis	499	1,776-2,745	9-12
Silene lancelata	374-377	9,938-10,198	5-10
Solanum incompletum	0	66	2+
Spermolepis hawaiiensis	0	4,834-5,274	5
Stenogyne angustifolia	286	1,586-1,830	10-15
Tetramolopium arenarium ssp. *arenarium*	24	343-357	1
Vigna o-*wahuensis*	-	71	3
Zanthoxylum hawaiiense	77	462	7-10
Total	3,027-3,278	45,116-50,033	

* Data was established by survey data from Arnett (2001).

+ An additional population was found since the BA

1.1 Scope and Purpose

Pertinent background and project scope

This document was prepared to guide conservation efforts of the Army NRO at PTA as required by the 2003 BO issued by the USFWS. In 2003, the Army initiated formal consultation under section 7 of the Endangered Species Act 8 (16 U.S.C. 1531 et seq.) with the USFWS to determine if routine military training and transformation at PTA would jeopardize the continued existence of 19 threatened and endangered species. The measures outlined in this plan are designed to reduce the overall project impacts associated with Legacy and SBCT Transformation training activities by avoiding or minimizing specific Army action on listed species and PCH.

The consultation used an AA that is contained within the boundaries of PTA and KMA, which was acquired by the Army in August 2006. In December 2003, the USFWS issued a BO (USFWS 2003) concluding that routine military training and SBCT Transformation training and the conservation measures identified by the Army in its BA would not jeopardize the threatened or endangered species found within the AA or adversely modify critical habitat. The conclusion of no jeopardy and no adverse modification was based on certain restrictions to military training, preparation and implementation of an IWFMP, implementation of management actions identified in the BA for the 19 threatened or endangered species on PTA, and assemblage of an IT to prepare the PIP. The PIP is an adaptive management document that will incorporate annual reviews of the plan to assist with setting yearly goals. The IT includes the Army, USFWS personnel, and State biologists familiar with the species and the conservation areas. Successful implementation of the PIP assures that the Army will be in compliance with the Endangered Species Act and will still be able to accomplish its training mission.

1.2 Principal Program Areas

1.2.1 BOTANICAL

Tasks related to rare plant monitoring and outplanting:

- Management and monitoring protocols for the conservation, augmentation, and reintroduction of all listed plant species on PTA except *Portulaca sclerocarpa* and *Spermolepis hawaiiensis*. Annual monitoring to assess population structure (plant height, number and type of reproductive structures, and age class), vigor, and damage.
- Outplanting strategy for all listed plant species on PTA (except *Portulaca sclerocarpa* and *Spermolepis hawaiiensis*) in order to increase genetic variability of listed plant species and species distribution.

Tasks related to control of invasive plants:

- The PIP contains strategies for controlling invasive plants around rare plant populations and in key ecosystems.
- The PIP includes a nonnative invasive plant monitoring program for landing zones, trails, and roadsides. Monitoring and eradication methods for invasive alien plants are included.
- The PIP includes an invasive plant management plan to reduce and control the threats from non-native plant species and enhance habitat quality for listed species.

Tasks related vegetation control for fuel breaks

- The PIP includes maps and descriptions of fuel breaks that have been established at PTA and KMA.
- Methodologies used to control vegetation along fuel breaks are described.
- Progress to date for each fuel break is reported.

1.2.2 WILDLIFE

Tasks related to endangered bird surveys:

- The PIP includes survey methodology for the three endangered bird species that occur at PTA: Hawaiian hawk (‘Io), Hawaiian goose (Nēnē) and the Hawaiian petrel (‘ua‘u).

Tasks related to the endangered HHB:

- The PIP includes a HHB survey methodology to determine species occupancy, habitat use and reporting methodology on PTA.
- The PIP includes a species conservation plan for the HHB to address implementation of the Terms and Conditions as stated in the 2003 BO.

Tasks related to rodent control:

- The PIP includes management protocols for rodent control.
- The details of the Army’s assistance and involvement in the registry and NEPA compliance for aerial broadcast of rodenticide shall be addressed in the PIP.

Tasks related to invertebrate control:

- The PIP includes management protocols for controlling invertebrates including Argentine ants and invasive wasps.

1.2.3 FENCING

Tasks related to fencing:

- The exact locations of all fence alignments and buffers (e.g., western fence unit, eastern fence units, and the cinder cones on the KMA) are identified in the PIP.
- The PIP addresses the frequency and logistics associated with fence maintenance and the feral ungulate removal program to accomplish the ultimate objective of “ungulate free” fence units.

PTA and the KMA are large and access to many parts of the installation is poor, therefore, resources need to be focused for efficient field work with the maximum benefit.

1.3 Management Units and Areas of Species Recovery

Figure 1.1-1. Small-scale fencing at ASR 8.

Management Definitions

The Army NRO at PTA utilizes an adaptive management approach to manage listed species and natural resources. As such, the terminology used to describe the program has adapted to most accurately describe how management has evolved to meet the needs of the resources that are being protected.

To determine areas for management rare plant surveys have been ongoing and to date approximately 16, 231 acres have been searched. In 2004, 31 areas were identified for rare plant management, which were called IMUs. The boundaries for these were drawn in the GIS and were intended to represent groups of plants and habitat that would be managed. The boundaries were intended to be dynamic and fluctuate to best manage the resources with available time and personnel. They were not intended to be specific, static geographic areas.

The IMUs were intended to focus limited personnel and resources to maximize management of rare plants. As management began, it became clear that intensive management of the IMUs identified was not feasible. This was due, in part, to not correlating the sizes of the IMUs and the resources necessary to manage them intensively. Furthermore, the IMU terminology did not account for the management of animals or other projects that didn't have limited geographic area (i.e., the HHB that is found throughout much of the installation). Therefore, in 2007, IUMs were re-termed Management Projects (MP). This was done to more accurately describe what the NRO is capable of managing, account for animals, and have a record keeping mechanism. The IMU terminology appears in many documents prior to 2006.

In 2008, NRO used a set of criteria to develop ASRs, which are defined as 100m management buffers around rare plant populations in which management will be focused. The 100 m distance was based on three criteria; 1) wildfire flame lengths of 40-50 m, 2) an area large enough for listed species populations to expand, and 3) the potential area for management with current resources. Like the IMU and MP classifications before, ASRs strive to identify areas in which plant management will be focused and is a record keeping mechanism (Figure 1.3-1; Table 1.3-1). Currently, there are 45 ASR and 17 managed outplanting sites. ASRs cover approximately 2,789 acres and various management actions are conducted in each ASR (Table 1.3-1).These criteria and the ASR boundaries will be reviewed and modified as the resources require.

Because management practices for other species are conducted over large areas, the ASR term does not properly describe management. Therefore, management for listed animals, outplanting sites, individual weed species, or ecosystem level projects such projects will continue to be called MPs. The large-scale fence units are assigned a number to track work conducted outside ASR and MP areas.

In summary, the fence units are the largest management entities. Within the fence units are the ASRs. The MP may not be contained within a fence unit or ASR because of the geographical expanse of the projects. These terms serve as a record keeping system, to provide a common frame of reference for staff, and help to focus management efforts. Although the terminology has changed to better reflect actual management, all rare plant populations identified in the 2003 BO are receiving management and protection.

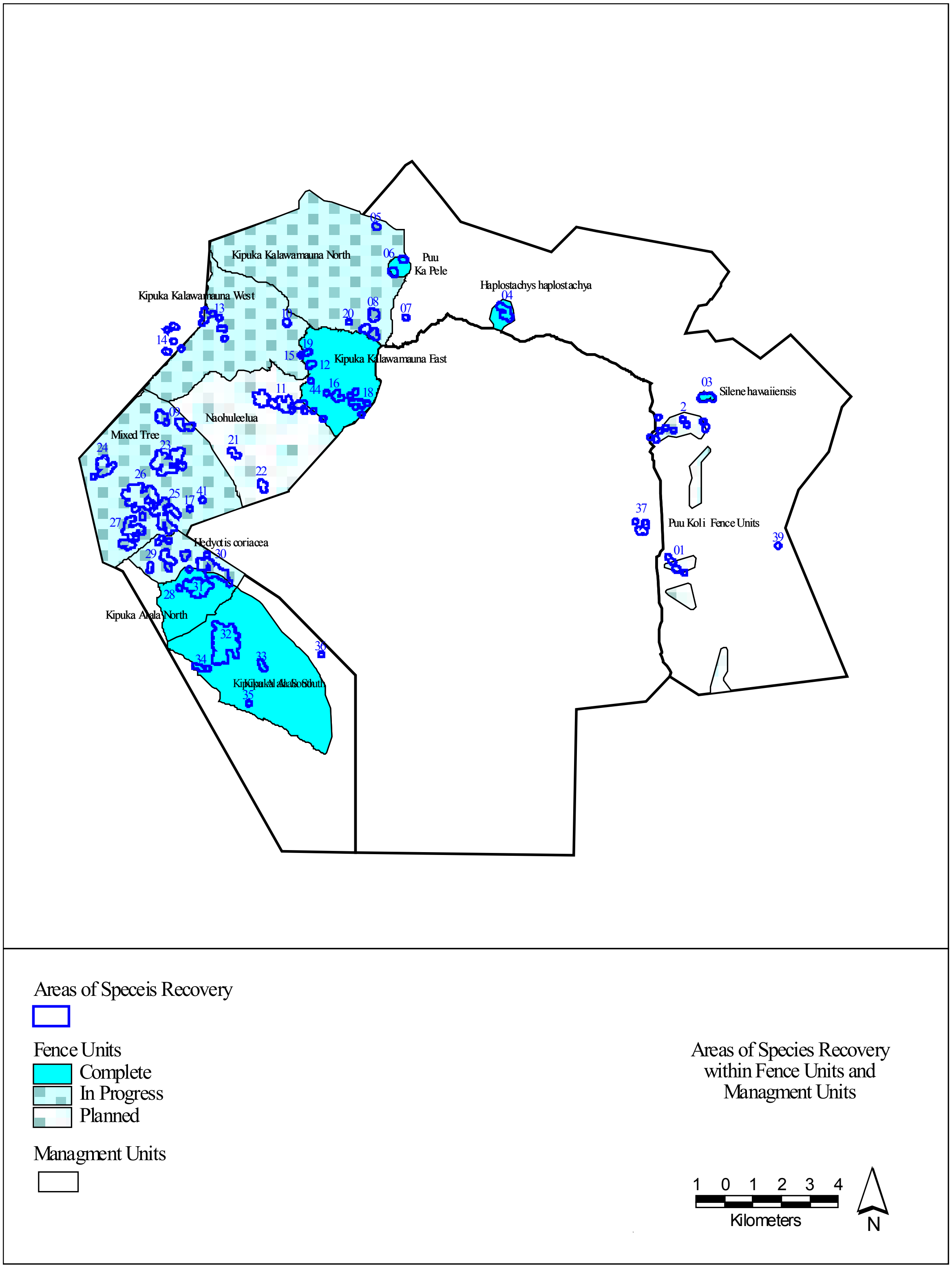


Figure 1.3-1. ASRs within Completed and Planned Fence Units.

Table 1.3-1. Summary of management actions conducted in each ASR.

ASR/ Outplanting Site	Fence Units	Acres	Number of Monitoring Units	Number of Individual Plants Monitored*	Weed Control	Rodent Control
1	Pu‘u Koli	61	19	-	-	-
2	Pu‘u Koli	84	30	-	-	-
3	Silene	39	14	20	-	-
4	Haplostachys haplostachya	53	15	9	-	-
5	Kīpuka Kālawamauna North	13	12	-	5	-
6	Pu‘u Ka Pele	36	18	-	-	-
7	*Solanum incompletum*	9	?	-	1	-
8	Kīpuka Kālawamauna North	83	67	-	43	-
9	Mixed Treeland	84	-	-	-	-
10	Kīpuka Kālawamauna West	13	3	-	-	-
11	Nā‘ōhule‘elua	190	2	40	10	-
12	Kīpuka Kālawamauna East	17	7	-	5	-
13	Kīpuka Kālawamauna West	83	9	1	18	10
14	State Land	42	-	5	7	11
15	Kīpuka Kālawamauna West	6	-	-	0.5	-
16	Kīpuka Kālawamauna East	33	35	1	10	-
17	Mixed Treeland	8	-	1	-	-
18	Kīpuka Kālawamauna East	68	9	5	9	-
19	Kīpuka Kālawamauna East	18	8	-	2	-
20	Kīpuka Kālawamauna North	8	1	-	2	-
21	Nā‘ōhule‘elua	24	-	6	2	-
22	Nā‘ōhule‘elua	26	-	3	3	-
23	Mixed Treeland	176	-	-	-	-
24	Mixed Treeland	86	-	37	20	45
25	Mixed Treeland	147	5	-	10	-
26	Mixed Treeland	199	-	-	-	-
27	Mixed Treeland	136	6	-	-	-
28	Kīpuka ‘Alalā North	9	-	-	-	-
29	Kīpuka ‘Alalā North	92	7	13	-	-
30	Hedyotis coriacea	168	-	70	-	-
31	Kīpuka ‘Alalā North	118	10	-	5	-
32	Kīpuka ‘Alalā South	268	-	-	-	-
33	Kīpuka ‘Alalā South	21	-	-	-	-
34	Kīpuka ‘Alalā South	27	-	-	-	-
35	Kīpuka ‘Alalā South	8	-	-	-	-
36	Kīpuka ‘Alalā South	8	-	-	-	-

Table 1.3-1. Summary of management actions conducted in each ASR.

ASR/ Outplanting Site	Fence Units	Acres	Number of Monitoring Units	Number of Individual Plants Monitored*	Weed Control	Rodent Control
37	Pu‘u Koli	34	8	-	-	-
38	Pu‘u Koli	40	-	-	-	-
39	Pu‘u Koli	8	-	-	-	-
40	*Solanum incompletum*	38	-	7	12	-
41	Mixed Treeland	9	-	1	-	-
44	Kīpuka Kālawamauna East	56	26	1	8	-
71	Pu‘u Nohona o Hae	73	-	6	-	-
72	Pu‘u Pāpapa	53	30	1	-	-
73	KMA	8	-	1	-	-
206	Kīpuka Kālawamauna East	-	-	-	0.5	3
207	Kīpuka Kālawamauna East	-	-	-	0.5	3
208	Kīpuka Kālawamauna East	-	-	-	2	-
209	Kīpuka Kālawamauna East	-	-	-	4	-
210	Kīpuka Kālawamauna East	-	-	-	1	-
211	Kīpuka Kālawamauna	-	-	-	2	-
212	Kīpuka Kālawamauna East	-	-	-	3	-
213	Mixed Treeland	-	-	-	1	3
214	Kīpuka ‘Alalā North	-	-	-	5	6
215	Kīpuka ‘Alalā North	-	-	-	4	-
	Totals	2789	342	199	224	81

*For species with low population numbers, each individual is monitored. These individuals are not monitored using MUs.

1.4 PTA Natural Resource Office Organization

The PTA NRO has one permanent Civil Service position. This Army Biologist oversees the NRO and ensures the Army remains in compliance with the terms and conditions in the BO. To complete the tasks defined in the BO and PIP, the Army maintains a cooperative agreement with CSU, CEMML. Each year, the Army provides CEMML with a SOW outlining the tasks to be completed from the BO and PIP and defines deliverables to the Army. CEMML employs biologists and laborers to fulfill the SOW. Currently there are approximately 50 CEMML employees who work for PTA NRO.

The contractor operations for technical assistance to the Army Biologist are organized into six principal program areas, including Botanical, Wildlife, Invasive Plants Control, GIS/Database, Fence Inspection and Maintenance, and Administration. Program areas, sub-programs, and staffing are shown on the budget documents in Section 5.0.

1.5 Implementation Team

The PTA NRO created an IT to assist the Army in preparing the PIP. The IT is comprised of subject matter experts representing the Army, US FWS, USFS-Pacific Research Station, State of Hawaiʻi , USGS-BRD, Volcanoes National Park, and endangered species and ecosystem experts (Table 1.5-1). The IT convened a series of meetings to develop the draft PIP.

Table 1.5-1. Pōhakuloa Implementation Team members.

Team Member	Affiliation	Specialty
Patrice Ashfield	US FWS	ESA Section 7
Donna Ball	US FWS	ESA Section 7
Paul Banko	USGS-BRD	Native Vertebrates
Thomas Belfield	RCUH	Native Plant Propagation and Outplanting
Frank Bonaccorso	USGS-BRD	Hawaiian hoary bat
Susan Cordell	USFS	Monitoring and Research Design
Reginald David	Rana Productions	Native Vertebrates
Steve Evans	CEMML	PTA Botanical Resources
Dawn Greenley		
Kathy Kawakami	CEMML	PTA Native Plant Propagation and Outplanting
Joe Kern	CEMML	PTA predator control
Tiffany Knight	Washington University	Population viability analysis
Sarah Knox	CEMML	PTA Wildlife Coordinator
Marcos Gorreson	University of Hawaii, RCUH	Hawaiian hoary bat
Steve Hess	USGS-BRD	Predator control
James Jacobi	USGS-BRD	Monitoring and Research Design
Tiana Lackey	CEMML	PTA Botanical Coordinator
Michelle Mansker	US Army	Chief, Natural Resource Section-USAG-HI
Eric Moller	US Army	Wildfire Prevention
Patty Moriyasu	Volcano Rare Plant Facility	Native Plant Propagation
Nikhil Narahari	CEMML	PTA Monitoring and Research Coordinator
Lyman Perry	DoFAW	Native Plant Resources
Jakob Rowny	CEMML	PTA Fuel Breaks
Caleb Slemmons	CEMML	PTA Invertebrates
Lena Schnell	CEMML	PTA Animal Resources
Les Takayama	CEMML	PTA Vegetation Control Coordinator
Brian Tucker	CEMML	PTA Data and GIS Coordinator
Jeff Zimpfer	US FWS	ESA Section 7

2.0 BOTANICAL PROGRAM

Figure 2.0-1. *H. haplostachya* in blooming Kīpuka Kālawamauna.

Introduction

PTA comprises 53,750 hectares of the saddle formed by Mauna Kea, Mauna Loa, and Hu‘alalāi volcanoes on the Big Island of Hawai‘i. This region includes of some of the last remaining sub-alpine tropical dryland ecosystems in the world. PTA houses 15 federally designated threatened and endangered plant species, six of which occur almost exclusively on PTA land. Like most dryland communities in Hawai‘i, the primary threats to ecosystem health at PTA come from changes to the landscape brought by ungulates, invasive weeds, and fire. To counter these deleterious impacts, the NRO conducts management activities including invasive weed control, rare plant propagation and outplanting, and large-scale fencing and ungulate removal. To most effectively manage PTA’s sizeable land area with limited human and financial resources, it is essential to incorporate the latest and best scientific knowledge available. To this end, a comprehensive monitoring program is being established at PTA.

Prioritization of Tasks

As described previously, ASRs are used to focus management for listed plant species. There are 44 ASRs with varying degrees of management (Table 1.3-1). To determine which ASRs require immediate attention, criteria such as high natural resource value, quality of habitat, rarity of species and threats to the species present are used to prioritize ASRs from 1 (higher priority) to 3 (lower priority). These priority ranks help the NRO systematically implement management over large-scale areas for multiple species in various habitats. Once threat management in high priority ASR becomes routine, management begins for the next priority ASRs until each ASR is adequately managed. Before management begins in an ASR, rare plant surveys are conducted to determine the distribution of listed species within the ASR. Following surveys, the threats to the species in the ASR are assessed, prioritized, and controls implemented.

Using the MU, the ASRs can be easily grouped, identified and organized on a landscape-scale. The MUs are also used to organize and catalog groups of listed plant species both in the monitoring database and the GIS. Using a format that decreases in geographical scale from MU to ASR to species helps organize the vast amount of information and facilitates reporting information.

2.1 Rare Plant Monitoring Protocols

Figure 2.1-1. *H. haplostachya* monitoring plots.

Introduction

In 2007, a new methodology for monitoring rare plants at PTA was introduced. The overall goal of the rare plant monitoring program at PTA is to provide the best information possible regarding the current and likely future status of target species populations to the NRO. This information will enable the evaluation of current and future management actions so as to optimize management techniques and the allocation of management resources, with the ultimate goal of protecting and restoring these rare plant species. This program will constitute a key component of the adaptive management strategy employed by the NRO at PTA. Adaptive management is driven by a predetermined resource objective (e.g., maintain or expand the number of extant individuals of *Tetramolopium arenarium* ssp. *arenarium* at PTA). To achieve this objective, management actions are taken (e.g., control invasive weeds in a 25 meter buffer surrounding known individuals). The resource is monitored to determine if the objective is being met. If yes, the objective may be modified if desired; if no, management strategies should be reevaluated and alternative methods should be devised so as to achieve the defined resource objective (Elzinga *et al.* 1998) (Figure 2.1-2).

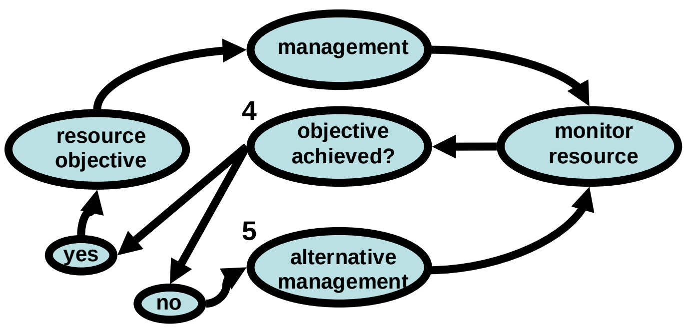


Figure 2.1-2. Flow diagram depicting an adaptive management strategy.

The monitoring program at PTA will provide information regarding management effects on target species populations and on the overall plant community. Specific monitoring objectives are grouped into short-term and long-term goals. Short-term goals (1-2 year timeframe) include the consistent and effective execution of a well-designed, long-term, statistically-defensible, and resource-efficient protocol for collecting and analyzing rare plant population data, and the implementation of a methodology to assess the status of the surrounding plant community. As of the 2009 PIP update, this short term goal has been achieved for ten of the fifteen listed species at PTA. The long term goal of the program (10 year timeframe) is to reliably and defensibly quantify and predict future trends in managed and unmanaged rare plant populations, and to assess future trends for the surrounding plant community.

The specific objectives of the monitoring program are to 1) When infeasible to perform a full census of a species, implement a sampling methodology that will allow for statistically defensible population parameter estimation and characterization of population demographic structure, and 2) manage and analyze data to assess population health and viability in the context of management efficacy. Population parameters and demographic characteristics to be estimated include:

- Mean number of individuals by life stage
- Mean size of individuals (either height or expanse)
- Frequency by size class (size distribution)
- Relative fecundity
- Plant vigor
- Occurrence of herbivory by source
- Survival and mortality by life stage

In addition to these parameters, detailed demographic and phenology data will be recorded for a subset of individuals for chosen species. Data from at least three monitoring cycles will be necessary before estimates of these plant and population attributes will allow for statistical inferences to be made regarding population status and trends. For some species data collection began in 2007; therefore statistical inferences should be feasible in 2010.

Monitoring program development comprised four stages: Stage One involved 1) a review of previous monitoring methodologies used for data collection by PTA NRO; 2) the development and population of a relational database to facilitate data management and analysis; 3) analysis of data; and 4) a review of the literature to ensure that new protocols would incorporate the best science available. Stage Two consisted of defining a methodology that integrates all elements of Stage One to elucidate a general protocol to implement the monitoring program. At this stage, peer review was essential to ensure that the methodology defined would provide a readily executable monitoring program that is statistically and scientifically sound. Stage Three entailed the development of species-specific sampling and monitoring strategies and the determination of species- and ASR-specific sample sizes and locations for randomized plots throughout sections of PTA to be included in the monitoring program. Stage Four is the actual on-the ground implementation of the monitoring program, consisting of the installation of monitoring plots in the field and the first cycle of data collection. To date, all four stages of the rare plant monitoring program have been completed for all but five species. These species are *Asplenium peruvianum* var. *insulare*, *Melanthera venosa*, *Spermolepis hawaiiensis, Stenogyne angustifolia*, and *Zanthoxylum hawaiiense*. Protocols for these species are in development pending the collection and analysis of pre-monitoring data to be discussed in detail in the sections following sections.

Monitoring Units

Two monitoring unit configurations will be used for monitoring rare plant species for which sampling methods are used. One configuration includes subplots for sub-sampling plant attributes while the other does not (Figures 2.1-2 and 2.1-3, respectively). All monitoring units are permanent 10 x 25 meter plots comprised of three 25 meter transects (Figure 2.1-3). Monitoring units for species that will be sub-sampled will contain fourteen 2 x 2 meter subplots (Figure 2.1-4). These subplots are systematically positioned to maximize spatial coverage and minimize spatial autocorrelation within the monitoring units. The 10 x 25 meter monitoring unit size was selected based on information obtained from other studies conducted in similar ecosystem types (e.g., CVS protocol by Peet *et al.* (1998), Jacobi *et al.* (2003) vegetation monitoring protocol, options described by Elzinga *et al.* (1998), from personal communications with other researchers, from analyses of previously collected data and methodologies used at PTA, and from personal knowledge and judgment. Generally, longer/narrower quadrats reduce statistical variance between sampling units versus square or round plots because of the ability to incorporate a larger amount of spatial variability along resource availability gradients (Abella and Covington 2004, Korb *et al.* 2003; Christman 2000; Elzinga *et al.* 1998). A 10 x 25 meter permanent plot comprised of three transects and 14 subplots also would allow for the collection of other types of data (e.g. plant community type, cover, substrate, etc.) and would facilitate comparison of results with other studies. A vegetation study by Jacobi *et al.* (2003) in Kīpuka Kālawamauna and Kīpuka ʻAlalā chose this plot size based on analyses simulating various plot sizes in these community types. The areas used to determine plot size in their analysis are roughly similar in terms of plant distributions and clumping as most rare plant habitat at PTA. Also, a uniform plot size that is flexible in sub-sampling options will facilitate the comparison of results across substrate and plant community types. It would also facilitate the statistical comparison of management efficacy for the same species in different ASRs.

Monitoring units are delineated with three base stakes and three end stakes in the form of either 3/8" diameter rebar or three inch masonry nails, depending on substrate. Base and end stakes mark the beginning and end of each transect comprising the monitoring unit, respectively, and are marked with pink and black flagging (Figure 2.1-3). Units are identified with unique alpha-numeric designations at the ASR level. For example, sequentially, monitoring units in a given ASR will be labeled A1, B1, C1,…, Z1, A2, B2, C2, etc. Likewise, transects are identified with unique numeric designations (1, 2, 3, …, 100, etc.) at the ASR level. In other words, no two monitoring units or transects in a given ASR will have the same unique identifier. Tags are placed on each base and end stake identifying each transect, with the center transect for each monitoring unit labeled with the alpha-numeric monitoring unit designation (Figure 2.1-5). Subplots are marked using either 3/8" diameter rebar or three inch masonry nails and are marked with blue flagging and/or blue spray paint. Subplots are established only when target individuals are present in the designated subplot area. Subplots located on the outside transects of the monitoring unit are labeled with the appropriate unit and subplot designation.

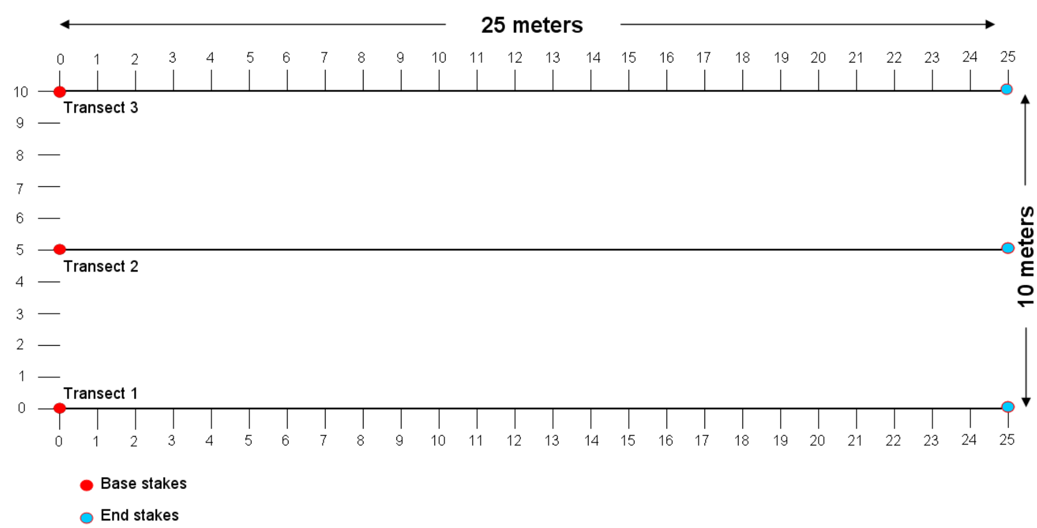


Figure 2.1-3. Layout of 10 x 25 meter monitoring plot with three transects.

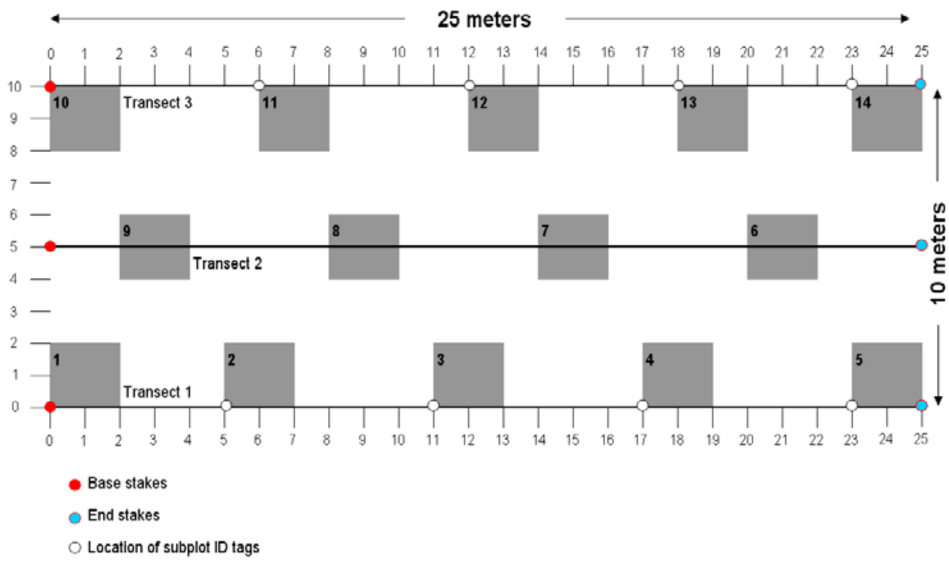


Figure 2.1-4. Layout of 10 x 25 meter monitoring plot with three transects and fourteen 2 x 2 meter subplots.

Location of monitoring units will be determined using the following protocol:

1. Biologists will navigate to plant point locations representing clusters of plants as uploaded from the GIS database.
2. Biologists will perform a brief survey to assess the spatial extent of species occurrence.
3. Biologists will identify a location and bearing for transect one of the monitoring unit (Figure 2.1-3) that seeks to incorporate as much topological variation as possible in the monitoring unit, and as much of the spatial extent of plant occurrence as possible.
4. From this location, biologist will pace a random number of paces (between 0 and 5) at a random bearing between +90° and +180° from the initially proposed bearing and location for the transect (Table 2.1-1).
5. This is the location for the first base stake of transect one of the monitoring unit. Use the same bearing for the unit as noted in step three.
6. A GPS coordinate is recorded at the base stake of the first transect of each monitoring unit and is designated 'GPS Code' within the GIS.

Monitoring units will be installed contiguously (side to side or end to end) so as to encompass the entire spatial extent of plant occurrence at that plant location. For some species, depending on local abundance, the maximum number of monitoring units installed at each plant location was limited to three. Establishing the monitoring plots using this procedure was repeated for each randomly selected plant point in each ASR. The object of this method is to incorporate an element of systematic randomization to monitoring unit placement. For sampling and analysis purposes, it is not appropriate for units to be subjectively placed in specific locations.

Table 2.1-1. Random Paces and Bearing table to be used for monitoring unit location selection.

Unit	Paces	Bearing	Unit	Paces	Bearing	Unit	Paces	Bearing	Unit	Paces	Bearing
A1	2*	110	Q1	3	170	G2	3	150	W2	4	150
B1	1	140	R1	4	140	H2	2	100	X3	3	100
C1	2	90	S1	1	90	I2	2	160	Y3	2	120
D1	4	170	T1	4	90	J2	0	100	Z2	0	180
E1	4	170	U1	2	150	K2	1	170	A3	4	160
F1	4	110	V1	3	170	L2	3	100	B3	3	170
G1	0	170	W1	2	150	M2	4	120	C3	2	160
H1	2	150	X1	1	90	N2	2	110	D3	5	120
I1	0	140	Y1	2	150	O2	1	160	E3	4	130
J1	0	110	Z1	5	100	P2	3	110	F3	4	100
K1	2	130	A2	3	150	Q2	5	100	G3	3	100
L1	3	170	B2	0	150	R2	3	160	H3	0	170
M1	4	110	C2	3	140	S2	1	130	I3	1	160
N1	3	170	D2	5	90	T2	4	120	J3	1	180
O1	0	140	E2	3	100	U2	2	170	K3	1	100
P1	3	110	F2	0	120	V2	3	110	L3	5	140

*Numbers are from a random number generator with the following constraints: Paces – number between zero and five; Bearing – between 90° and 180° rounded to the nearest 10 degrees.

Monitoring Unit Base Stake Tags

Monitoring Unit A-1

Transect 1 Base

25 m @ 160°

Monitoring Unit End Stake Tags

Monitoring Unit A-1

Transect 1 End

Transect Base Stake Tags

Transect 1

Base Stake

Transect End Stake Tags

Transect 1

End Stake

Figure 2.1-5. Tagging format for base and end stakes.

Data Collection

Data will be collected annually for all monitoring units (Figure 2.1-6). Unless otherwise noted, all live plants located within a monitoring unit will be tallied by life stage and measured for height (or expanse). Attributes recorded for live juvenile and adult plants are: 1) plant height (or expanse), 2) life stage, 3) presence/absence of buds, flowers, and fruit (adults), 4) category class or count of reproductive structures present on plant (adults), 5) plant vigor, and 6) evidence of ungulate, rodent, or insect herbivory. All adult individuals will be tagged with a unique identification number to allow for the tracking of individuals through time (Figures 2.1-6). For some species, coordinate locations within the monitoring unit is also recorded. For species that utilize a sub-sampling methodology (see species-specific sections below), this suite of measurements will be made only for individuals occurring in subplots.

Date ____________________
Species ____________________
Site # ____________________
Monitoring Unit(s) ____________________

Observers ________________
Notes ________________

Structure Classes:
1) 1-25
2) 25-100
3) 100-250
4) 250-500
5) 500+

MonUnit	Height	Lif Stg	Subplt	Plnt ID#	Ycrd	L - R	Xcrd	Strctrs (P/A)			Strctr	Plnt Vgr	Brws	Dead	Notes
		S,J,A				(circle one)		Bu	Fl	Fr	Class	H,M,P,D	N,R,O	Jv/Ad	(Note if Browse from Ungulate, Rodent, or Insect)
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									
						L R									

Figure 2.1-6. Data sheet used to record monitoring data.

The following fields are required: Date, Species, Site number(s), Monitoring Unit(s), and Observers. The ‘L – R’ field identifies to which side of the monitoring unit a particular plant or tally is referring.

Adult Plant Tags

Mon Unit A1
HH 001
3/10/09

Plant Tags in Subplots

Mon Unit A1
SL 001
Subplot 03

Figure 2.1-7. Format for plant tags.

Height measurements are made in centimeters from the base of the plant to the apical meristem of the longest branch. For species with scandent or sprawling growth habits (e.g., *S. angustifolia, P. sclerocarpa*), expanse will be estimated by measuring the greatest width of the plant through the rooting center, and the associated perpendicular measurement of width (projected area). Life stage is classified as either seedling, juvenile, or adult. A seedling is a plant with apparently functional cotyledons present. A juvenile is classified as a plant that has lost its cotyledons or if present they are apparently non-functional and it has not flowered. An adult is a plant that has developed reproductive structures in its lifetime, regardless of its current phenological state. The presence/absence of buds, flowers, or fruit will be used to assess an individual's current phenological state, with the number of structures representing a plant's potential contribution to regeneration. Plant vigor is classified as healthy, moderate, poor, or dead. A healthy plant has foliage that appears green and vigorous, with less than 10% dead leaves or defoliation. To be classified as moderate, leaves on plants may have some chlorosis, with 10 – 50% of the leaves dead or defoliated. Plants in the poor vigor class have mostly dead or chlorotic leaves, with greater than 50% dead leaves or defoliation. Vigor class definitions are taken from Jacobi (2003). Herbivory (Table 2.1-2) is recorded as none, when no parts of the plant have been consumed, recent, or old, and is categorized by source (ungulate, rodent, or insect).

Table 2.1-2. Codes used to record herbivory.

Codes for timeframe:	Codes for browse source:
O = Old	U = Ungulate
R = Recent	I = Insect
N = None	Ra = Rodent
	B = Bird

Herbivory codes are combined and recorded in the 'Brs' field of datasheets:

RU = Recent ungulate browse, OB = Old bird browse. If more than one combination is necessary, join them with a dash '-'; e.g., RI-RU-OR = Recent insect and ungulate browse with evidence of old rodent browse. Training exercises will occur in the Rare Plant Propagation facility prior to annual monitoring to ensure that all biologists are consistent in their measurement techniques.

Plant or plant cluster locations are recorded using the following format:

Ycoord, L/R, Xcoord

Ycoord = the distance along the transect, rounded up to the next whole meter

L/R = whether the plant or plant cluster falls on the left or right half of the MU, and

Xcoord = the distance from the center transect of the MU, rounded up to the next whole meter

Therefore, the coordinates for the points shown in Figure 2.1-8 should be recorded as follows:

Plant point 1: 6, R, 3

Plant point 2: 15, L, 4

Plant point 3: 25, R, 5.

Using this method, all Ycoord values will be between 1 and 25, and all Xcoord values will be between 1 and 5.

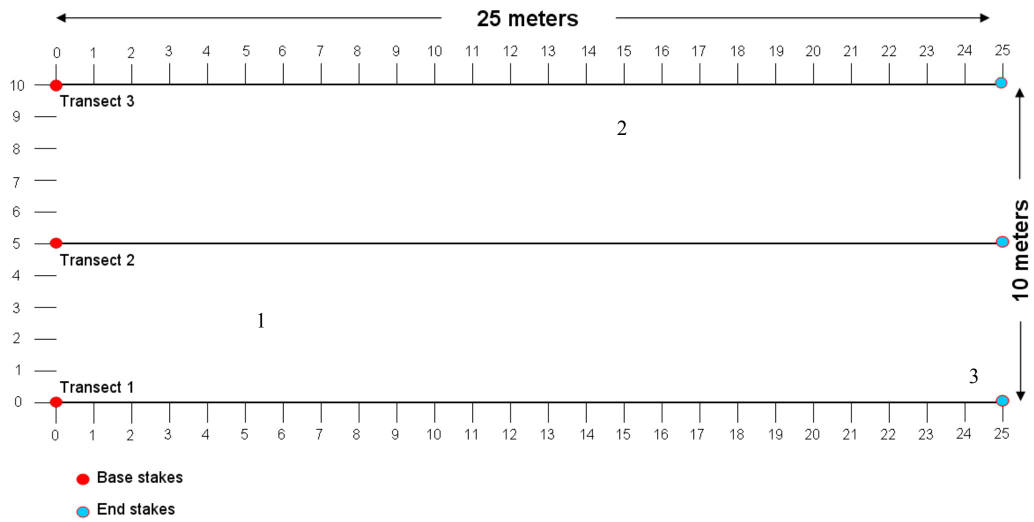


Figure 2.1-8. Diagram illustrating plant points within a monitoring unit.

<u>Data Analysis</u>

Data collected will be used for population parameter estimation, and statistical inference (t-tests, ANOVA, and repeated measures ANOVA) to determine if there are significant differences in key plant attributes between monitoring cycles. Non-parametric analogs and resampling statistical methods (e.g., Kruskall-Wallis, Wilcoxon-Mann-Whitney, randomization, bootstrap, Monte Carlo, etc.) will be used for analysis in the event that sampled populations do not meet normality assumptions (Dytham 1999). Demographic data will also be used in the construction of stochastic projection matrix models for population viability analysis (PVA). These models use changes in plant demographics in the relative short-term to make long-term predictions on population viability. Procedures for PVA will largely follow methods described by Morris and Doak (2002). The time frame for results from PVA is in the five to 10 year range; i.e., data from at least five monitoring cycles are needed before any reliable assessments of long-term population viability can be made.

2.1.1 MONITORING METHODS

In 2007, a total of 363 monitoring units were installed for five species at PTA and KMA. Of the remaining ten species that are included in the monitoring program at PTA, five are monitored using a full census methodology without monitoring units and five are in pre-monitoring data collection stages to optimize monitoring methods.

<u>Full Census Species</u>

The following species are monitored using a complete census, where every known individual is visited with aforementioned data elements recorded annually:

- *Hedyotis coriacea*
- *Neraudia ovata*
- *Portulaca sclerocarpa*
- *Solanum incompletum*

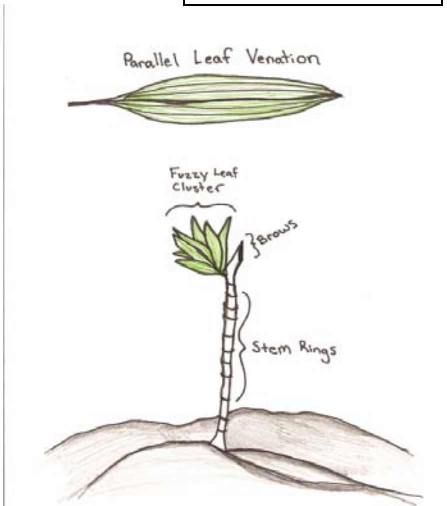
- *Vigna o-wahuensis*
- *Tetramolopium arenarium*

Despite a full census for *Tetramolopium arenarium,* monitoring units were installed to facilitate the collection of data relating to the effects of management on vegetative structure and community composition. Monitoring units are installed to cover the entire known extent of species occurrence. Aids for field identification were developed (Figure 2.1-9). A total of 59 monitoring units were installed for this species.

Monitoring methodology:

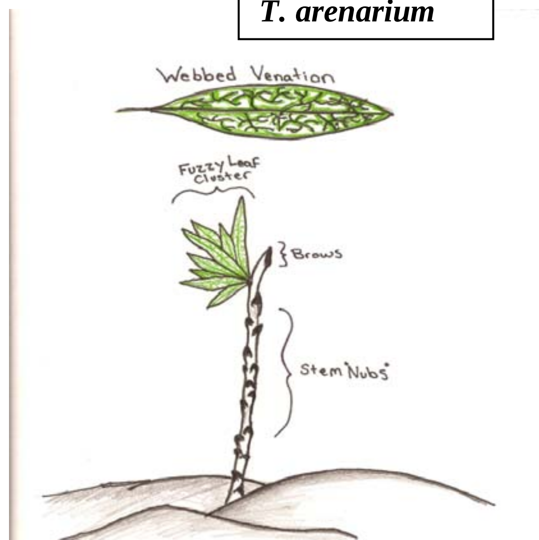
1. Navigate to monitoring unit (MU) using the GPS Code field from GIS.
2. Stretch 25m tapes from base stake to end stake for each transect making up that MU.
3. Commence monitoring with two people walking between the first two transects and then looping back between the second and third transects.
4. Tally and record coordinates for all seedlings and juveniles less than 10cm tall within the MU.
5. Tag and record coordinates for all adults and juveniles 10 cm and taller within the MU.
6. For all tagged individuals measure and record plant attributes:
    - Height – Base of plant to tip of apical meristem in centimeters
    - Structures – Count the number of buds, flowers, and fruit per plant (no classes)
    - Life stage – Whether plant is an adult or a juvenile (A, J)
    - Vigor – Health, Moderate, Poor, or Dead (H, M, P, D)
    - Browse – Recorded as described previously

Dubautia sp.



- New leaves can be soft and fuzzy like Tet are and come in as clusters.
- Stem has leaf scar rings not "nubs" like tet are
- Leaves have parallel venation

T. arenarium



- New leaves are soft and fuzzy and can grow in as clusters
- Stem has leaf scar "nubs" not rings like Dubautia
- Leaves have webbed venation

Figure 2.1-9. Telling the difference between small *T. arenarium* and *Dubautia* species

<u>Sampled species</u>

Because of the great number and large geographical distribution of the following species, a modified randomized cluster sampling methodology is used for monitoring. This methodology involves the complete census of a random selection of previously known plant clusters within each ASR. This method is preferable for rare species monitoring where plants tend to be spatially clustered given the total extent of species occurrence, and where an objective is to quantify attributes of individual plants (Platts *et al.* 1987; Thompson 1992; Elzinga *et al.* 1998; Christman 2000; and Muttlak and Khan 2002).

<u>Monitoring methodologies</u>

Haplostachys haplostachya

1. Navigate to monitoring unit (MU) using the GPS Code field from GIS.
2. Stretch 25m tapes from base stake to end stake for each transect making up that MU.
3. Commence monitoring with two people walking between the first two transects and then looping back between the second and third transects.
4. Record data for all previously tagged individuals located outside of subplots.
5. Tally all seedlings within subplots.
6. Tag and measure all juveniles and adults within subplots.
7. For all adults and juveniles inside subplots measure and record plant attributes:
    - Height – Base of plant to tip of apical meristem in centimeters

- Structures – Determine presence or absence of buds, flowers, and fruit on each plant. Classify total number of structures using the following classes:

  1) 1-25, 2) 26-50, 3) 51-150, 4) 151-250, 5) 250+
- Life stage – Whether plant is an adult or a juvenile (A, J)
- Vigor – Health, Moderate, Poor, or Dead (H, M, P, D)
- Browse – Recorded as described previously

Isodendrion hosakae

1. Navigate to monitoring unit (MU) using the GPS Code field from GIS.
2. Stretch 25m tapes from base stake to end stake for each transect making up that MU.
3. Commence monitoring with two people walking between the first two transects and then looping back between the second and third transects.
4. Tally and record coordinates for all seedlings within the MU.
5. Tag and record coordinates for all adults and juveniles within the MU.
6. For all tagged individuals measure and record plant attributes:
   - Height – Base of plant to tip of apical meristem in centimeters
   - Structures – Count the number of buds, flowers, and fruit per plant (no classes)
   - Life stage – Whether plant is an adult or a juvenile (A, J)
   - Vigor – Health, Moderate, Poor, or Dead (H, M, P, D)
   - Browse – Recorded as described previously

The 10 cm Rule for *I. hosakae*

This species has shown a considerable amount of vegetative reproduction (underground runners, etc.) that has sometimes made it problematic to differentiate between individuals. For this reason we have instituted the '10 cm Rule'. This rule states that, unless clear evidence exists to the contrary, all individuals less than 10cm tall that are greater than 10cm apart are classified and tagged as individuals. Conversely, unless clear evidence indicates otherwise, all individuals less than 10cm tall that are within 10cm from each other are classified and tagged as one individual with a note made as to the number of stems represented by one plant tag. Finally, unless clear evidence exists to the contrary, all individuals greater than 10cm tall are assumed to be separate individuals.

Silene lanceolata

1. Navigate to monitoring unit (MU) using the GPS Code field from GIS.
2. Stretch 25m tapes from base stake to end stake for each transect making up that MU.
3. Monitor plants only within subplots. If plants expand into one of the pre-determined but previously unoccupied subplot locations, install subplot.
4. Tally all seedlings within subplots.
5. Measure all juveniles within subplots.
6. Tag and measure all adults within subplots.
7. For all adults and juveniles measure and record plant attributes:

- Height – Base of plant to tip of apical meristem in centimeters
- Structures – Determine presence or absence of buds, flowers, and fruit on each plant. Classify total number of structures using the following classes:
  1) 1-25, 2) 26-50, 3) 51-150, 4) 151-250, 5) 250+
- Life stage – Whether plant is an adult or a juvenile (A, J)
- Vigor – Health, Moderate, Poor, or Dead (H, M, P, D)
- Browse – Recorded as described previously

Silene hawaiiensis

1. Navigate to monitoring unit (MU) using the GPS Code field from GIS.
2. Stretch 25m tapes from base stake to end stake for each transect making up that MU.
3. Commence monitoring with two people walking between the first two transects and then looping back between the second and third transects.
4. Tally and record coordinates for all seedlings within the MU.
5. Tag and record coordinates for all adults and juveniles within the MU.
6. For all tagged individuals measure and record plant attributes:
   - Height – Base of plant to tip of apical meristem in centimeters
   - Structures – Count the number of buds, flowers, and fruit per plant (no classes)
   - Life stage – Whether plant is an adult or a juvenile (A, J)
   - Vigor – Health, Moderate, Poor, or Dead (H, M, P, D)
   - Browse – Recorded as described previously

Pre-monitoring species

The following species exhibit characteristics that warrant investigation prior to the implementation of formalized monitoring protocols. Collection of pre-monitoring data was initiated in 2007 for most of these species and will continue through the 2009 monitoring cycle so that a sufficient data set can be used in the development of optimal monitoring strategies.

Asplenium peruvianum* var. *insulare

Monitoring for this species is currently in the development stage. Known plant locations are being re-surveyed to verify species presence and habitat characteristics are being quantified. So far, 14 of 33 plant locations have been visited. Plants at these locations are counted, measured, and photographed. Specific habitat characteristics quantified include temperature, humidity, light environment, and if applicable, size and depth of cave. These data will be analyzed to determine if correlations exist between habitat characteristics and plant health, size, and vigor. Based on these analyses, a monitoring methodology will be developed in 2009 so that long term management strategies for this species can be optimized.

Melanthera venosa

Monitoring was initiated for this species in 2008, however, it was determined that the methodology as applied could potentially bring harm to individuals because of its growth habit and its very steep habitat. Therefore, monitoring was suspended pending the development of a less invasive methodology. In 2009, a protocol that uses visual estimation of plant expanse will be tested.

Spermolepis hawaiiensis

Due to its annual life cycle, a monitoring technique that relies on following individuals through time is not appropriate for this species. It is unclear specifically how weather conditions prompt germination for this species, but water availability likely plays a role. Large numbers of S. have been previously observed after heavy amounts of rainfall. Because little is known about the time of year this species germinates, or the specific moisture availability thresholds that elicit germination, it is prudent to collect data for this species with greater temporal frequency to prevent missing regeneration events. In 2008, pre-monitoring activities were conducted to collect information that will inform the development of an appropriate monitoring methodology to be implemented on a pilot basis in 2009.

Stenogyne angustifolia

Based on preliminary data collected in 2008, a monitoring methodology is currently being developed for this species. The final protocol will likely involve the random selection of a set of known plants which will be monitored annually. In addition, monitoring for this species within the Kīpuka Kālawamauna East fence unit will take place in the context of an ecological restoration study. This study will seek to quantify the relative impacts of weed control, shade, and seed amendments on the health and vigor of *S. angustifolia* as well as on the recovery and growth of common native species.

Zanthoxylum hawaiiense

The development and implementation of a monitoring protocol for this species is pending the completion of a study to ascertain its current distribution at PTA. This study will characterize the number of individuals present at historically recorded plant locations. Initially, a random selection of 140 known plants will be visited to determine their status (e.g.., presence, sex, and phenology). Seventy of these individuals will then be selected so that all individuals to be included in future monitoring will represent a random sample of all known plants stratified by plant community type. The collection of these data will allow for the development of a more efficient and meaningful monitoring methodology for this species.

2.2 Rare Plant Propagation and Outplanting Protocols

Figure 2.2-1. PTA Interpretive Garden

Introduction

Pōhakuloa Training Area (PTA) houses 80-100% of the remaining genetic material for 12 of the 15 federally listed species found there (USFWS 2003). The low population numbers and very limited geographic range combined with the multiple threats of alien weeds, ungulates, fire and chance catastrophic events make these species extremely vulnerable to extinction. Weed and rodent control, large-scale fencing and wildfire management are underway to protect the remaining natural populations and to encourage species and habitat recovery. However, even with these management efforts the probability of a single plant population eventually becoming extinct is nearly certain (Mangel and Tier 1994; Lubow 1996; Ludwig 1996). To further reduce the risk of catastrophic loss the PTA outplanting program strives to increase population abundance and distribution of these rare species. The time-sensitive nature of rare plant preservation has necessitated initiating this program with limited biological, horticultural and historical knowledge.

Goals and Objectives

The ultimate goal of the PTA outplanting program is to contribute toward the recovery of the federally listed species occurring on PTA. While achievement of this goal is fraught with uncertainty and unpredictability two fundamental objectives have been set:

1. To ensure complete genetic representation of the target species in *ex situ* storage
2. To increase species abundance and distribution within the known historic range or other suitable habitat

Complete and secure genetic storage will safeguard genetic material and variability against unexpected loss and provide material for outplanting and research. Actions toward this end are priority management actions for the short-term (1-5 years).

Outplanting has begun to increase species abundance and distribution. During this initial phase of outplanting the focus has been to determine the habitat preferences of the target species and to develop successful outplanting techniques through the process of adaptive management at sites both on and off PTA. More sites will be established as larger areas at PTA are fenced and managed for threats. It is hoped that in the long term (>25 years) some of these early outplantings will show evidence of the persistence and resilience necessary for a self-sustaining population.

Objective 1. Ensure Complete Genetic Representation

Complete genetic representation in *ex situ* storage for all of PTA's listed species will serve to reduce extinction risk and provide propagules for outplanting that will maximize the genetic diversity represented in the natural population.

METHODS

Seed Collection

Seed collection will follow protocols developed by the HPRPG (see Appendix 1.1: HRPRG Collecting and Handling Protocols and also Appendix 1.2: Plant Propagule Collection Protocols). These protocols are the same as used in the Makua Implementation Plan but are applicable to the PIP as well. The general guidelines of collection from 50 populations, 50 individuals/ population, and 50 propagules/ individual will be modified according to individual species needs and seed availability. Species with the lowest numbers and/or lack of recruitment will receive priority. Collections from population units with greater than 50 individuals may be sampled. Table 2.2-1 lists species by priority category based on rarity and other concerns as determined by PTA NRO for prioritizing management actions. Individual species information concerning collection goals and population unit priorities can be found in the individual species sections.

Table 2.2-1. Priority Species for Seed Collection.

Priority	Species	Estimated Population at PTA	Collection Method*	Propagule Type	Comments
1	Hed cor	167	Complete	Seed	No recruitment in natural population
1	Iso hos	870	Sample	Seed	No seed in storage; population in area of high fire threat; unfenced
1	Mel ven	1,250	Sample	Seed/Cuttings	No seed in storage; population in area of high fire threat
1	Ner ova	210	Complete	Seed	Only 37 individuals are adults
1	Sol inc	75	Complete	Seed	Only 53 individuals are adults
1	Tet are	693	Complete	Seed	Only 245 adults; big annual fluctuations; population in area of high fire threat
1	Vig owa	75	Complete	Seed	Population in area of high fire threat
2	Asp per	>200	Complete	Spores	Number of plants that can be collected from may be much smaller than population estimate
2	Por scl	34	Complete	Seed	
2	Zan haw	488	Sample	Seed	Dioecious, male/female ratio presently unknown
3	Hap hap	>5,000	Sample	Seed/cuttings	Poor seed germination may necessitate use of cuttings
3	Sil haw	>10,000	Sample	Seed	
3	Sil lan	>5,000	Sample	Seed	
3	Spe haw	5,000	Sample	Seed	Population ephemeral, seed collection is opportunistic
3	Ste ang	>5,000	Sample	Seed/cuttings	Poor seed germination may necessitate use of cuttings

*Complete: collection from all founders in the natural population.
Sample: collection from at least 50 founders.

Seed from all wild individuals (founders) will be collected separately. The collector will record the following information for each collection:

- Genus, species
- Collection location
- Date of collection
- Collector
- Plant identification number

If an individual plant has not been tagged for monitoring purposes, a tag will be attached near the base of the plant. This tag will be labeled **Seed collection**, dated and will also include the location and plant number following current monitoring plant tag protocols.

Whenever possible, smaller collections over an extended period are preferred in order to reduce negative impacts to the natural population, increase genetic variability of the collection, and insure only collection of quantities that can be used efficiently. Field collected seed will be used primarily for genetic storage and outplanting purposes. Seed needed for research will be grown and collected in the RPPF whenever possible.

Seed Storage

Seed storage testing is not complete but preliminary results and information on related species indicate that most seeds will store well refrigerated for several years. Current information on seed storage recommendations can be found in Appendix 1.3: Lyon Arboretum Seed Storage Summary. Future seed storage testing will be conducted at the Schofield Seed Storage Facility.

After collection, seeds are prepared for storage by drying at ambient temperature (60°F and 45% relative humidity) for two to four weeks depending on seed size. Seeds are labeled with an accession number and the collection information is entered into a database. Seeds are stored in a refrigerated unit at PTA at 39°F and 23% relative humidity in polyethylene bags. As the seed collection expands and a duplicate collection is possible, seeds will be sent to the Schofield Seed Storage Facility as a further safeguard against loss.

Due to the poorly understood germination requirements for some species and the small amount of seed in storage, monitoring seed viability and longevity with any precision is unlikely. Some loss of viability over time is expected and therefore seed stock will be rotated with the oldest seeds being used first for outplanting needs. Depending on species specific storage characteristics the collections will be refreshed at least every three to seven years.

Germination/Propagation Protocol

To successfully propagate a species, a thorough understanding of its seed dormancy characteristics, its mating system, and its possible reliance on insects or animals for dissemination of pollen and/or seeds is essential. This information is not available for most of PTA's rare plants. In addition to this lack of biological and horticultural information, small population size may reduce seed set, seed viability, germination percentage, and overall seedling vigor (Ellstrand and Elam 1993). The situation is further exacerbated by the intraspecific diversity often exhibited by Hawaiian plants (Wagner *et al.* 1999) and the variable environmental conditions that can affect plant fecundity (Baskin and Baskin 2001). Previous germination methods do not always have repeated success. Germination and propagation protocol development remains incomplete and ongoing. The aforementioned uncertainties translate into often unpredictable numbers of propagules for outplanting that make planning difficult. Nonetheless, seeds remain the preferred propagule for storage and outplanting purposes because of their unique genetic makeup that may exhibit enhanced ecological adaptability and resistance to environmental stresses in their new environments.

Objective 2. Increase Species Abundance and Distribution

Outplanting will serve as a supplement to the broader management actions conducted by PTA's NRO to minimize the threats of alien weeds, ungulates and fire. While these actions will provide needed protection and encourage recovery of the natural populations they do not address the risk of unexpected loss faced by small single populations. The probability of a single plant population eventually being lost is almost certain (Mangel and Tier 1994; Lubow 1996; Ludwig 1996). The best strategy to ensure the survival of small populations subjected to multiple threats is to create geographically isolated populations (Carroll *et al.* 1996; Lubow 1996). The following outlines PTA's outplanting strategy. Whenever possible methods will be consistent with the restoration guidelines of the HRPRG (Appendix 1.4). Species have been prioritized according to small population size and limited geographic range (Table 2.2-2). Tentative outplanting sites have been selected but are subject to change as more information is gained on individual species habitat preferences.

Table 2.2-2. Priority Species for Outplanting.

Priority	Species	Estimated Population at PTA	Candidate Outplanting Sites
1	Hed cor	167	Koai'a Tree Sanctuary, Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, Kīpuka 'Alalā North, Mixed Tree 1, Upper Waik'i Gulch, West Hawai'i Veterans Cemetery.
1	Iso hos	870	Mixed Tree 1, Upper Waik'i Gulch, Pu'u Nohona o Hae, Pu'u Wa'awa'a Cone Unit, Koai'a Tree Sanctuary, West Hawai'i Veterans Cemetery.
1	Mel ven	1,250	Mixed Tree 1, Upper Waik'i Gulch, Pu'u Pāpapa, Pu'u Wa'awa'a Cone Unit, Koai'a Tree Sanctuary, West Hawai'i Veterans Cemetery.
1	Ner ova	210	Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, Mixed Tree 1 and 2, Kīpuka Kālawamauna West, West Hawai'i Veterans Cemetery.
1	Sol inc	75	Kīpuka Kālawamauna East 4, Kīpuka 'Alalā South, Pu'u Huluhulu, Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, Kīpuka 'Alalā North, Mixed Tree 2, Kīpuka Kālawamauna North, Upper Waik'i Gulch, West Hawai'i Veterans Cemetery.
1	Tet are	693	Kīpuka Kālawamauna East 5 and 6, Pu'u Huluhulu, Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, Kīpuka Kālawamauna North, Upper Waik'i Gulch, West Hawai'i Veterans Cemetery.
1	Vig owa	75	Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, Pu'u Nohona o Hae, Pu'u Pāpapa, Upper Waik'i Gulch, West Hawai'i Veterans Cemetery.
2	Zan haw	488	Pu'u Wa'awa'a Cone Unit, Kīpuka 'Owe'owe, Pu'u Nohona o Hae, Pu'u Pāpapa, Upper Waik'i Gulch, Mixed Tree 2, West Hawai'i Veterans Cemetery.
3	Asp per	>200	None chosen thus far.
3	Hap hap	>5,000	Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, Pu'u Nohona o Hae, Upper Waik'i Gulch, West Hawai'i Veterans Cemetery.
3	Por scl	34	No outplanting required in BO. Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, West Hawai'i Veterans Cemetery.
3	Sil haw	>10,000	Pu'u Huluhulu. Will be used in habitat restoration at other sites.
3	Sil lan	>5,000	Kīpuka Kālawamauna East 5, 6 and 7, Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, Kīpuka Kālawamauna North.
3	Spe haw	5,000	No outplanting required in BO. Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, West Hawai'i Veterans Cemetery.
3	Ste ang	>5,000	Pu'u Huluhulu, Kīpuka 'Alalā South, Kīpuka 'Owe'owe, Pu'u Wa'awa'a Cone Unit, Kīpuka 'Alalā North, Mixed Tree 2, Kīpuka Kālawamauna North, Upper Waik'i Gulch, West Hawai'i Veterans Cemetery.

METHODS

Site Selection

Selection of an outplanting site may be the central decision that influences the eventual outcome of any outplanting project. This decision is made difficult by the inability to define optimal habitat for most rare species. Ecological parameters in areas of historical distribution are in continual flux due to habitat degradation and loss and the changing global climate (Falk *et al.*1996). Choice is limited further by the scarcity of secure outplanting locations both on and off PTA. While historical distribution and biological functions influence site selection, some consideration must also be given to security and feasibility of management and monitoring.

At least four outplanting sites for each species will be established within the target species known historical range or other suitable habitat both on and off PTA. Establishment of at least two sites off PTA will be given priority in the short-term (1-5 years) while fencing and firebreak construction are completed at PTA. These sites will provide opportunities to increase understanding of species specific habitat preferences and to improve outplanting techniques. This information will contribute toward more efficient and successful methods in the long run both for PTA's NRO and others interested in the recovery of these species.

The present range of most of PTA's listed species represents only a portion of their former and potential range. Many have been known historically from other islands, elevations, substrates and moisture regimes. And the historical record is far from complete. Annual rainfall at PTA averages 37.4 cm with elevation ranging from 1265-2713 m. ʻaʻā and pāhoehoe cover over 80% of the installation (Shaw and Castillo 1997). For many of the target species, PTA may represent the fringe of their former range and as such may be marginal habitat. Five outplanting sites (Figure 2.2-2) have been established on state lands under various jurisdictions in order to better understand habitat preferences of the target species. These sites represent variations in elevation, substrates, moisture regimes and community types (Table 2.2-3). All are located in areas designated for long term conservation. Monitoring data will be used to compare survival, growth, fecundity and recruitment among the various outplanting sites both on and off PTA to try to determine optimal outplanting site characteristics.

Table 2.2-3. Current Outplanting Sites off PTA.

Outplanting Site	Ownership	Elevation	Substrate	Annual Rainfall	Community Type
Puʻu Huluhulu	State Rare Plant Sanctuary	2050 m	Mauna Kea cinder	89 cm	Koa/Māmane Dry Forest
Koaiʻa Tree Sanctuary (Kohala)	State Rare Plant Sanctuary	1040 m	Fine silt loam	76 cm	Remnant Koaiʻa Dry Forest
Kīpuka ʻOweʻowe	State Forest Reserve	630 m	Hualālai ʻaʻā	51 cm	Lama (*Diospyros*) Dry Forest
Puʻu Waʻawaʻa Cone Unit	State Forest Reserve	1112 m	Fine sandy loam	76 cm	Remnant Koa, ʻŌhiʻa , Māmane, Kikuyu understory
West Hawaiʻi Veterans Cemetery	State of Hawaiʻi	195m	Hualālai cinder	Irrigation	Remnant Lama,/Naio Dry Forest

In addition to providing valuable information, these sites also provide an additional source of genetic material in case of unexpected loss to the natural population. They are suitable for planting multiple species, allow for possible expansion and have proven to be an economical way of gathering needed information and establishing outplanting sites. More sites off PTA will be established in the future depending on individual species needs and site suitability and availability. All four current sites are in public access areas and afford high profile locations for both the individual species and the Army. It is hoped this will encourage interest in these species and future partnerships for further recovery actions.

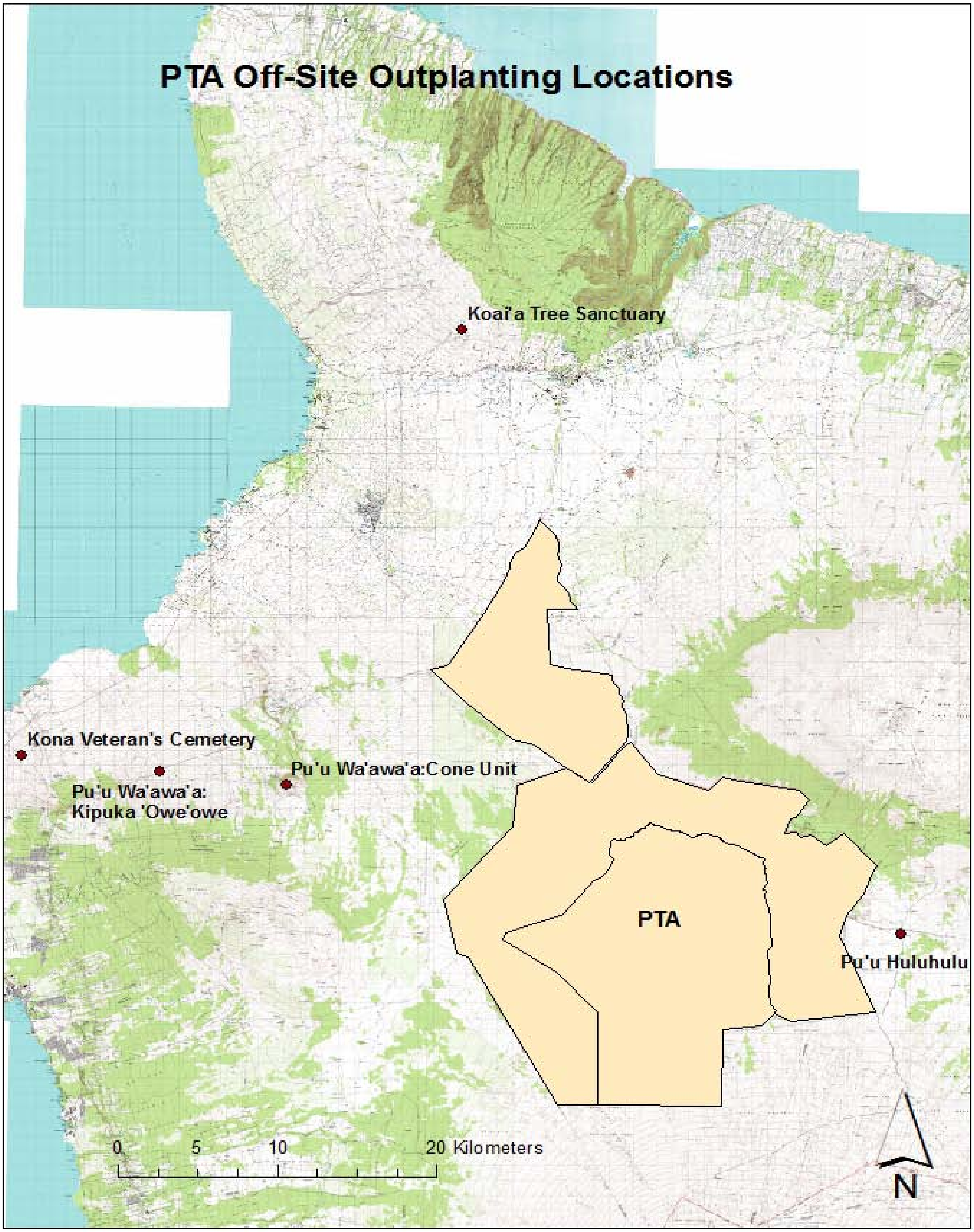


Figure 2.2-2. PTA Off-Site4 Outplanting Locations

Outplanting has also begun at PTA within the established fence units. As future fence units are completed more sites will be added. However complete ungulate removal from fenced areas has proven to be a difficult and lengthy undertaking in the past. Temporary fencing has been and may be necessary around outplanting sites within larger fence units as a safety precaution. Current and proposed outplanting sites on PTA are subject to substrate, temperature and moisture limitations and will likely be of smaller size than sites off PTA. More management will be required in terms of site preparation, watering and weed control. Even with the firebreaks in place PTA will remain at high risk for fire (Moller, pers. comm. 2007).

Four current outplanting sites in Kīpuka Kālawamauna East and one in Kīpuka ʻAlalā South may be suitable for expansion. Other candidate sites in future fence units are shown in Figures 2.2-2 and 2.1-3. Sites reflect variations in community type, substrate and elevation to continue exploring species specific habitat preferences and to create geographically discrete population units (Table 2.2-4).

Table 2.2-4. Current and Candidate Outplanting Sites at PTA.

Fence Unit/Outplanting Site	Fenced	Substrate	Elevation	Community Type
Kīpuka Kālawamauna East 4 (Current)	Yes	Pāhoehoe with scattered soil	1585m	*Myoporum* Shrubland
Kīpuka Kālawamauna East 5 (Current)	Yes	Rocky outcrops with scattered soil	1555m	*Dodonaea* Mixed Shrubland
Kīpuka Kālawamauna East 6 (Current)	Yes	Rocky outcrops with scattered soil	1665m	Myoporum Shrubland
Kīpuka Kālawamauna East 7 (Current)	Yes	Rocky outcrops with scattered soil	1550m	Dodonaea Mixed Shrubland
Kīpuka ʻAlalā South (Current)	Yes	Pāhoehoe, ʻaʻā, ash deposits	1850m	Myoporum-*Sophora* Shrubland
Kīpuka ʻAlalā North	Yes	ʻaʻā with soil pockets	1640m	Myoporum-*Sophora* Shrubland
Kīpuka Kālawamauna North	No (Spring 2009)	Ash and cinder	1600m	Dodonaea Mixed Shrubland
Mixed Tree 1	No (Summer 2010)	Pāhoehoe with scattered soil	1440m	Open *Metrosideros* Treeland
Mixed Tree 2	No (Summer 2010)	Pāhoehoe with scattered soil	1580m	Myoporum Shrubland
Upper Waikʻi Gulch (Keʻāmuku)	No (To be coordinated with ITAM)	Sandy loam	1560m	Kikuyu (P. *clandestinum*) pastureland
Puʻu Nohona o Hae (Keʻāmuku)	Yes	Stony fine sandy loam	900 m	Native Shrubland
Puʻu Pāpapa (Keʻāmuku)	Yes	Stony fine sandy loam	1000 m	Native Shrubland

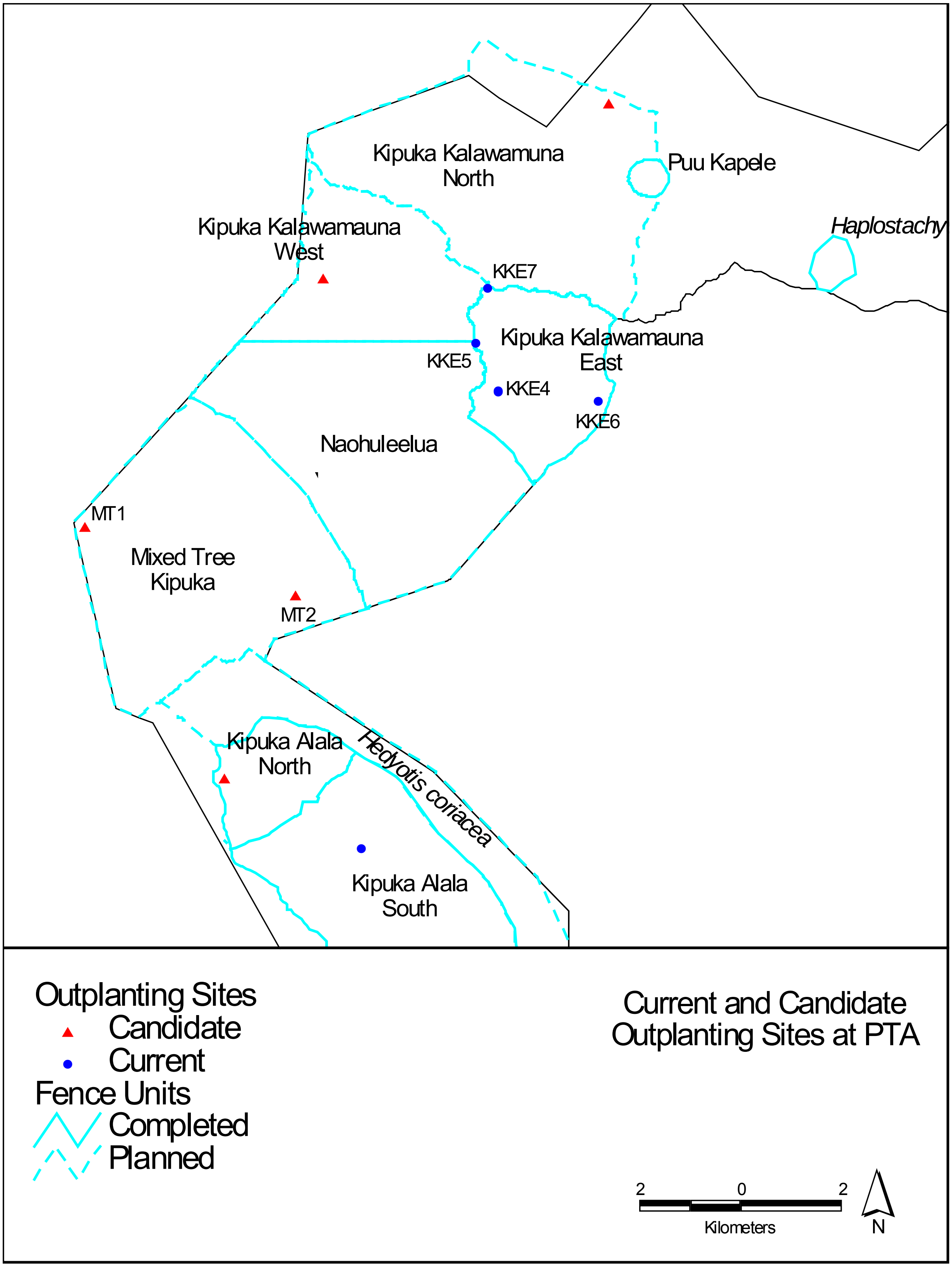


Figure 2.2-3. Current and Candidate Outplanting Sites at PTA

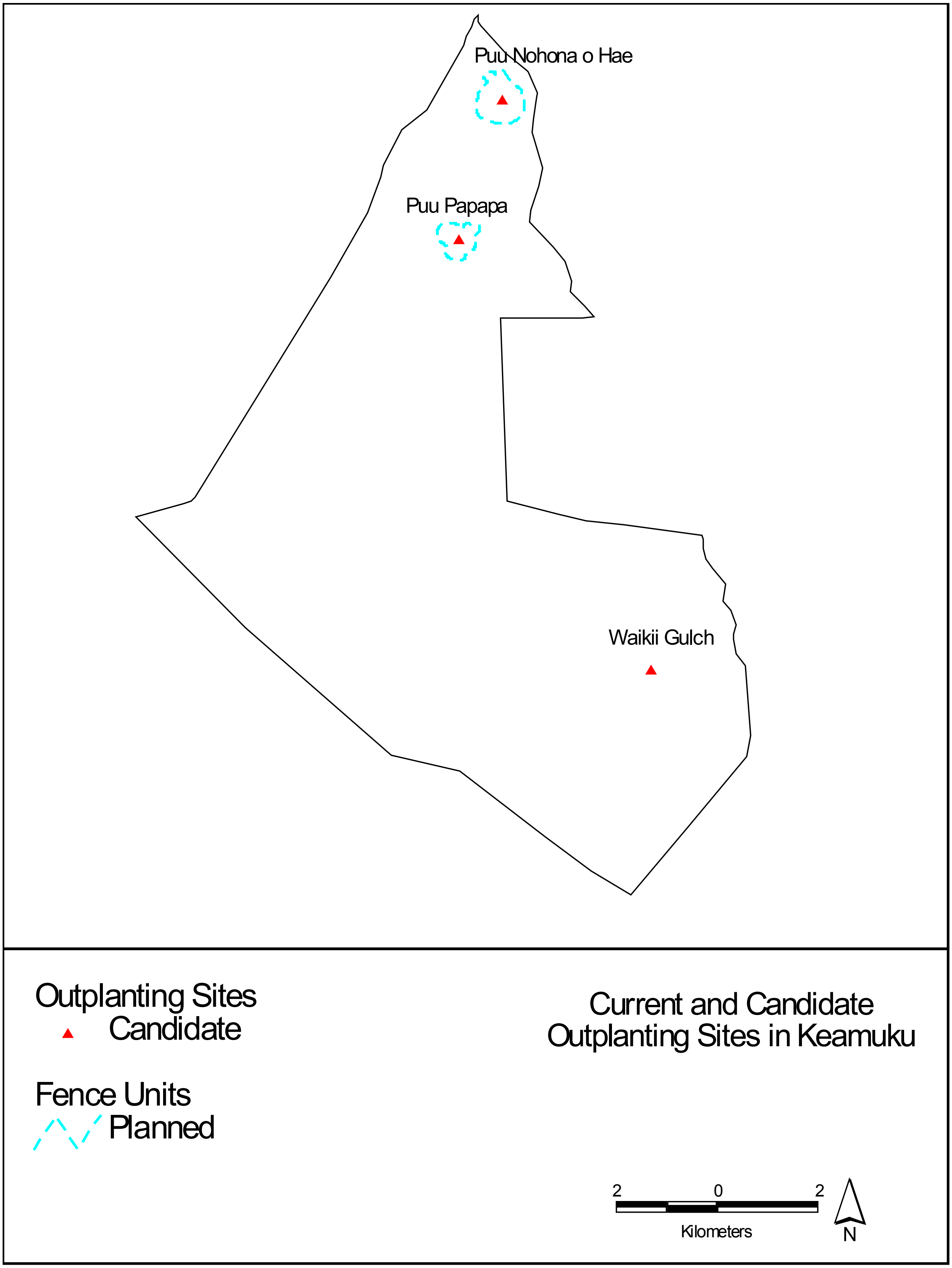


Figure 2.2-4. Current and Candidate Outplanting Sites in KMA

Minimum Target Population Size

Basic life history information such as life span is not known for PTA's rare species. Until this has been determined, all species will be considered short-lived perennials for the purposes of this plan except *Spermolepis* (annual) and *Zanthoxylum hawaiiense* (long-lived perennial).

The HPPRCC (1994) recommends 25 reproductive individuals for long-lived perennials (>10 year life span), 50 reproductive individuals for short-lived perennials (<10 year life span), 100 reproductive individuals for annuals as the target population size to ensure short-term stability. In recovery plans for several of PTA's target species, USFWS (1993, 1994, 1996a, 1996b, 1997, 1998a, 1998b, 1999) cites 300 mature individuals per population as the target population size for long- term viability. Guerrant (1996) recommends founding populations be as large as possible to avoid possible negative demographic and genetic concerns.

Because of the already low population numbers for many of the target species and the multiple threats they face, the minimum target population size at outplanting sites will be 100-300 reproducing adults, limited only by practical concerns (e.g. availability of propagules, suitability of habitat, etc.). Larger outplantings will potentially produce a larger seed bank more quickly. For species with often episodic recruitment, a large seed bank may greatly affect the likelihood of persistence over time. Larger numbers will also provide opportunities to test more microhabitats at each site. Outplanting will be done in increments to refine outplanting techniques and to increase genetic variability. The number of founders represented will be a function of the number in the natural population. Effort will be made to maximize and equalize founder representation whenever possible.

Augmentation

A very conservative approach will be taken with augmentation, the addition of individuals to an existing population in order to increase population size or genetic diversity. The preferred outplanting strategy for most of PTA's target species will be the establishment of new outplanting sites at least 1000 meters from the natural population, as recommended by the Makua Implementation Team (U.S. Army 2002). For the few target species where augmentation may be considered (see individual species plans) care will be taken to minimize any possible negative impacts to the natural population and their habitat. Sanitation guidelines created by the Makua Implementation Team (Appendix 1.5) will be followed and careful monitoring during the early post-planting phase will insure no new pathogens have been introduced. It is hoped that threat management alone (ungulate removal, weed control, etc.) will result in stabilization and recruitment in the natural population making augmentation unnecessary.

Planting Guidelines

Planting methods will be standardized across outplanting sites.

- Site preparation will include fencing and clearing of deadfall if necessary. Alien weed removal will begin at least two months prior to planting. For species requiring rodent control a grid of bait boxes will be set out two months prior to planting at PTA. For sites off PTA rodent control will be determined with the landowner.
- Phytosanitation guidelines developed by the Makua Implementation Team will be followed (Appendix 1.5).

- Planting will usually be conducted during the fall and early winter months to take advantage of seasonal rainfall.
- Various microhabitats will be chosen at each site to test habitat preferences.
- Planting densities will be based on plant densities within the natural population, size of the plant at maturity, and microsite availability at the outplanting site.
- Holes will be dug approximately twice the size of the planting pot.
- One gallon of water will be supplied to each plant at planting time. Half the amount of water will be poured into the planting hole prior to placement of the plant. The remaining water will be poured over the replaced soil after planting.
- Fertilizer generally will not be used except at the discretion of the horticulturist.
- Mulch from the site (rocks, leaf litter, etc.) will be placed around the base of the plant to conserve moisture.
- Wire stake flags will secure plant tags near the base of outplants. Tags will be labeled with the species name, plant number, founder and date of outplanting. For sites off PTA tags will also be labeled **US Army**.
- Plants will be hand-watered according to the following schedule: one gallon per plant every week for two weeks; one gallon two weeks after that; one gallon every month for the following two months. The watering regime may be modified depending on natural rainfall.
- Weed control to reduce competition and encourage seedling establishment will be conducted on a quarterly, semi-annual or annual rotation depending on site specific characteristics.
- Plants will be monitored for possible pathogens and other site specific threats during post-care watering and quarterly after that.
- All outplants will be monitored annually to assess growth, survival, reproduction and recruitment.

Monitoring

Monitoring will provide information to adapt management actions, assess site suitability, and better understand the biology and viability requirements of PTA's listed species. During the initial post-planting phase, monitoring will determine the efficacy of outplanting techniques (water requirements, specific threat control, etc.). During these early stages, annual monitoring data will also be used to assess the appropriateness of outplanting sites. Survivorship of at least 50% and healthy vigor of at least 50% of the outplanted individuals will be general guidelines in determining site suitability.

Annual monitoring will follow protocols developed for the natural populations (see Monitoring Section). Data collected will include survival, age class, size, reproductive status and fecundity, plant vigor and browse. Monitoring data will be collected from all individuals for the near future. As numbers increase, a sampling methodology may be employed. Monitoring data from outplanting sites will provide information on basic life history processes that can be compared to data from the natural populations to broaden our understanding of the target species requirements for long-term viability.

Partnerships

Partnerships play an integral part in the success of most restoration efforts. Given the limited geographic range of many of the target species, outplanting sites off PTA are essential to increase species distribution. NRO will continue to seek partners who can provide suitable habitat and are interested in the recovery of the target species. Lands dedicated to long-term conservation will be given priority. Partnerships may involve varying degrees of participation from NRO. Activities may range from supplying propagules, helping with outplanting and doing short-term or long-term site maintenance.

A list has been compiled (Appendix 1.6) that includes public and private agencies that will be notified regarding availability of propagules. Propagules of *Haplostachys haplostachya, Neraudia ovata, Solanum incompletum, Spermolepis,* and *Stenogyne angustifolia* have already been provided to DOFAW, HVNP, NTBG, Amy Greenwell Botanical Garden, and the Queen Lili‘uokalani Trust.

2.2.1 Species Specific Propagation and Outplanting Protocols

Figure 2.2-5. PTA RRPF

Asplenium peruvianum* var. *insulare

Spore Collection

Monitoring data from 2004 recorded between 552 and 902 plants at 34 locations. The majority of these were located on the east side of PTA where the ferns are found in the breakdown entrances of caves growing in cracks and crevices in the rubble and in mineral deposits. These individuals were small specimens with little evidence of spore formation and collection may yield little usable material. The population on the west side is mostly found in skylights with some soil deposition and has larger reproductive specimens. Collection will be attempted at each of the 34 locations. Collection will be planned for late summer to early fall.

Spore Storage

Valerie Pence, Director of Plant Research, Cincinnati Zoo and Botanical Garden (pers. comm. 2007) reports good germination from spores stored in liquid nitrogen for three years and expects similar results from frozen storage (-20°C) although no comparative study has been done. Spore storage testing will continue at the Cincinnati Zoo and Botanical Garden. The spore collection at PTA will be refreshed every five to seven years.

Germination Protocol

Germination has been successful at the Lyon Arboretum Micropropagation Facility, the Volcano Rare Plant Facility and the PTA Rare Plant Propagation Facility (RPPF). Spores can be sown thickly over fine cinder, provided high humidity and kept well shaded (Moriyasu, pers. comm. 2007). Gametophytes usually appear within two to three months. The length of time for moving from the gametophyte to the sporophyte stage may vary and be temperature dependant. Further trials will be necessary at PTA. Micropropagation has also been successful at the Lyon Arboretum Micropropagation Facility (Sugii, pers. comm. 2006).

Propagation Protocol

Germination can be done directly in individual 2” pots to avoid the need for early transplanting. Keep humidity high and grow in a well shaded location. Not enough information is available to determine the length of time required to reach optimal outplanting size. More trials are needed.

Outplanting

Because of the special habitat requirements for this species and lack of propagules ready for outplanting, no sites have been chosen. Several caves have been identified as possible sites and will be compared to natural sites with relation to moisture, temperature, light and substrate to determine suitability. In addition to outplanting, direct sowing of spores in caves selected for outplanting will be experimented with. Outplanting sites that are not subterranean will also be considered as long as light and moisture requirements are met. Priority actions for the short-term include spore collection and development of appropriate propagation protocols. Outplanting will not begin for 3-5 years.

Genetic considerations

Genetic material collected from east PTA will be used as propagules for east side outplanting. Material from the western side will be used for west side outplanting. If sites are established off PTA or in terrestrial habitat rather than subterranean, outplanting material will be of mixed genetic stock.

Haplostachys haplostachya

Seed Collection

For the two subpopulation units within Kīpuka Kālawamauna and Pu'u Kapele the Army will collect from a minimum of 50 individuals. In addition, all individuals in the *Haplostachys* Fence Unit (n=49) will be collected from. The subpopulation unit in the Ke'āmuku parcel has not been surveyed since 2002. Depending on the numbers remaining, sampling or complete collection will be determined. Other locations will be visited in 2008 to determine current numbers but ungulates have been devastating to the unfenced subpopulations in recent years. Collection may be most successful during summer.

Seed Storage

There is very little data for this species. The great majority of mints store well using conventional techniques, e.g. 39° F and 20% relative humidity (Yoshinaga, pers. comm. 2007). Seeds will be stored refrigerated until more information is available. The collection will be refreshed every five to seven years.

Germination Protocol

Germination of this species is problematic. Dr. Carol Baskin (pers. comm. 2006) reported only 2-3% germination after more than 2.25 years. Cracking the seed coat may produce slightly better results (10-20%) but not consistently. In addition to work conducted at PTA, germination has been attempted at the National Tropical Botanical Gardens, Amy Greenwell Botanical Garden, Lyon Arboretum and the Volcano Rare Plant Facility with equally poor results. Time and patience will be necessary to gain a better understanding of the physiological requirements necessary for germination.

Propagation Protocol

Cracking or sanding of the seed coat to reveal the embryo will force germination of a small percentage of seeds. This process also increases susceptibility to fungus and destroys many seeds. Until germination requirements are better understood cuttings will also be used as propagules for outplanting and to improve genetic representation at outplanting sites. The use of clonal propagules (cuttings) will allow the plants themselves to identify the best habitat (Guerrant and Fiedler 2004).

Propagules in 4" pots are suitable for outplanting. The species is susceptible to powdery mildew and should be grown in full sun. In the PTA RPPF powdery mildew can be controlled with potassium bicarbonate.

Outplanting

Outplantings have been done at several sites (Table 2.2-5). This species is known from open areas in both soil and rocky substrates. Both substrates will be represented at outplanting sites. Planting should be done in full sun to minimize the occurrence of powdery mildew. In addition to planting, seed will be broadcast at outplanting sites to establish an early seed bank and allow time for any extended dormancy.

Table 2.2-5. Current and Proposed Outplanting Sites for *H. haplostachya*.

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Kīpuka ʻOwēʻowē (Current)	4	Hualālai ʻaʻā	630 m	Lama (*Diospyros*) Dry Forest
Puʻu Waʻawaʻa Cone Unit (Current)	120	Fine sandy loam	1112 m	Remnant Koa, ʻŌhiʻa , Māmane, Kikuyu understory
Kīpuka Kālawamauna East 6 (Current)	32	Rocky outcrops with scattered soil	1665m	Myoporum shrubland
Puʻu Huluhulu	23	Mauna Kea cinder	2050m	Koa/Māmane Dry Forest
West Hawaiʻi Veterans Cemetery	38	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Puʻu Nohona o Hae (Proposed)	-	Stony fine sandy loam	900 m	Native Shrubland
Upper Waikʻi Gulch (Keʻāmuku) (Proposed)	-	Sandy loam	1560m	Kikuyu (*P. clandestinum*) Pastureland

Genetic considerations

Founders from all subpopulation units will be represented at outplanting sites to optimize reproductive vigor and to serve as a buffer against possible inbreeding depression.

Collection in the Battle Action Course (Training Area 7)

The BO requires collection from the 17 occurrences that were found in 2002. Unfortunately the subpopulation unit at the Battle Action Course (BAX) has been severely impacted by ungulates and drought during the last four years and disappeared between 2005 and 2007. After seasonal rains in 2008, over 1,000 seedlings appeared. Some of them were transported to the RPPF. These individuals are being used for outplanting and seed collection for storage. Because of the possibility of a persistent seed bank, an annual visit to the area will be conducted to recover any remaining genetic material.

Hedyotis coriacea

Seed Collection

Monitoring data from 2006 recorded 166 adults and one juvenile in the natural population. Because of the lack of recruitment, collection will be made from all fruiting adults. Smaller quantities collected every year is preferred over one large collection because of possible short storage life. Seed collection has been most successful during fall and winter.

Seed Storage

There is no data for *H. coriacea*. *H. acuminata* stored well for one year but not two. Refrigeration appears better than freezing (Yoshinaga, pers. comm. 2007). Seeds stored for one to five years have germinated at PTA's Rare Plant Propagation Facility (RPPF). Until further testing is done seed will be refreshed at least every three to four years.

Germination Protocol

Begin germination in March-April. Seeds can be surface sown in a mixture of perlite, cinder, vermiculite, peat (4:4:1:1) in 2” pots. Time to germination (2-4 weeks) seems to be shortened when temperatures are warmer. Germination occurs in a flush over several days. Germination percentage has been variable (30-80%).

Propagation Protocol

Seedlings are very small and growth is extremely slow. Transplanting should be delayed until the root system has time to develop (at least 2-3 months). There is high seedling mortality (80%) during the early stages of growth and initial transplanting. More trials are necessary to determine optimal propagation protocol. Plants are ready for outplanting in 12-16 months in 4” pots. Species is susceptible to scale insects at some outplanting sites. Treatment has included hand removal and applications of insecticidal soap or neem products.

Outplanting

The natural population is found in open *Metrosideros* treeland. Outplants have also shown adaptability to koaiʻa and *Diospyros* treeland (Table 2.2-6). Cold temperatures may be a limiting factor and frost damage has been noted at some locations. Elevations below 1700 m are recommended. At current outplanting sites this species has adapted to a variety of substrates (pāhoehoe, ʻaʻā, fine silt loam).

Table 2.2-6. Current and Proposed Outplanting Sites for *H. coriacea*.

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Koaiʻa Tree Sanctuary (Current)	39	Fine silt loam	1040 m	Remnant Koaiʻa Dry Forest
Kīpuka ʻOwēʻowē (Current)	60	Hualālai ʻaʻā	630 m	Lama (*Diospyros*) Dry Forest
Puʻu Waʻawaʻa Cone Unit (Current)	60	Fine sandy loam	1112 m	Remnant Koa, ʻŌhiʼa , Māmane, Kikuyu understory
West Hawaiʻi Veterans Cemetery (Proposed)	-	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Kīpuka ʻAlalā North (Proposed)	-	ʻaʻā with soil pockets	1640m	Myoporum-*Sophora* Shrubland
Mixed Tree 1 (Proposed)	-	Pāhoehoe with scattered soil	1440m	Open *Metrosideros* Treeland
Upper Waikʻi Gulch (Keʻāmuku) (Proposed)	-	Sandy loam	1560m	Kikuyu (*P. clandestinum*) Pastureland

Genetic considerations

Most of the population can be divided into two subpopulation units separated by approximately five kilometers, one in Kīpuka Kālawamauna (50 individuals) and the other in Kīpuka ʻAlalā (97 individuals). The remaining 19 individuals are scattered between the two larger groups in three smaller groupings. No obvious morphological differences have been noted among the population units. Planned genetic testing will determine the degree of homozygosity in the natural population. Until test results are available the source population for Kīpuka ʻAlalā North will be the Kīpuka ʻAlalā subpopulation unit. The source population for Mixed Tree 1 will be the Kīpuka Kālawamauna subpopulation unit. Genetic material from the founders in the smaller groups will be added to each outplanting site. For outplanting sites outside of PTA and at the Keʻāmuku site founders from the entire PTA population will be used. It is hoped the species has retained genetic potential for many habitats and natural selection will determine the genotypes most suited to the new communities (Falk *et al.* 1996).

Isodendrion hosakae

Seed collection

Collection will be made from at least 50 individuals of the estimated 870 at Puʻu Pāpapa. A complete collection will be made from any and all individuals that may remain on Puʻu Nohona o Hae. Collection should be conducted at various intervals to determine species phenology.

Seed Storage

Very little data is available for any *Isodendrion* species though the great majority of Violets store well using conventional techniques, e.g. 39° F and 20% relative humidity (Yoshinaga, pers. comm. 2007). Seed will be stored refrigerated until more information is available. Collection will be refreshed every five years.

Germination Protocol

Germination has not been attempted at PTA. Attempts to grow *I. hosakae* from seed and from cuttings have had meager success (USFWS 1994). P. Moriyasu, IT Member, (pers. comm. 2007) reports poor germination for this species at the Volcano Rare Plant Facility during limited trials. Seedlings were susceptible to damping off, the collapse and rapid death of very young seedlings due to fungal disease. Germination of *I. pyrifolium* has not been problematic (Kiyabu, pers. comm. 2007). Fresh seed can be sown in a mixture of perlite/vermiculite (3:1) after soaking in water overnight. Germination usually occurs in 2-4 weeks. Due to the high variability in germination of native Hawaiian plants similar results cannot be expected.

Propagation Protocol

Plants can be grown in well drained media and kept fairly dry (Moriyasu, pers. comm. 2007). The length of time to optimal outplanting size has not been determined. It may be necessary to propagate this species at a lower elevation facility if it appears to be sensitive to the colder temperatures at PTA.

Outplanting

No outplanting has been done by PTA NRO. Several individuals outplanted in 2002 by DOFAW at Puʻu Huluhulu (2050m) did not survive, presumably because of low winter temperatures. Small plantings will be attempted at the Mixed Tree 1 site (1440m) and the Upper Waikʻi Gulch site (1560 m) to test the species cold tolerance (Table 2.2-7). It may be necessary to have all outplanting sites at lower elevations off PTA. Augmentation/reintroduction will be attempted at Puʻu Nohona o Hae. Priority will be given to seed collection and development of germination/propagation protocols. Outplanting may not begin for 2-4 years.

Table 2.2-7. Proposed Outplanting Sites for *I. hosakae*.

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Mixed Tree 1 (Proposed)	-	Pāhoehoe with scattered soil	1440m	Open *Metrosideros* Treeland
Upper Waik‘i Gulch (Ke‘āmuku) (Proposed)	-	Sandy loam	1560m	Kikuyu (*P. clandestinum*) Pastureland
West Hawai‘i Veterans Cemetery (Proposed)	-	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Pu‘u Nohona o Hae (Proposed)	-	Stony fine sandy loam	900 m	Native Shrubland
Pu‘u Wa‘awa‘a Cone Unit (Proposed)	-	Fine sandy loam	1112 m	Remnant Koa, ‘Ōhi’a , Māmane, Kikuyu understory
Koai‘a Tree Sanctuary (Proposed)	-	Fine silt loam	1040 m	Remnant Koai‘a Dry Forest

Genetic Considerations

Outplanting sites that may include *I. pyrifolium* will be avoided to prevent possible hybridization.

Melanthera venosa

Seed Collection

Collection will be made from at least fifty individuals of the estimated population (1,250). Seed collection may be most successful during spring and early summer and is likely related to natural rainfall. Cuttings may also be taken during the winter rainy season.

Seed Storage

Very little storage data is available for *Melanthera* species because of difficulty in germination. Composites store well using conventional techniques, e.g. 39° F and 20% relative humidity (Yoshinaga, pers. comm. 2007). Seed will be stored refrigerated until more data is available. The collection will be refreshed every three to five years.

Germination Protocol

Moriyasu (2007) reports limited success germinating seed of this species but cuttings will root well at the nodes. Root cuttings in mixture of perlite/vermiculite (1:1). More seed trials will be attempted as seed becomes available.

Propagation Protocol

Temperature at Pōhakuloa’s RPPF may be too severe for this species and propagation may be necessary at a lower elevation site. Trials will be done to determine temperature tolerances as soon as propagules are collected.

Outplanting

No outplanting has been done by PTA NRO. Small plantings will be done at the Mixed Tree 1 site (1440m) and the Upper Waik‘i Gulch site (1560 m) to test this species cold tolerance (Table 2.2-8). It may be necessary to have all outplanting sites at lower elevations off PTA. Augmentation/reintroduction will be attempted at Pu‘u Pāpapa. Priority will be given to seed collection and development of germination/propagation protocols. Outplanting may not begin for 2-4 years.

Table 2.2-8. Proposed Outplanting Sites for *M. venosa*.

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Mixed Tree 1 (Proposed)	-	Pāhoehoe with scattered soil	1440m	Open *Metrosideros* Treeland
Upper Waik‘i Gulch (Ke‘āmuku) (Proposed)	-	Sandy loam	1560m	Kikuyu (*P. clandestinum*) Pastureland
Pu‘u Pāpapa (Proposed)	-	Stony fine sandy loam	1000 m	Native Shrubland
West Hawai‘i Veterans Cemetery (Proposed)	-	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Pu‘u Wa‘awa‘a Cone Unit (Proposed)	-	Fine sandy loam	1112 m	Remnant Koa, ‘Ōhi‘a , Māmane, Kikuyu understory
Koai‘a Tree Sanctuary (Proposed)	-	Fine silt loam	1040 m	Remnant Koai‘a Dry Forest

Genetic Considerations

Outplanting sites that may include *M. subcordata* will be avoided to prevent possible hybridization.

Neraudia ovata

Seed Collection

Collection will be made from all fruiting individuals (n=37) in the field. Collection will also be done in the RPPF where both male and female specimens of all adult PTA founders are represented to facilitate pollen transfer and improve genetic variation. Seed has been collected at various seasons.

Seed Storage

There is little data for *N. ovata*. *N. angulata* stores well refrigerated for at least two years. Frozen seeds survived but with lower germination (Yoshinaga, pers. comm. 2007). Seeds under trees dead for at least seven years germinated after a particularly wet rainy season in 2004 at PTA. Until more information is available seed will be stored refrigerated. The collection will be refreshed every five to seven years.

Germination Protocol

Germination treatments have included water soak (varying from 2 hours to 2 days), chemical scarification with gibberellic acid-3 at various concentrations, mechanical scarification, stratification, dry heat at 80°C and germination in soil from the field site. L. Weisenberger (pers. comm. 2007), Propagule Management Specialist, US Army Schofield Barracks, HI, reports success by sowing seeds on agar and keeping them in the dark for twelve months (35% germination during the following six months). In the end, patience is a necessary component of the process. Seeds germinate sporadically over several years. Seeds can be sown in a mix of perlite/vermiculite (1:1). Transplanting can be done safely when three to four sets of true leaves have formed.

Propagation Protocol

Plants can be grown in well drained media and are usually ready for outplanting in 8-12 months. Outplanting has been successful with both 4" and gallon size pots. Cuttings are also possible but will not improve the low genetic diversity this species is experiencing. *N. ovata* is susceptible to red spider mites both in the RPPF and in the field. Avid® miticide has been used successfully in the RPPF.

Outplanting

Previous outplantings at lower elevation sites with higher moisture regimes than PTA (Pu‘u Wa‘awa‘a and Kīpuka ‘Owe‘owe) have shown the most vigorous growth (Table 2.2-9). At HVNP outplants in mesic habitat have also shown more vigorous and sustained growth than plants in drier habitat (Belfield, pers. comm. 2007). Most individuals reach reproductive status before leaving the RPPF but return to the vegetative state or experience severe leaf drop at the drier outplanting sites. Survival (84%) has been encouraging. Two seedlings from 2004 outplants were recorded at Kīpuka ‘Owē‘owē in 2006.

Augmentation will be conducted near both subpopulation units when fences are completed. Planting as well as broadcast seeding will be done.

Table 2.2-9. Current and Proposed Outplanting Sites for *N. ovata*.

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Kīpuka ‘Owē‘owē (Current)	42	Hualālai ‘a‘ā	630 m	Lama (*Diospyros*) Dry Forest
Pu‘u Wa‘awa‘a Cone Unit (Current)	74	Fine sandy loam	1112 m	Remnant Koa, ‘Ōhi’a , Māmane, Kikuyu understory
West Hawai‘i Veterans Cemetery (Proposed)	-	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Mixed Tree 1 (Proposed)	-	Pāhoehoe with scattered soil	1440m	Open *Metrosideros* Treeland
Mixed Tree 2 (Proposed)	-	Pāhoehoe with scattered soil	1580m	Myoporum Shrubland
Kīpuka Kālawamauna West (Proposed)	-	‘a‘ā with soil pockets	1400m	Myoporum Shrubland

<u>Genetic Considerations</u>

Whenever possible all founders will be represented by both male and female specimens at outplanting sites to create the greatest potential for genetic mixing. Founders (2) recently discovered on State land at Pu‘u Anahulu will be incorporated into PTA outplanting sites to increase genetic diversity. A duplicate living collection is being established at Hawai‘i Volcanoes National Park representing all the present founders at PTA. This will provide material for their reintroduction efforts and also provide a safeguard against unexpected loss of the PTA population.

Portulaca sclerocarpa

<u>Seed Collection</u>

Collection will be made from all reproductive individuals in the PTA population (n=34). Collection has been made from spring through fall.

<u>Seed Storage</u>

No storage data is available for *P. sclerocarpa.* In general *Portulacas* store well using conventional techniques, e.g. 39° F and 20% relative humidity (Yoshinaga, pers. comm. 2007). Seed will be stored refrigerated until more data is available. The collection will be refreshed every three to five years.

<u>Germination Protocol</u>

Seeds germinate readily. Seeds can be sown over a mixture of perlite/vermiculite (1:1). Germination usually begins in three weeks.

<u>Propagation Protocol</u>

Propagules are ready for outplanting in 6-8 months in 4” pots. Cuttings are also easily rooted. Seedlings and cuttings are relatively pest resistant in the greenhouse. Rodents will eat the seeds and may inhibit recruitment in the field.

<u>Outplanting</u>

Outplanting for this species is not required in the 2003 Legacy and Transformation Biological Opinion but plants that “volunteer” in the RPPF have been planted at several outplanting sites to gain a better understanding of this species. Outplants at the Koai‘a Tree Sanctuary did well for about one year but did not persist. This site can experience prolonged dry spells. In 2006 plants were introduced into the Pu‘u Wa‘awa‘a Cone Unit and Kīpuka ‘Owe‘owe. Monitoring data will be available in 2007. When outplanting begins for other species at Pu‘u Pāpapa and Pu‘u Nohona o Hae, seed from the RPPF will be broadcast at these sites as part of the restoration effort. This species was recorded at Pu‘u Nohona o Hae and nearby pu‘u in the 1980s (Cuddihy *et al.* 1983).

Silene

<u>Seed Collection</u>

Subpopulations in Kīpuka Kālawamauna, Kīpuka ‘Alalā, ASRs 02, 03, and 38 will be sampled (Figure 2.2-2), with collections from at least 50 founders represented whenever possible. Collection may be most successful during summer.

Seed Storage

Seed will be stored refrigerated until more data are available. The collection will be refreshed every five years.

Germination Protocol

Seeds germinate readily. Seeds can be sown over a mixture of perlite/vermiculite (2:1). Germination usually begins in 2-3 weeks.

Propagation Protocol

Plants can be grown in a mixture of perlite, cinder, vermiculite, peat (4:4:1:1) Propagules are ready for outplanting in 6-8 months in 4" pots.

Outplanting

No outplanting has been conducted for this species. It is anticipated that once fencing is complete, ungulates removed, and weed control underway this species will show signs of recovery and recruitment that will make augmentation unnecessary. Because of the broad range of this species throughout PTA and other parts of the island large-scale outplanting is not planned. Small plantings may be included at some outplanting sites as part of habitat restoration.

Silene lanceolata

Seed Collection

S. lanceolata occurs in a broad range across western PTA, with the current population estimated near 10,000. Collection will be done in ASRs 11, 13, 14, 16, 18, 25 and 31 (Figure 2.2-2). Collection will made from at least 50 individuals in each ASR. Collection may be most successful during summer.

Seed Storage

Seed will be stored refrigerated until more data is available. Collection should be refreshed every five years.

Germination Protocol

Halward and Shaw (1996) recommend an after-ripening period of 40-60 days. Seeds soaked in water overnight can be surface sown on perlite/vermiculite (2:1). Germination usually begins in 10-20 days.

Propagation Protocol

Plants can be grown in a mixture of perlite, cinder, vermiculite, peat (4:4:1:1) Plants are ready for outplanting in 6-8 months in 4" pots.

Outplanting

Outplanting sites were established at three locations in the Kīpuka Kālawamauna East Fence Unit between 2003 and 2004 (Table 2.2-10). Results have been promising with over 80% survival at these sites and recruitment noted at one site in 2006. An outplanting in Kīpuka ʻAlalā South Fence Unit (1850 m) did not survive cold winter temperatures but did produce juveniles in

2006-2007. The persistence of these juveniles will be monitored. Outplanting sites have also been established off PTA at Kīpuka ʻOwēʻowē and Puʻu Waʻawaʻa Cone Unit in 2006.

This species is capable of growing in a wide range of habitats both on and off PTA but is susceptible to frost damage at higher elevations (>1850 m). Current threat control measures at PTA should stabilize and increase populations there. Partnerships with other agencies will be sought to expand the current range.

Table 2.2-10. Current and Proposed Outplanting Sites for *S. lanceolata*.

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Kīpuka Kālawamauna East 5 (Current)	116	Rocky outcrops with scattered soil	1555m	*Dodonaea* Mixed Shrubland
Kīpuka Kālawamauna East 6 (Current)	49	Rocky outcrops with scattered soil	1665m	Myoporum Shrubland
Kīpuka Kālawamauna East 7 (Current)	23	Rocky outcrops with scattered soil	1550m	Dodonaea Mixed Shrubland
Kīpuka ʻOwēʻowē (Current)	197	Hualālai ʻaʻā	630 m	Lama (*Diospyros*) Dry Forest
Puʻu Waʻawaʻa Cone Unit (Current)	204	Fine sandy loam	1112 m	Remnant Koa, ʻŌhiʼa , Māmane, Kikuyu understory
Kīpuka Kālawamauna North (Proposed)	-	Ash and cinder	1600m	Dodonaea Mixed Shrubland

Genetic Considerations

At PTA genetic material for outplanting sites will be taken from the nearest subpopulation units. At sites off PTA genetic material from all subpopulations will be mixed.

Solanum incompletum

Seed Collection

Collection will be made from all reproductive individuals in the current population. Collection may be most successful in late summer to early fall but seed has been collected at various seasons.

Seed Storage

Seed will be stored refrigerated until more data is available. The collection will be refreshed every five to seven years.

Germination Protocol

S. incompletum possesses a complex physiological dormancy that is not well understood (Baskin, pers. comm. 2003). Germination may be stimulated with gibberellic acid (GA-3) at 400 ppm or by allowing the flats to dry out for several months and then rewetting them. Seeds should be sown in late winter as cooler temperatures may also stimulate germination. Seeds can be sown in perlite/vermiculite (2:1) and can be transplanted easily even in the cotyledon stage. Germination can begin after two weeks and continue sporadically for several years.

Propagation Protocol

Plants can be grown in a mixture of perlite, cinder, vermiculite, peat (4:4:1:1). They are ready for outplanting in 6-8 months in 4” pots.

Outplanting

Over 1,000 plants have been outplanted since 2002 (Table 2.2-11). Overall survival has been greater than 80%. Natural recruitment was noted for the first time at one site (Kīpuka ‘Alalā South) in 2006. Individuals at upper elevation sites (>1850 m) are susceptible to frost damage. The most vigorous growth and earliest reproduction have been noted at the mid-elevation mesic site at Pu‘u Wa‘awa‘a Cone Unit. Cold temperatures and low rainfall are limiting factors at PTA. The species has adapted to a variety of substrates.

The subpopulation at ASR 13 will be augmented with plants and broadcast seeding. Broadcast seeding will be conducted in ASR 24 (Figure 2.2-2). Genetic representation will be increased at current outplanting sites. Partnerships will be sought with other agencies.

Table 2.2-11. Current and Proposed Outplanting Sites for *S. incompletum.*

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Kīpuka Kālawamauna East 4 (Current)	32	Pāhoehoe with scattered soil	1585m	*Myoporum* Shrubland
Kīpuka ‘Alalā South (Current)	102	Pāhoehoe , ‘a‘ā, ash deposits	1850m	Myoporum-*Sophora* Shrubland
Pu‘u Huluhulu (Current)	290	Mauna Kea cinder	2050 m	Koa/Māmane Dry Forest
Kīpuka ‘Owē‘owē (Current)	194	Hualālai ‘a‘ā	630 m	Lama (*Diospyros*) Dry Forest
Pu‘u Wa‘awa‘a Cone Unit (Current)	212	Fine sandy loam	1112 m	Remnant Koa, ‘Ōhi’a , Māmane, Kikuyu understory
West Hawai‘i Veterans Cemetery (Proposed)	-	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Kīpuka ‘Alalā North (Proposed)	-	‘a‘ā with soil pockets	1640m	Myoporum-*Sophora* Shrubland
Mixed Tree 2 (Proposed)	-	Pāhoehoe with scattered soil	1580m	Myoporum Shrubland
Upper Waik‘i Gulch (Ke‘āmuku) (Proposed)	-	Sandy loam	1560m	Kikuyu (P. *clandestinum*) Pastureland

Genetic Considerations

Genetic material from both subpopulations will be mixed at all outplanting sites.

Spermolepis

Seed Collection

Due to the ephemeral nature of this species at PTA, collection in the field has been possible only twice in the last ten years. Collection in the RPPF is continuous as new plants “volunteer” all over the facility. At least three to five previously known locations will be visited annually in midsummer to determine if seed collection is possible. Seed will continue to be collected in the RPPF.

Seed Storage

Seed will be stored refrigerated until more data is available. The collection will be refreshed every three years.

Germination Protocol

Seeds germinate readily. Seeds can be sown in a mixture of perlite/vermiculite (2:1). Germination usually begins in three weeks.

Propagation Protocol

Plants can be grown in well drained media. They are ready for outplanting in approximately three months in 4” pots. Plants in the RPPF have been pest resistant.

Outplanting

No outplanting is required for this species in the 2003 Biological Opinion. Several small outplantings have not yielded a persistent population. Plants mature and show some recruitment but have not persisted past the juvenile stage at PTA. Seeds have been supplied to HVNP for reintroduction efforts. T. Belfield, (2007) reports a similar loss of juveniles at HVNP. Insect predation is thought to be the cause. Broadcast seed experiments will continue at outplanting sites using seed grown in the RPPF.

Stenogyne angustifolia

Seed Collection

This species is widespread across western PTA, with the population estimated at 1,500-5,000. Seeds and cuttings will be collected from at least 5 founders in ten different locations across western PTA to include Training Areas 19, 22, and 23. Focus will be directed to areas of greatest known density, e.g. ASRs 11, 93, 18, 90, 92, 08, 91, and 99. Seed can be collected at various seasons. Cuttings should be taken in late winter or after significant rainfall.

Seed Storage

Seed will be stored refrigerated until more data is available. The collection will be refreshed every five to seven years.

Germination Protocol

Germination of this species is problematic. Complete removal of the hard seed coat is sometimes successful but more often leads to injury to the embryo or increased incidence of fungal contamination. *S. angustifolia* is propagated easily from cuttings. Until germination requirements are better understood, cuttings will be used for outplanting.

Propagation Protocol

Plants can be grown in well drained media. Cuttings are ready for outplanting in three to five months in 4” pots. This species is susceptible to powdery mildew, most often appearing on the sepals. The occurrence of mildew does not seem to adversely affect plant vigor.

Outplanting

Approximately 100 plants have been put into four sites between 2002 and 2007 (Table 2.2-12). Survival averages 83%. Vegetative reproduction has been noted at all sites. This species tolerates a wide elevation range and variable substrates. Partial to full sun is recommended to lessen the occurrence of powdery mildew.

S. angustifolia can be an important contributor to habitat restoration at outplanting sites. Its sprawling habit can quickly increase native cover at degraded sites. The combination of rhizomatous and aerial rooting is useful on slopes to deter erosion.

Table 2.2-12. Current and Proposed Outplanting Sites for *S. angustifolia.*

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Pu‘u Huluhulu (Current)	77	Mauna Kea cinder	2050 m	Koa/Māmane Dry Forest
Kīpuka ‘Alalā South (Current)	2	Pāhoehoe , ‘a‘ā, ash deposits	1850m	Myoporum-*Sophora* Shrubland
Kīpuka ‘Owē‘owē (Current)	4	Hualālai ‘a‘ā	630 m	Lama (*Diospyros*) Dry Forest
Pu‘u Wa‘awa‘a Cone Unit (Current)	12	Fine sandy loam	1112 m	Remnant Koa, ‘Ōhi’a , Māmane, Kikuyu understory
West Hawai‘i Veterans Cemetery (Proposed)	-	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Kīpuka ‘Alalā North (Proposed)	-	‘a‘ā with soil pockets	1640m	Myoporum-*Sophora* Shrubland
Mixed Tree 2 (Proposed)	-	Pāhoehoe with scattered soil	1580m	Myoporum Shrubland
Kīpuka Kālawamauna North (Proposed)	-	Ash and cinder	1600m	Dodonaea Mixed Shrubland
Upper Waik‘i Gulch (Ke‘āmuku) (Proposed)	-	Sandy loam	1560m	Kikuyu (P. *clandestinum*) Pastureland

Genetic considerations

Equalize founders at all outplanting sites.

Tetramolopium arenarium ssp *arenarium*

Seed Collection

This species is subject to fluctuations in population size. The most current monitoring data reported 245 adults. Collection will be made from all reproductive adults. Collections have been made at various times of the year.

Seed Storage

Seed will be stored refrigerated until more data is available. The collection will be refreshed every five to seven years.

Germination Protocol

No special germination requirements are necessary for this species. Seeds can be surface sown on a mixture of perlite, cinder, vermiculite, peat (4:4:1:1) in 2” pots. Seeds usually germinate within 8-10 days. Germination percentages have ranged from 15-72%. Germination percentages from individuals at northern locations are usually lower than those from southern locations.

Propagation Protocol

Plants can be grown in well drained media in a sunny location. They are ready for outplanting in 6-8 months in 4” pots. The species is attractive to aphids. Merit® and Enstar II® have been used effectively in the RPPF.

Outplanting

Planting was done at three sites on PTA in 2003 (Table 2.2-13). Of the 175 planted less than 20% remain. Most outplants reached reproductive status but were relatively short-lived. Sparse recruitment has been noted at two sites. Three sites off PTA with different habitats and moisture regimes were planted in 2006 (Pu‘u Huluhulu, Kīpuka ‘Owe‘owe, Pu‘u Wa‘awa‘a Cone Unit). Several seedlings were noted after six months at Pu‘u Wa‘awa‘a Cone Unit.

This species occurs in partial to full sun. Outplanting sites should be kept well weeded. Stump *et al.* (1994) suggest that *T. arenarium* may perform best in an environment with low competition from co-occurring vegetation.

Table 2.2-13. Current and Proposed Outplanting Sites for *T. arenarium.*

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Kīpuka Kālawamauna East 5 (Current)	33	Rocky outcrops with scattered soil	1555m	*Dodonaea* Mixed Shrubland
Kīpuka Kālawamauna East 6 (Current)	2	Rocky outcrops with scattered soil	1665m	Myoporum Shrubland
Pu‘u Huluhulu (Current)	32	Mauna Kea cinder	2050 m	Koa/Māmane Dry Forest
Kīpuka ‘Owē‘owē (Current)	18	Hualālai ‘a‘ā	630 m	Lama (*Diospyros*) Dry Forest
Pu‘u Wa‘awa‘a Cone Unit (Current)	64	Fine sandy loam	1112 m	Remnant Koa, ‘Ōhi’a , Māmane, Kikuyu understory
West Hawai‘i Veterans Cemetery (Proposed)	-	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Kīpuka Kālawamauna North (Proposed)	-	Ash and cinder	1600m	Dodonaea Mixed Shrubland
Upper Waik‘i Gulch (Ke‘āmuku) (Proposed)	-	Sandy loam	1560m	Pennisetum *clandestinum* pastureland

Genetic Considerations

Four species of *Tetramolopium* occur at PTA. Outplanting sites for *T. arenarium* will not be established within the known geographic range of the other *Tetramolopium* species to avoid possible hybridization.

Vigna o-wahuensis

Seed Collection

The most recent population estimate at the three Ke‘āmuku locations was 75(Arnett 2002). Collection will be made from all reproductive individuals. Known locations will be visited quarterly to better understand the phenology of this species.

Seed Storage

Seed will be stored refrigerated until more data is available. The collection will be refreshed every three to five years.

Germination Protocol

The seed coat can be lightly scarified, soaked in water overnight, and sown in a mixture of perlite/vermiculite (1:1). Seeds germinate in approximately two weeks.

Propagation Protocol

Plants can be grown in well drained media in a sunny location. They are ready for outplanting in 6-8 months in 4” pots. The species was susceptible to powdery mildew in the RPPF.

Outplanting

Plantings in 2003 at Kīpuka Kālawamauna and Pu‘u Huluhulu did not persist presumably because of cold temperatures (Table 2.2-13). A trial at the lower elevation Koai‘a Tree Sanctuary also did not persist. Broadcast seeding was done in 2006 at Kīpuka ‘Owē‘owē and Pu‘u Wa‘awa‘a Cone Unit. There was some evidence of germination after a few weeks. Future monitoring will determine if seedlings were able to persist into adulthood.

Subpopulations at Pu‘u Nohona o Hae and Pu‘u Pāpapa will be augmented once fencing is complete. Cold winter temperatures at PTA may be a limiting factor for this species at the installation.

Table 2.2-14. Current and Proposed Outplanting Sites for *V. o-wahuensis*.

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Kīpuka ‘Owē‘owē (Current)	To be monitored	Hualālai ‘a‘ā	630 m	Lama (*Diospyros*) Dry Forest
Pu‘u Wa‘awa‘a Cone Unit (Current)	To be monitored	Fine sandy loam	1112 m	Remnant Koa, ‘Ōhi’a , Māmane, Kikuyu understory
West Hawai‘i Veterans Cemetery (Proposed)	-	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Pu‘u Nohona o Hae (Proposed)	-	Stony fine sandy loam	900 m	Native Shrubland
Pu‘u Pāpapa (Proposed)	-	Stony fine sandy loam	1000 m	Native Shrubland
Upper Waik‘i Gulch (Ke‘āmuku) (Proposed)	-	Sandy loam	1560m	Kikuyu (P. *clandestinum*) Pastureland

Genetic Considerations

Genetic material from the three Ke‘āmuku locations will be mixed at all outplanting sites.

Zanthoxylum hawaiiense

Seed Collection

Collection for this species will be time consuming and labor intensive. Trees are widely scattered and often solitary. The sex of less than 5% of the population is known making it necessary to visit individuals during both flowering and fruiting periods. A planned management project to determine the sex of individual trees will yield useful data to streamline the collection process. Until that information is available 5-10 locations with the highest densities in each of the following ASRs will be visited annually. ASRs to be visited include: 07, 09, 13, 14, 23, 25, 26, and 27. Previous collections have been most successful in fall.

Seed Storage

Seed will be stored refrigerated until more data is available. The collection will be refreshed every five to seven years.

Germination Protocol

Like many other *Rutaceae*, germination of *Z. hawaiiense* has been slow and erratic with low germination percentages (9%). There was some success with stratification in 2007 and more trials will be done in this area. Experiments utilizing smoke treatments and fresh vs. aged seed will also be conducted in a continued effort to understand dormancy and germination requirements.

Propagation Protocol

Plants can be grown in well drained media. Seedlings are fairly slow growing and may not be ready for outplanting for at least 12-18 months in gallon size pots.

Outplanting

Very little outplanting has been done for this species because of the difficulties with germination. Between 2002 and 2005 nineteen individuals were planted at five sites with 57% survival (Table 2.2-15). Growth has been most vigorous at Pu‘u Wa‘awa‘a Cone Unit where conditions are more mesic. Individuals at higher elevation sites have suffered frost damage. A dry mesic habitat at mid elevations (600-1200 m) may be most suitable for this species.

Because this species is dioecious, outplanting sites should be large enough to accommodate at least 50-75 individuals. Ideally the male to female ratio should be one to ensure genetic variation. It is not possible to determine the sex of individuals in the RPPF before outplanting. It may also be several years before individuals are reproductive in the field. Therefore large plantings are preferred to smaller ones to offset the possibility of a skewed sex ratio. Outplanting sites may need augmentation as sex determination is made.

The population is fairly widespread across western PTA. Augmentation may be done near solitary individuals to enhance pollen transfer and productivity. Otherwise it may be most beneficial to seek out partners with suitable habitat in other areas to enlarge the geographic range of this species.

Table 2.2-15. Current and Proposed Outplanting Sites for *Z. hawaiiense*.

Outplanting Site	Number Present	Substrate	Elevation	Community Type
Pu‘u Wa‘awa‘a Cone Unit (Current)	8	Fine sandy loam	1112 m	Remnant Koa, ‘Ōhi’a , Māmane, Kikuyu understory
West Hawai‘i Veterans Cemetery (Proposed)	-	Hualālai cinder	195m	Remnant Lama/Naio Dry Forest
Kīpuka ‘Owē‘owē (Proposed)	-	Hualālai ‘a‘ā	630 m	Lama (*Diospyros*) Dry Forest
Pu‘u Nohona o Hae (Proposed)	-	Stony fine sandy loam	900 m	Native Shrubland
Pu‘u Pāpapa (Proposed)	-	Stony fine sandy loam	1000 m	Native Shrubland
Upper Waik‘i Gulch (Ke‘āmuku) (Proposed)	-	Sandy loam	1560m	Kikuyu (*P. clandestinum*) Pastureland
Mixed Tree 2 (Proposed)	-	Pāhoehoe with scattered soil	1580m	Myoporum Shrubland

Genetic Considerations

Founders from as many ASRs as possible will be included at all outplanting sites. Effort will be made to equalize males and females.

2.3 Invasive Plant Management and Control Techniques

Figure 2.3-1. Weed Crew working in Kīpuka Kālawamauna.

Introduction

The mission of the weed control program is to reduce non-native plant cover to; (1) create areas around listed plant species free from non-native plant competition, (2) reduce fine fuels (i.e., introduced grasses) within a prescribed distance from listed plant species in fire prone habitats to prevent catastrophic loss due to wildfire, and (3) improve native dominated habitats in proximity to listed plant populations.

The WCP is responsible for minimizing threats posed by non-native species on listed species and native habitats. Like most dryland forest ecosystems in Hawai‘i, non-native plant species often dominate the landscapes of PTA. These non-native species out-compete native species for limited water, nutrient and space availability. Furthermore, non-native species create fine fuels highly susceptible to fire, of which native species vulnerable. (Shaw Citation) The WCP strives to minimize these threats by reducing non-native plant cover.

The challenge facing the WCP is to balance many factors in order to develop a strategy that efficiently controls non-native species and improves as much native habitat as possible. These factors include invasiveness of the non-native species, proximity of non-native species to listed species, surrounding vegetation density, and remoteness of a site. These factors are highly variable between sites, resulting in the necessity of site-specific management strategies. Weather, specifically precipitation, is an uncontrollable factor and will modify methods and strategies employed. The PIP will outline the WCP goal define objectives and priorities, and discuss current and future research.

Weed Control Program Goals and Objectives

Currently, the NRO manages 98 weed control buffers each ranging in size from 0.5 acre to 20 acres in size for a total of 177 acres. In 2002, the first weed control buffers were established. These buffers were established at different times, and often expanded through the years from their original size. Each weed control perimeter is therefore unique in its stage of the program goals. Along with each objective is a metric to which weed control perimeters are compared in assessing their progress and success.

WCP Goal (15 to 20 years)**:** Provide a favorable microclimate for native ecosystem restoration and conservation of listed species.

> Metric: Success is determined by the NRO monitoring yielding a consistently positive statistical indicator of population growth. Improved native species cover should correlate with listed species population growth to validate the assumption that native habitat improvement is important for listed species' conservation, thus justifying weed control efforts.

Short-Term Objective (Annually): Reduce competition from non-native species in proximity to listed species and reduce fine fuels in fire prone habitats. Maintain all actively managed sites and determine the number of annual site visits for weed control needed to effectively reduce these threats.

> Metric: Success is determined by monitoring the effectiveness of treatments and completing the number of annual site visits for effective weed control.

Intermediate Objective (3 to 5 years): Recovery of common native species in weed control buffers.

> Metric: Success is determined by a statistically significant increase in native species cover inside weed control buffers versus outside weed control buffers.

Long-term Objective (8 to 10 years): Maintain activities supporting short-term and intermediate goals. Includes annual assessment of weed control activities; to evaluate alternatives and incorporate new research and technology, adapting management objectives as needed.

> Metric: Success is determined by improved native species cover when analyzing the Weed Control Efficacy and Habitat Improvement Monitoring Protocol.

Strategic Planning

Weed control requires prioritizing the non-native species by threat posed to listed species, developing a strategy to effectively control them, prioritizing locations for treatment, and determining how much effort to expend at a particular site to achieve short-term program goals. This section will outline how these various factors are used to guide the WCP and effectively focus limited resources.

FACTOR #1: NON-NATIVE SPECIES

There are many non-native species found throughout PTA. It is impossible to eradicate all weeds; therefore a priority ranking system was developed to focus limited resources in an effective manner to achieve stated objectives (Table 2.3-1). The ranking system is based upon the following criteria:

- Invasiveness – species' ability to reproduce and colonize an area in a temporal context.
- Population extent – how widespread is the current distribution.
- Species' ability to outcompete native species for resources.
- Amount of fine fuels created.
- Ability to contain the spread of the invasive given available resources.

Table 2.3-1. Weed Priority Ranking developed by PTA NRO

Weed Priority Ranking	Characteristics	Species
1	Currently widespread Landscape altering Creates fine fuels	*Pennisetum setaceum*(fountain grass) *Senecio madagascarensis*(fireweed)
2	Potential to become Priority 1 Landscape altering when left unmanaged	*Passiflora tarminiana*(banana poka) *Kalanchoe tubiflora*(chandelier plant) *Senecio mikanoides*(German ivy) *Salsola kali*(Russian thistle)
3	Not as widespread and/or limited impacts on native species or landscape	*Lophospermum erubescens* (creeping gloxinia) *Aesclepias physocarpa* (balloon plant) *Verbascum thapsus* (mullein) *Solanum pseudocapsicum* (Jerusalem cherry) *Cercium vulgare* (bull thistle)
4	Incipient species Not yet prioritized as 1-3	*Nicotiana glauca* (tree tobacco)

FACTOR #2: CONTROL METHODS FOR NON-NATIVE SPECIES

In addition to assessing non-native species based upon threats posed to native ecosystems, non-native species are individually assessed based on physical characteristics and management needs. Differences in size and form require a variety of methods to most effectively and efficiently control targeted non-native species. This section describes the characteristics, distribution and control methods at PTA for each non-native species. Species are ranked based on perceived threat to listed species at PTA.

***Pennisetum setaceum* – Fountain Grass- Control Priority 1**

Characteristics: This highly invasive grass has altered native dryland forest ecosystems throughout Hawai‘i (Citation). Its invasion has created a fire regime alien to the Hawaiian ecosystem and its native plants (Citation). For these reasons, it is the top priority non-native species to control.

Distribution at PTA: Throughout installation, though much denser in western PTA.

Control Method: Research by PTA NRO in 2004 determined that initially spraying a solution of 2% glyphosate (RoundUp^{TM}) followed by cutting fuels reduces regeneration rates in *P. setaceum*. During periods of drought, herbicide uptake by *P. setaceum* is less effective, so initial cutting of live *P. setaceum* is the most effective way to encourage new growth before herbicide is applied. Sufficient time is necessary after cutting for complete re-growth of all culms for an application to be effective.

***Senecio madagascarensis* – Fire Weed – Control Priority 1**

Characteristics: Advantageous annual species, which has been often observed to act like a perennial species. When moisture is available, it densely carpets openings in vegetation and can become extremely dense.; Although this species is not necessarily landscape altering in terms of competition for available nutrients, *S. madagascarensis* receives the highest weed priority ranking due to creating high volumes of fine flash fuels throughout its vast range (Moller, pers. comm. 2007).

Distribution at PTA: Throughout installation.

Control Methods: Herbicide application of 2% glyphosate (Roundup ^{TM}) has proven effective. The greatest challenge to controlling with herbicide is that *S. madagascarensis* will grow up into the middle of native species so care must be taken to avoid damage to native species.

***Passiflora tarminiana* – Banana Poka – Control Priority 2**

Characteristics: *P. tarminiana,* previously mistaken as *Passiflora molissima* (Motooka *et al.* 2003), is a vine species that engulfs forest canopies, eventually killing the trees. Seeds are spread by pigs and game birds. Vines have the ability to re-root if left untreated (Motooka *et al.* 2003).

Distribution at PTA: Throughout much of Kīpuka ʻAlalā where fencing and ungulate removal have resulted in native forest regeneration. Also present in low densities in TA 22 along the western fire break road near ASR 13 and 14.

Control Methods: Cut stump and apply a 100% concentration of triclopyr (Garlon^{TM}) directly on stump. Hand-pulling or Garlon^{TM} application on seedlings and juveniles is effective. Cut and pulled vines will be removed from proximity to the ground to prevent rooting. Collecting and disposing of fruits wherever possible will minimize spreading of seeds. Efforts to map satellite populations are an on-going.

***Kalanchoe tubiflora* – Chandelier Plant – Control Priority 2**

Characteristics: *K. tubiflora* is a succulent that grows in dense patches. It has been documented during the past decade and is believed to expand its range slowly. It has the ability to persist and re-root if the plant is pulled and not thoroughly sprayed with herbicide.

Distribution at PTA: Western boundary of PTA at and around ASR 24 and expanding to the East and Southeast. New populations have been discovered in ASR 27 and in KMA.

Control Methods: Spraying a mix of 1% triclopyr (Garlon^{TM}) and 1% glyphosate (Roundup ^{TM}) has proven to be very effective. When hand-clearing around listed species, pile the cleared material several meters distance from listed species and thoroughly spray the pile with the herbicide.

***Delairea odorata*- Cape Ivy – Control Priority 2**

Characteristics: *Delairea odorata,* previously known as *Senecio mikanoides* (Alvarez 1997), is an aggressive vine that is drought-tolerant, storing water in its leaves and stems. It expands through vegetative spread of stolons, or fragments as short as one-half inch can be transported and re-root (Alvarez 1997). This species has the ability to form an impenetrable mat, completely engulfing existing vegetation.

Distribution at PTA: Kīpuka ʻAlalā, TA 22 along the western fuel break road near ASR 13 and 14, and in TAs 1-4 (Palila Critical Habitat).

Control Methods: PTA NRO has controlled this species predominately by hand-clearing and spraying with 2% glyphosate (Roundup ™). One study has found spraying 0.5% triclopyr (Garlon™) and 0.5% glyphosate (Roundup ™) mixed will yield the greatest initial reduction (Bossard and Benefield 1996). Due to the climbing nature of the species, however, manual removal often remains the most efficient method (Bossard and Benefield 1996).

***Salsola kali* – Russian thistle - Control Priority 2**

Characteristics: An annual forb that can produce up to a million seeds per plant, then break off at the taproot and spread seeds while rolling like tumbleweed. This species is highly competitive in semiarid ecosystems and are heavily favored by disturbance (USDA 2009).

Distribution at PTA: This species is found in highly disturbed areas, such as cantonment, military firing points and roadsides; and historically grazed areas in Keʻāmuku.

Control Methods: Spraying 2% glyphosate (Roundup ™) has proven effective.

***Lophospermum erubescens* – Creeping gloxinia – Control Priority 3**

Characteristics: This vine species has the ability to engulf and kill tree canopy. In Hawaiʻi, "sparingly naturalized in dry forest, alien grassland, and shrub land, 200-1,440 m in elevation" (Wagner *et al.*, 1999). Though in low numbers that do not reproduce and spread aggressively, it can have localized deleterious impacts on native forest canopies.

Distribution at PTA: Few occurrences in Kīpuka ʻAlalā and in TA 22

Control Methods: NRO has not developed any detailed management for this species to date, other than some potential hand-clearing. Due to similarities in form and location, NRO would likely manage species same as *P. tarminiana.*

***Aesclepias physocarpa* - Balloon Plant - Control Priority 3**

Characteristics: A semi-woody shrub about 2m tall with wind-born seeds. This species does not appear to be spreading rapidly at PTA. Further observation is required and will include mapping the population extent.

Distribution at PTA: Only known to occur in a patch at the end of Bravo Trail near the top of Kīpuka ʻAlalā.

Control Methods: No management techniques have been developed to date other than some hand-clearing. Research has shown adult plants to be tolerant of herbicides, except for high levels of herbicides not currently used by PTA NRO, such as metsulfuron or a crop oil carrier with ester formulation dicot killer (Motooka *et al.* 2003). If control is necessary, research must be initiated to determine if triclopyr and/or glyphosate are effective.

***Verbascum thapsus* – Mullen – Control Priority 3**

Characteristics: A biennial herb (acts as an annual at PTA due to no over wintering), first producing a low vegetative rosette followed by a long-erect seed stalk. This species produces over 100,000 seeds per plant, and is carried by wind and animals (USDA 2009).

Distribution at PTA: Throughout most of installation.

Control Methods: Spraying 2% glyphosate (Roundup ™) has proven effective in weed control perimeters.

***Solanum pseudocapsicum* - Jerusalem Cherry – Control Priority 3**

Characteristics: A woody shrub about one meter tall. It prefers moist habitats in shady forest gullies and can tolerate deep shade (SCC 2009). This species distribution heavily overlaps with the endangered *Spermolepis* distribution.

Distribution at PTA: Numerous pockets in Kīpuka ʻAlalā and to the north in Training Area 22.

Control Methods: Spraying 2% glyphosate (Roundup ™) has proven effective in weed control perimeters.

***Cercium vulgare* - Bull Thistle- Control Priority 3**

Characteristics: An annual plant. It is unknown how long the duration is of its life cycle at PTA. The species is known to be highly competitive for space, water and nutrients once it becomes established (USDA 2009). For that reason, PTA NRO will continue to monitor and record occurrences, adapting management as needed.

Distribution at PTA: Sporadic occurrences in Kīpuka ʻAlalā and Training Area 22.

Control Methods: Spraying 2% glyphosate (Roundup ™) has proven effective in weed control perimeters. During rare plant or wildlife surveys, these plants are hand-cleared.

***Nicotiana glauca* – Tobacco Tree – Control Priority 4**

Characteristics: A small tree highly invasive throughout West Hawaiʻi. Considered an incipient weed at PTA, NRO will continue to monitor and record occurrences, adapting management as needed.

Distribution at PTA: A few occurrences reported in the western portions of PTA (TA 22). Also occurs in the Keʻāmuku Parcel.

Weed Control: No management to date other than hand-clearing, which is effective for young plants. H and-clearing is effective. For mature plants which cannot be pulled, stumps are cut and herbicide applied (PIER 2009). The PIER web site listed the herbicide 2,4,5-T as effective in South Africa (PIER 2009). PTA NRO will first attempt to use triclopyr (Garlon™) and monitor its efficacy.

FACTOR #3: SITE SELECTION

A key element to site selection is prioritizing the endangered and threatened species, which are prioritized based on population numbers. . It is important to note that prioritizing listed species is used as a management tool and does not aim to place greater significance upon any one species over any other. Species with fewer individuals are given higher priority status for weed control. This is based upon the assumption that a species with several thousand individuals is less likely to go extinct before a species with less than one hundred individuals. Priority ranking as a management tool is designed to be re-evaluated annually and adapted to changing priorities; for example, listed species that may reproduce well, but are highly susceptible to ungulate browse, may flourish when ungulate threats are removed. Such species would then have their priority status for weed control lowered. The following is a complete list of prioritization of listed species developed by PTA NRO.

Priority Species 1 – Plant species with fewer than 500 individuals and/or 5 or fewer populations remaining statewide.

- *Hedyotis coriacea* (E)
- *Isodendrion hosakae* (E)
- *Melanthera venosa* (E)
- *Neraudia ovata* (E)
- *Solanum incompletum* (E)
- *Tetramolopium arenarium* ssp. a*renarium* (E)
- *Vigna o-wahuensis* (E)

Priority Species 2 – Plant species with 500 – 5,000 individuals and/or 6 – 40 populations remaining statewide.

- *Asplenium peruvianum* var. *insulare* (E)
- *Zanthoxylum hawaiiense* (E)
- *Silene lanceolata* (E)
- *Portulaca sclerocarpa* (E)

Priority Species 3 – Plant species with more than 5,000 individuals and/or more than 40 populations remaining statewide.

- *Silene* (T)
- *Spermolepis* (E)
- *Stenogyne angustifolia* (E)
- *Haplostachys haplostachya* (E)

Weed control is initiated first for the highest priority listed species, and then for lower priority listed species as available resources allow. Occasionally, species with lower priorities are selected for weed control as an outcome of the matrix. For example, weed control has been initiated for *H. haplostachya* (Priority Species 3) in some ASRs due to the fire threat, while no weed control for *Z. hawaiiense* (Priority Species 2) has been initiated because of its wide distribution. Also, PTA NRO has not developed techniques to safely remove non-native plants from steep cinder slopes where some high priority species such as *Melanthera venosa* occur.

FACTOR #4: SITE RADIUS

Vegetation density and percent weed cover are assessed to determine fine fuel content at each site. One purpose of weed control buffers is to protect listed species from the constant threat of catastrophic wildfires by creating a buffer with fewer fine fuels to lessen the intensity of the burn through the populations. In densely vegetated areas dominated by *P. setaceum* flame lengths can reach approximately 30 meters; therefore a 50 meter radius "buffer" around target plants should be sufficient for protection (Moller, pers. comm. 2007). Consequently, sites where fine fuel content is high will require a 50 meter radius buffer around individual listed plants and sites where fuel content is lower will require a 25 meter radius buffer around listed plants.

FACTOR #5: SITE ACCESSIBILITY

Many weed control buffers are located close to roads. However, some key areas such as ASR 24 are an hour or more hike from roads and require helicopter support to transport supplies. Therefore, accessibility to some sites is limited.

FACTOR #6: COPING WITH THE UNKNOWN

Plant growth at PTA is dependent upon the weather and rainfall is a key component to plant vigor and overall survival. However, rainfall is unpredictable. Periods of high rainfall usually yield high plant growth rates, resulting in a greater need for non-native species removal. In addition, precipitation events subsequently provide an opportunity to more effectively treat fountain grass with herbicide as it "greens up". Being dependent on weather, weed control efforts often come in boom and bust cycles.

Weed Control Buffers

The first step after a site is selected for weed control is to thoroughly survey the surrounding area to determine the spatial extent of the listed species. The next step is hand-clearing non-native species within a one-meter radius around listed individuals. Herbicide application via back pack sprayer and fuels removal via gas-powered weed whacker is then completed throughout the remainder of the 25 meter to 50 meter buffer. The buffer is marked in the field using flagging tape. The perimeter of the buffer is recorded with a GPS unit and spatial records are generated in the GIS to track area under control. The number of times a site is visited during the year is determined by the non-native species present in the buffer. Annual, quarterly and monthly schedules are developed (see Chapter 5). Because plant growth is so dependent on rainfall, sites scheduled for the upcoming month are checked to determine maintenance needs.

Additional Weed Control Projects

Limited control projects involving *S. kali*, *P. tarminiana* and *K. tubiflora* have been initiated because they are highly invasive (Weed Priority Rank 2) and have great potential to alter native ecosystems.

S. kali (Russian thistle) has been managed regularly for several years at PTA, and until recently 25% of Weed Crew time was spent on control efforts to prevent a widespread infestation. As of 2006, *S. kali* control areas totaled 884 acres. At PTA this weed tends to occur around cantonment, military firing points, and Saddle Road. Because it occurs near listed species only in a few locations, control of *S. kali* is not a current priority. But, to keep *S. kali* from invading additional biologically sensitive areas, a monitoring and control program will be implemented.

First, a boundary will be established and all *S. kali* occurrences south (i.e. the non-infested side) of the boundary will be controlled (Figure 2.3-2). The greatest invasion potential occurs in northern PTA in Training Areas 13, 17 and 18. The boundary will follow established roads and fence lines including Pu‘u Kapele, Kīpuka Kālawamauna North and *Haplostachys haplostachya* fence units. Surveys for *S. kali* will be conducted in conjunction with incipient weed surveys as described in the following section (Chapter 2.3). Occurrences of *S. kali* across the boundary will be treated immediately. Additionally, heavy infestations of *S. kali* occur within KMA near listed species. *S. kali* populations in proximity to the listed species will be controlled in a rotating schedule.

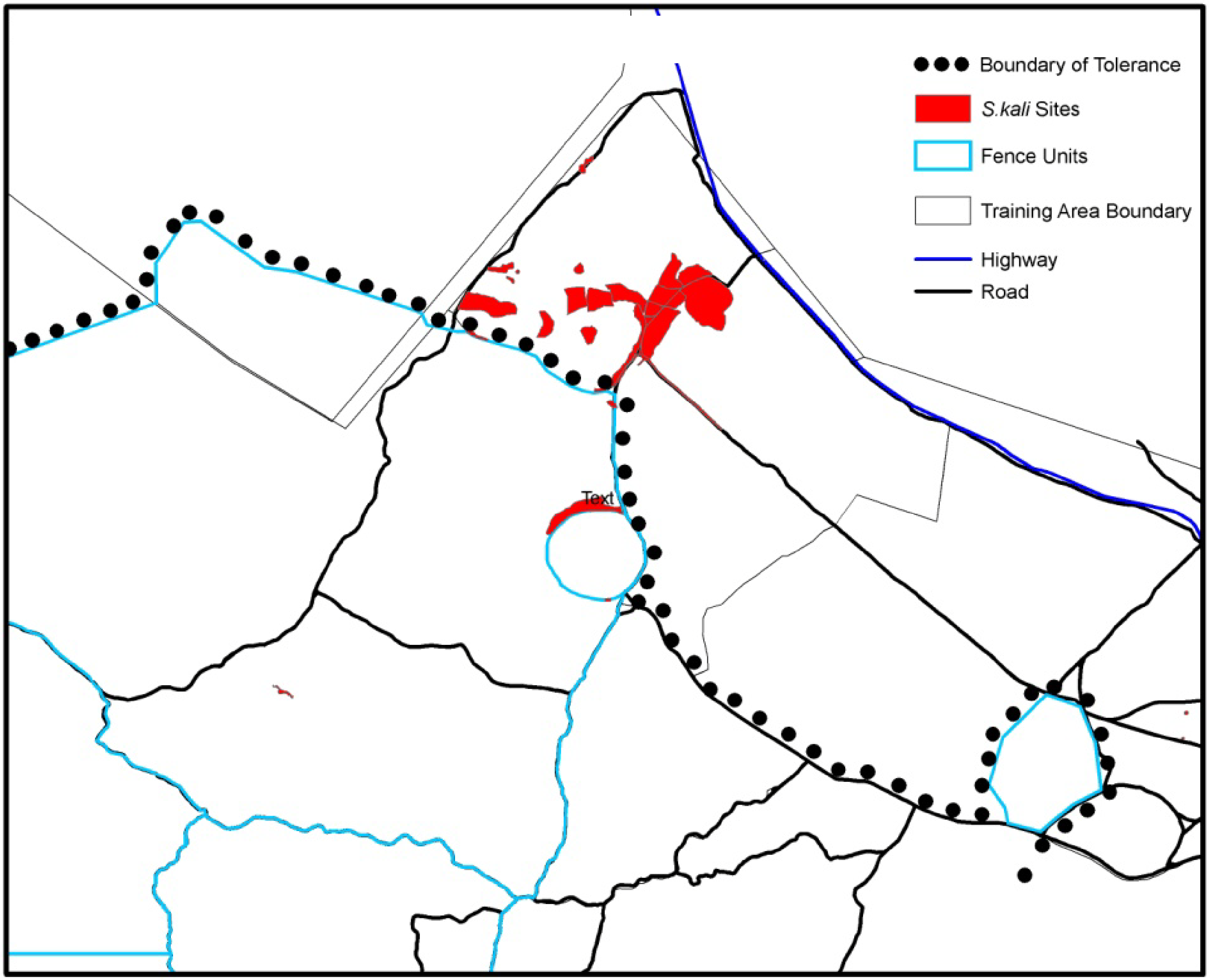


Figure 2.3-2. Boundaries for *S. kali* control in northern PTA.

P. tarminiana is managed in Kīpuka ʻAlalā because it occurs in *Spermolepis* and HHB habitat. The Army has also committee to managing the Kīpuka ʻAlalā forest as mitigation for PCH lands destroyed as a result of the Saddle Road alignment (Saddle Road EIS) *S.* typically grows in ash and soil pockets where moisture frequently accumulates (Shaw 1997). *P. tarminiana* infestations can negatively alter and reduce suitable *S.* habitat by smothering trees, which also tend to occur in the soil pockets. The loss of trees can also affect the soil moisture further impacting S. habitat. NRO have surveyed and controlled *P. tarminiana* in over 430 acres within Kīpuka ʻAlalā. Follow up maintenance is conducted monthly, as well as expanding to surrounding areas with dense infestations. PTA NRO continues to record and map the extent of the infestation.

K. tubiflora persists near some of the most endangered plant species at PTA, *N. ovata, S. incompletum*. While it is well controlled within weed control buffers, densities are high in the surrounding area. Complete eradication is unlikely due to its high population density and remote location, which is not easily accessible. In 2005, a portion of the distribution was mapped and PTA NRO will continue to monitor its spread and control outlying populations.

Weed Control Efficacy and Vegetation Monitoring

To determine success for the WCP, the Vegetation Monitoring Protocol (VMP) will be initiated. This protocol evaluates the increase or decrease of native plant densities within weed control buffers. Currently, about half of the weed control buffers are ready to be evaluated because weed management has been performed for three or more years, giving the natives time to recover. .

In 2004, PTA NRO developed a monitoring protocol attempting to assess the effects of *P. setaceum* removal. The framework for the protocol was based on protocols developed by James Jacobi of the USGS-BRD (Jacobi 2003). Data collection for the 2004 PTA NRO monitoring protocol was modified to include only data necessary for assessing the effects of weed control. Additionally, some data collection techniques were modified in order to assess short-term vegetation changes. The VMP is an update of the 2004 PTA NRO weed control monitoring protocol. The VMP strives to maintain consistency with Jacobi's previous vegetation monitoring protocols (Jacobi 2003), to achieve statistical power, and to integrate with the PTA Rare Plant Monitoring Program. The goal of the VMP is to correlate vegetation cover in specific areas with the conservation of listed species populations.

Methods

Monitoring will be done using 10 m x 25 m plots consisting of three 25 m transects spaced 5 m apart, and further subdivided into ten 5 m x 5 m subplots (Jacobi 2003). To achieve statistical power, a stratified random block design with replication will be used. Combining vegetation types of PTA (Shaw and Castillo 1997) into four strata with three replicates of two monitoring units (one unit inside weed control buffer and one outside of weed control buffer) for a total of 24 monitoring units (12 inside weed control buffers and 12 outside weed control buffers). Monitoring units within weed control buffers will consist of randomly selected, existing rare plant monitoring units. Each randomly selected monitoring unit will then be paired with a randomly selected location outside of the weed control buffer (and within the same stratus). These will be permanent, long-term VMP monitoring units.

Re-sampling will occur every year for the first three years, after which data will be analyzed to determine if there are enough monitoring units to maintain statistical power and if re-sampling can be scaled back to every two years. Re-sampling will occur during rare plant monitoring as to minimize site visits, reducing potential human impacts on rare plant populations and increasing efficiency of personnel hours used. To provide visual documentation, photo points will be established from the base stake to end stake of the center transect.

DATA COLLECTION

Species diversity: All plant species within the plot or within five meters of the perimeter will be identified and recorded using the first three letters of the genus and species. Species found only in the five meters outside the perimeter will be indicated on the data sheet.

Understory Species Cover and Ground Cover: Species cover will be sampled using the pole-intercept method at 0.5 m increments along each 25 m transect. Ground cover will be recorded at the same time (Table 2.3-2). Any plant species that touches the pole will be recorded. Each species hit will be recorded only once per layer even in the instance there is more than one hit in that layer. See Table 2.3-3 for pole-intercept height classes.

Table 2.3-2. Ground Cover Classes Used for Pole-intercept Understory Monitoring.

Category	Code	Description
Basal Cover	Sp. 3 x 3	That part of a plant where the leaves and/or stem join the roots at the soil surface. Vascular plants are recorded by species code. Bryophytes will be recorded as MOSS, LICHEN, or ALGAE.
Litter	LG, LF, LS, LT	Detached, herbaceous plant parts of any size, and woody material < 2.5 cm in at least two dimensions. The second letter code identifies the source of litter (G=grass, F=forb, S=shrub, and T=tree).
Dead PenSet	DPS	Dead *Pennisetum setaceum*, having no green growing parts. Distinct from litter.
Rock	RO	Rock and other non-biodegradable material.
Bare Ground	BG	Exposed soil.

Table 2.3-3. Stem Length Classes for Pole-intercept Understory Cover and Woody Species Counts.

Pole-intercept height code	Height Range	Pole-intercept height code	Height Range
1	> 0.0 – 0.1 m	12	> 1.1 – 1.2 m
2	> 0.1 – 0.2 m	13	> 1.2 – 1.3 m
3	> 0.2 – 0.3 m	14	> 1.3 – 1.4 m
4	> 0.3 – 0.4 m	15	> 1.4 – 1.5 m
5	> 0.4 – 0.5 m	16	> 1.5 – 1.6 m
6	> 0.5 – 0.6 m	17	> 1.6 – 1.7 m
7	> 0.6 – 0.7 m	18	> 1.7 – 1.8 m
8	> 0.7 – 0.8 m	19	> 1.8 – 1.9 m
9	> 0.8 – 0.9 m	20	> 1.9 – 2.0 m
10	> 0.9 – 1.0 m	21	> 2.0 m
11	> 1.0 – 1.1 m	??????	

Woody Species Counts: Woody plant counts will be done for all 5 m x 5 m subplots. Only individuals with a stem height of at least 5 centimeters will be counted. Individuals will be recorded by species using the same stem length classes as used during pole-intercept (Table 2.3-4). Only individuals rooted within the subplot will be counted. If a species is rooted on the dividing line between subplots the plant will be counted in the subplot in which the greater percentage of the plant is rooted. The same method will be used in determining if a plant is in the plot or not.

Table 2.3-4. Stem Length Classes for Pole-intercept Understory Cover and Woody Species Counts.

Pole-intercept height code	Height Range	Pole-intercept height code	Height Range
1	> 0.0 – 0.1 m	12	> 1.1 – 1.2 m
2	> 0.1 – 0.2 m	13	> 1.2 – 1.3 m
3	> 0.2 – 0.3 m	14	> 1.3 – 1.4 m
4	> 0.3 – 0.4 m	15	> 1.4 – 1.5 m
5	> 0.4 – 0.5 m	16	> 1.5 – 1.6 m
6	> 0.5 – 0.6 m	17	> 1.6 – 1.7 m
7	> 0.6 – 0.7 m	18	> 1.7 – 1.8 m
8	> 0.7 – 0.8 m	19	> 1.8 – 1.9 m
9	> 0.8 – 0.9 m	20	> 1.9 – 2.0 m
10	> 0.9 – 1.0 m	21	> 2.0 m
11	> 1.0 – 1.1 m	??????	

LONG-TERM GOALS

The most simplistic assumption is that by maintaining the weed control buffers, the habitat quality will improve due to higher native species densities, thus benefiting conservation of listed species. Based upon past field observations, it is anticipated that results from VMP will show increased native species densities and success in habitat improvement. The hope is that the improved native habitat will correlate with listed species monitoring data yielding consistently positive growth trends. Furthermore, as habitat quality improves, less time will be needed to complete site maintenance during scheduled visits, allowing expansion of current weed control buffers and/or installing new weed control buffers.

The key factor to attaining long-term success is adaptive management. Natural resource management at PTA is a little over a decade old, not much time compared to the life history of listed species at PTA. There is much unknown about the species and habitats NRO are managing. Field observations reveal new trends within plant communities that were previously unknown, and research often reveals new knowledge of targeted species and habitats. Adaptive management considers all of these aspects and compares that information to current management objectives. This re-evaluation process results in changes in management when new management objectives are deemed more effective and/or efficient than current objectives. New management objectives are then administered on a trial basis to ensure there is observable increase in effectiveness and/or efficiency. A key aspect to adaptive management is making further adjustments to management objectives at this stage if need be. Past research projects have changed management objectives. Present and future research projects may have future management implications as well. This process of adaptive management is continuous as need or opportunity arises. The following field observations and research projects may contribute to improving future management.

Current and Future Research to Guide Management

When contemplating weed control, questions involving eradication and fuels removal arise and the answers remain uncertain. Current and proposed research relating to weed control at PTA includes:

USFS-Pacific Research Station received a SERDP grant to research fuel control methods and native forest restoration. The research will utilize remote sensing technologies and practical field management to provide necessary information for fine fuels reduction and restoration planning and monitoring. Using historical through current remote sensing data and field validation of this data, fuel loads across all plant communities and threats will be assessed and methods to reduce fuel loads will be tested to create a working, practical plan. This plan will forecast fire hazards through mapping and various modeling techniques; and inform appropriate fuels management actions, including restoration prescriptions. The research also aims to compare various ecosystem types with the removal of various threats. The possibility remains that weed control may be more necessary in some ecosystem types than in others.

The remote sensing information itself will undoubtedly improve our knowledge and abilities to properly manage fuels. Possible further implications of this research may determine how fuel breaks are constructed and managed. Additionally, the research may determine other methods of weed control within the fuel breaks that may prove beneficial to habitat quality and protection. This includes research on fire behavior within a given plant community and assessing the effectiveness of current weed control buffers.

A University of Hawai‘i-Manoa College of Tropical Agriculture research study is designed to assess alternative means for *P. setaceum* control. The initial project aims to determine which herbicide and adjuvant combinations work most effectively and selectively to kill *P. setaceum*. The main comparison is using the glyphosate herbicide, Roundup ™, versus an Imazapyr herbicide, Habitat™. These herbicides are then tested with a non-ionic surfactant versus modified vegetable oil, and whether or not an inverted emulsion should be added. Three trials were set up, two on *P. setaceum* and one on native grasses and shrubs to test for effectiveness and selectivity. An additional component of the study was to test water samples to see if minerals in the water are affecting the herbicide's ability to bond to the plant. Subsequently, results of water tests showed that mineral levels in the water would not affect the herbicide effectiveness. Additional components to this study include a variety of techniques and strategies for *P. setaceum* control. These include using a fertilizer, molasses or a low concentration of glyphosate herbicide to increase palatability of *P. setaceum* and attract ungulate browse as a way of reducing biomass and standing fuels. Another technique will test the use of irrigation to induce new growth and those effects on subsequent herbicide applications. Once the results of this research are determined, adjustments to management may be implemented.

There are many research topics to be investigated at PTA including how *P. setaceum* has a profound impact on soil moisture available for native species (Cordell and Sandquist 2008). This research provided concrete evidence that removing *P. setaceum* will leave more moisture available to native species, likely resulting in higher growth rates. Other non-native species like *S. madagascarensis* have unknown impacts on soil moisture availability. Its infestation throughout PTA and West Hawaiʻi is relatively recent, becoming an increasing pest over the past six years. Research on potential impacts would provide justification on whether or not the middle zone of tolerance should be free of *S. madagascarensis*. There are several invasive weeds where little information on impacts is known and research would benefit decision making processes.

2.3.1 Incipient Weed Monitoring

Figure 2.3-3. Herbicide application for non-native plants.

Introduction

The development of the Incipient Weed Program is an important step in fulfilling related directives as outlined in the 2003 BO, which calls for the surveying and eradication of newly identified invasive plants (USFWS 2003). Newly identified invasive plants, or unknown, uncertain, or unusual growth forms of known weed species will be considered incipient and referred to as an incipient species throughout this document. Locations expected to have high incidents of invasion by weedy species include any type of disturbed area such as those adjacent to landing zones, trails, roadsides, and newly burned areas. Activities increasing opportunities of non-native plant introductions include the "construction of buildings and roads; mounted and dismounted training maneuvers; movement of equipment, vehicles, and troops; routine maintenance activities on the installation; environmental activities such as outplanting, propagule collection, and monitoring; and access for public uses such as hunting" (USFWS 2003). Surveying efforts should be focused in high-use disturbed areas as incipient weeds may be more likely to colonize these sites. Areas with high densities of protected native species are also at risk of invasion in which the impacts will have a greater detriment to natural resources and will be surveyed for incipient species during regular monitoring activities (Harris *et al.* 2001). The goals of the PTA Incipient Weed program are to

- Prevent the introduction and spread of incipient invasive plants in PTA and KMA.
- Decrease the area and density of recently established weed species in order to minimize the impact to natural and cultural resources
- Employ effective weed control methods upon invasive plant detection
- Educate staff, training units, and recreational users of PTA

The Incipient Weed Program aims to detect and eradicate new introductions of invasive plants before they establish by implementing roadside and high-use area surveys, written and electronic documentation regarding incipient plant locations, and chemical or manual eradication methods.

Methods

INCIPIENT WEED VIGILANCE

PTA NRO will be briefed on the goals and methods of the Incipient Weed Program, and the need for increased daily vigilance of incipient weeds during regular field activities. Staff will be instructed to collect incipient species as encountered in order to correctly identify the plant, take a GPS point of the population location noting UTM coordinates if possible, and note the occurrence on an Incipient Plant Inventory form (Figure 2.3-4), which will be entered into the management actions log and stored in a designated binder. A Most WANTED poster and/or brochure with pictures will be developed to educate employees of and visitors to Pōhakuloa, including hunters and training units. Management priorities for the Incipient Weed program are to:

- Prevent the establishment of potentially invasive plants;
- Eradicate newly introduced high-risk species;
- Survey roadsides, public access areas, and other high use areas for recent plant introductions;
- Contain the spread of highly invasive plants that are currently not widespread but are located in or adjacent to ASRs.

Incipient Plant Inventory Form | **Date:**

Staff:	**Hours:**	**Species name:**	**Location**	**Elevation** (m)
			ASR:	
			UTM Coords:	

Phenology (Y/N)		**Number of plants present** (Exact # if <50)			**Area covered** (m²)	**Other Location Description**	**Substrate**	
Vegetative		Immature		100-500			ʻaʻa	gravel
Buds			500-1000	> 1000			pāhoehoe	cinder
Fruit		Adult		100-500			soil	pavement
Flowers			500-1000	> 1000			other:	

Associated Species	**Notes:**

Photos:			**Further actions needed:**
Camera #		# of Photos taken:	
Description of photo:			
Habit	Leaf	File Name:	
Fruit	Flower		
Other:		* Collect unknown plants or unusual growth/color of known plants. Collect any flowers or fruits, roots of grass species. Place in ziplock bag if available. For large plants, cut a sample or take photos of habit.	**Date entered into database:**
			Initials:

Figure 2.3-4. Incipient Plant Inventory Form

CREATING A TARGET SPECIES LIST

Drawing on previous research and early detection efforts that have taken place on Maui and Oahu, the PTA Incipient Weed Program will implement a target based early detection method due to the large area of the training area, and numerous access points. The target based approach to early detection involves

- developing a list of potentially invasive plants that are known to occur on the island of Hawaiʻi using lists from weed tracking agencies like the Hawaiʻi Ecosystems At Risk website, the Invasive Species Committee target species list, or State and Federal noxious weed list;
- carrying out an initial assessment to filter the list down to a manageable target plant list. The initial assessment involves organizing the potential target species in relation to distribution (widespread versus localized or unknown) on the island, and documented invasiveness. Derive a list of possible target species from those plants that are not widespread and known to be weedy species. This list should be weed risk assessed using the UH Botany web page at <http://www.botany.Hawaiʻi.edu/faculty/daehler/WRA> and high scoring species should be added to the target list.

There are over 140 naturalized non-native plant species documented as occurring on PTA and have been compiled into a database list. This list was compiled using herbarium vouchers dating back to 1989, and will be utilized as a *Weed Species Checklist* identification tool during surveys. Of the documented naturalized species, sixteen have been designated as incipient weed targets throughout PTA or in specific high risk ASR (Table 2.3-5). Weed risk assessments, photographs, and control methods regarding these species were compiled in an Incipient Weed Program binder for staff reference and use in training. Herbarium vouchers will be made of incipient plant species to aide in identification. Locations of incipient plant populations will be mapped using GPS locations and ArcGIS to facilitate eradication and monitoring efforts. In addition to species that are already present at PTA, a list of over 100 potentially invasive species was compiled using the State HDOA list of noxious weeds (2003), the Weed Risk Assessment List (Daehler and Denslow 2007), and the BIISC (2008) target species lists. A "Top Five Most Wanted" list was created using methods stated above and based on the species most likely to be introduced to PTA and would have the most significant impacts on natural resources if they were to become established (Table 2.3-6). These lists are stored as the Incipient Table in the Herbarium database. Included in this database are notes from *A Tropical Garden Flora* and the *Manual of Flowering Plants of Hawai'i* (Staples 2005; Wagner *et al.* 1999). This table is a working document and will be added to and refined as new weeds are identified or as pertinent information becomes available.

Table 2.3-5 .Incipient Invasive Species at PTA

	Scientific name	Common name	H-WRA	Location/s
1.	*Passiflora tarminiana*	Banana poka	24	
2.	*Acacia mearnsii*	Black Wattle	15	
3.	*Salsola kali*	Russian thistle	19	
4.	*Delairea odorata*	Cape ivy	14	
5.	*Bryophyllum tubiflorum*	Chandelier plant	13	
6.	*Lophospermum erubscens*	Larger roving sailor	5	
7.	*Prosopis juliflora/pallida*	Kiawe	19	
8.	*Centaurea melitensis*	Malta star thistle	18	
9.	*Ricinus communis*	Castor bean	21	
10.	*Lantana camara*	Lantana	21	
11.	*Foeniculum vulgare*	Fennel	19	
12.	*Cirsium vulgare*	Bull thistle	17.5	
13.	*Nicotiana glauca*	Tree tobacco		
14.	*Grevillea robusta*	Silky oak	5	
15.	*Eschscholzia californica*	California golden poppy	7	
16.	*Frangula californica*	California coffee berry	5	

Table 2.3-6. Most WANTED Invasive Species

	Scientific name	Common name	H-WRA	Location/s
1.	*Ulex europaeus*	Gorse	20	Hakalau
2.	*Cortaderia selloana*	Pampas grass	24	N. Kona, S. Kohala
3.	*Schinus molle*	California pepper tree	10	Pu'u?
4.	*Coccinia grandis*	Ivy gourd	21	?
5.	Ambrosia *psilotachya*	Ragweed	15	Unknown

Survey Methods

DISTURBED/HIGH-USE AREAS, FUEL BREAK, AND ROADSIDE SURVEYS

A list of disturbed or high-use areas at PTA was compiled to rank priority regions for roadside surveys. These regions include those areas prioritized by the USFWS 2003 BO such as the BAAF, construction areas, landing zones, newly burned areas, maneuver training areas, and firing ranges (Table 2.3-7). Prioritization of survey areas was determined by frequency of use, quantity of public access points, and potential for new plant introduction (Figure 2.3-5). The 2003 BO requires quarterly BAAF surveys; therefore BAAF and surrounding areas were designated as Priority 1 due to the need to for frequent surveys. Major access points into PTA used by public and private entities, and the quarry which are typical introductions sites for new invasive species introductions are also classified as Priority 1. The Priority 2 area was given this designation because of the abundance of access points off the Saddle Road, new construction taking place due to the Saddle Road expansion, and the abundance of active training areas. New fuel break and access road expansions occur in Priority 3 areas, as well as a large portion of the high priority rare plant species which would be heavily impacted by new species introductions. This area has a lower ranking due to the difficulty of access to and limited use by the public. Priority 4 is comprised entirely of the Keʻāmuku Maneuver Area, and contains a variety of weedy species not found in any other area of PTA. This region is utilized by various private and public parties, contains numerous out-planting sites of non-native ornamental species, and is flanked by two major highways. It is a potential entrance point for new introductions, but due to infrequent use it is not a high priority area. Roadside surveys will follow methodology used in similar weed survey programs from neighbor islands (Starr *et al.* 2006; Geissler 2006; Chumley and Klausner 2005). High use roads, public access points, and fuel breaks will be surveyed by two to three people driving 8-16 km, scanning both sides of the road. If a possible incipient plant species is encountered, an incipient plant inventory form will be filled out with the estimated number of plants, density, and other relevant data (Figure 2.3-4). A voucher specimen will be collected to ensure proper plant identification and GPS point recorded. For incipient populations extending beyond 10 m x 10 m, GPS track-logs will be used to record the extent of the population. Using this method it will take an estimated two to three days to survey Priority 1 areas, three to four days for Priority 2 areas, a little over a week for roadsides in the Priority 3 region and less than a week for fuel breaks. The roadside calculation cannot be defined for the KMA due to lack of adequate information regarding road lengths, and its potential for prioritization revision upon training of the Stryker Brigade.

Table 2.3-7. List Priority Survey Areas for Incipient Weeds

Airfield	
	Bradshaw Airfield
Historical Burn Sites	
	Ke‘āmuku Parcel
	TA 21 Range 8
Construction Areas	
	Cantonment
	Saddle Road realignment
Fuel Breaks	
	Western Fuel Break
	FB 301 through 310
Firing Points	
801 through 810	
Maneuver Training Areas	
	Training Areas 1 through 4
Quarry	
Roadside	
	Access Road
	Ahi Road
	Armor Road
	Charlie Circle
	Horizontal Trail
	Infantry Road
	Ka‘ena Road
	Kaua Road
	Kapele Road
	Ke‘eke‘e Road
	Kīpuka Road
	Kulua Road
	Lava Road
	Leilani Road
	Lightening Trail
	Makai road
	Malahini Road
	McKenzie Road
	Menehune Road
	Mikilua Road
	New Bobcat Trail
	Old Bobcat Trail
	Old Kona Highway
	Redleg Trail

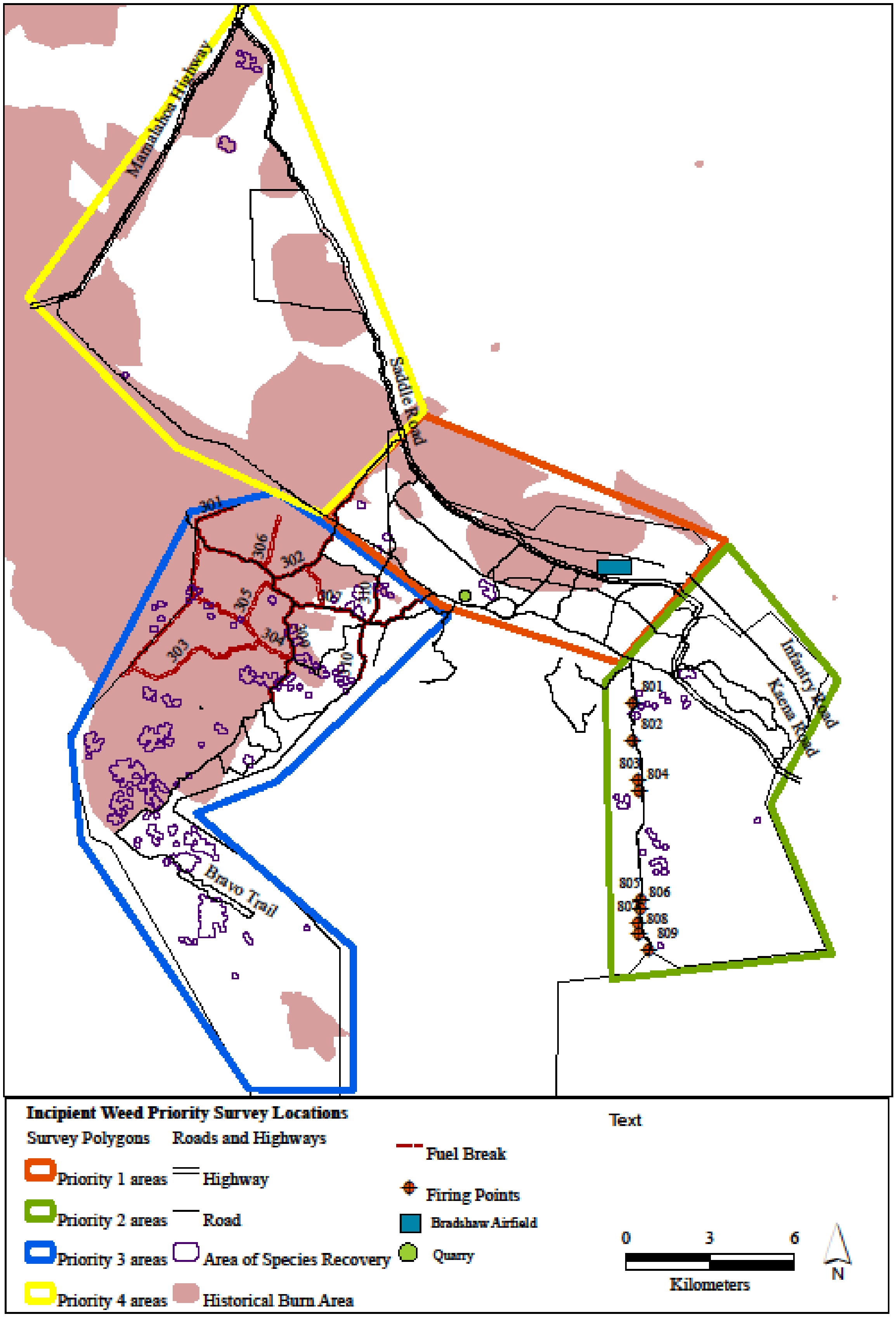
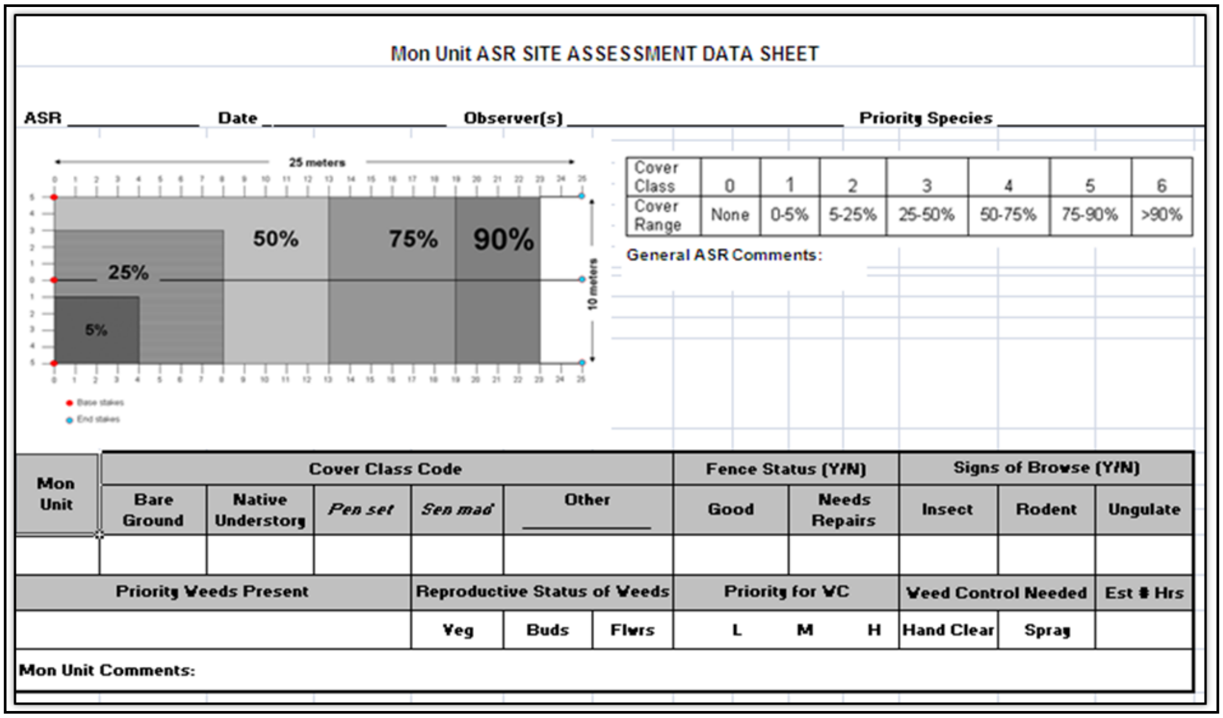


Figure 2.3-5. Incipient Weed Prioritized Control Areas

Areas currently being controlled for invasive plant species are considered disturbed sites that may be suitable habitat for invasion and should also be surveyed for incipient weeds (Cordell, pers. comm. 2007). Weed control areas and outplanting sites will be surveyed for incipient species using the ASR Threat Assessment Data Sheet during regular monitoring activities and recorded on the Weed Inventory Form (Figures 2.3-2 and 2.3-4). The ASR Threat Assessment Data Sheet has to be incorporated into the monitoring data collection to increase efficiency and vigilance.


Mon Unit ASR SITE ASSESSMENT DATA SHEET

ASR ____________ Date ______________ Observer(s) ________________________ Priority Species ____________

Cover Class	0	1	2	3	4	5	6
Cover Range	None	0-5%	5-25%	25-50%	50-75%	75-90%	>90%

General ASR Comments:

Mon Unit	Cover Class Code					Fence Status (Y/N)		Signs of Browse (Y/N)		
	Bare Ground	Native Understory	*Pen set*	*Sen mad*	Other ________	Good	Needs Repairs	Insect	Rodent	Ungulate

Priority Weeds Present	Reproductive Status of Weeds			Priority for WC	Weed Control Needed		Est # Hrs
	Veg	Buds	Flwrs	L M H	Hand Clear	Spray	

Mon Unit Comments:

Figure 2.3-6

SURVEY SCHEDULE

Roadsides, fuel break, disturbed, and high-use area surveys will begin in 2009 with survey areas rotating through four priority groupings based on requirements listed in the 2003 BO, which states that the perimeter of BAAF will be inspected quarterly for alien species and remove invasive plant or animal species identified within the airfield environs (USFWS 2003). Selected roads, fuel breaks, and disturbed or high-use areas, as mandated to monitor in the BO, are listed for each group (Table 2.3-7). Priority Area 1 will be surveyed quarterly for incipient species. This area consists of approximately 27km of roads, and will take two to three days to survey driving 8 to 16km an hour. These surveys will take place during the months of February/March, May/June, and October/November. The remaining priority survey areas will be monitored annually using a quarterly rotational schedule weighted to higher priority areas. Priority 2 areas may be monitored more frequently depending on training activities. It will take more than three weeks to conduct roadside surveys in the remaining priority areas.

Prioritizing for Control

The prioritization system used is taken directly from the Oahu Early Detection system (Imada *et al.* 2007). This prioritization system is described as "weed-led," meaning it allocates a score for potential target species to determine its threat to the ecosystem and its controllability. Using the score given by the WRA (0-29) each species is placed in a "weediness" category:

A= 26 and up (Highest scoring weeds)
B= 17-25
C= 7-16
D= 6 and below (lowest priority weedy species)

Upon this categorization, species will be assessed for the ability to control the spread of their populations and assigned a controllability score (Table 2.3-8). Control methods will be assessed by conducting research on current effectiveness of control methods being used for these species in Hawai'i.

Table 2.3-8. Incipient Weed Control Method Scores

Score	Description of Control
10	Control will be cheap and take less than a day with little or no need for follow up monitoring
9	Control is cheap, but may take up to a week and still with little or no monitoring needed
8	Control will take over a week, but little monitoring needed upon control
7	Control will take over a week, with intermediate follow up monitoring
6	Control will take over a week, with rigorous follow up monitoring
5	Species appear to widespread, based on surveys

These control scores will be combined with the "weediness score" to establish the priority control ranking score (Table 2.3-9).

Table 2.3-9. Incipient Weed Priority Control Rankings

Control Action Description	Score
Eradicate population immediately	A10
High priority population for control, assess for removal	A7-9, B 8-10, C7-8 D 9-10
Potential candidate for control, continue surveys for larger distribution	A6, B 6-7, C7-8, D9-10
Continue surveys to map population distribution	A 5, B5, C6, D6-8
Population beyond the goals of program	C5, D5

Removal techniques are dependent upon the species and population size. Removal techniques will be researched as incipient species are encountered by consulting invasive plant species experts and reviewing previously developed eradication methods. In cases where invasive species have spread beyond the ability to eradicate, a containment approach will be used to prevent the population from spreading to high priority ASRs. This will involve control outlying individuals, or recent encroachment of the species into new ASRs.

Discussion

The development of the Incipient Weed Program is an important step in fulfilling related directives as outlined in the 2003 BO. It is more efficient to concentrate efforts in detecting invasions before they have a chance to establish. The Incipient Weed Program at PTA is a cost-effective approach that will prevent the establishment of new invasive species and prevent the spread of locally established weed populations. The methods and references should be updated and adapted appropriately as the program progresses.

2.4 Fire Break System

Figure 2.4-1. FB at Pu‘u Pāpapa in KMA

Introduction

The IWFMP was drafted in 2003 to help reduce the threat and impact of wildfire at PTA. The plan includes provisions for the upgrade and/or creation of a fire break system (FBS) of 57.3 kilometers (35.6 miles) on western PTA (Figure 2.4-2) and encircling the two pu‘u in the KMA (Figures 2.4-2, 2.4-3). The FBS employs the 10-20-30 standard. This consists of 10 feet of vegetation control, a 20-foot wide, 4wd fire access road, and 30 feet of vegetation control. The FBS is a fire fighting asset and is not intended to stop an advancing fire. It is to be used to back-burn from to increase the size of the break during a fire. Fine flash fuels are controlled within the 10 and 30 foot sections.

At the end of 2008, road construction and upgrades within the FB network were mostly complete. However, some sections of road on the Western Boundary FB, the ‘Elua FB and the Kālawamauna West FB require maintenance or final dressing. Also, the Kālawamauna Spur FB road bed lacks final dressing.

Methods

In February 2008, vegetation control and fuels reduction within the FBS was initiated. Vegetation control consisted of the application of both pre and post emergent herbicides (Landmark XP and glyphosate). Field plots were established to determine the foliar sensitivity of common native shrubs to Landmark XP, a pre emergent herbicide. While ‘āweoweo (*Chenopodium oahuense*) showed dieback at all concentrations tested, no other species was visibly affected at any concentration. Further, fountain grass (*Pennisetum setaceum*) and other prominent weed species regeneration remained absent in the treated areas. Through trial and error the determination was made that herbicide application was more effective in the FBS if it was preceded by fuels reduction and a short period (1-3 weeks) where fountain grass and other weeds were allowed to regenerate. This pattern of fuels reduction, brief growth and herbicide application reduced the volume of herbicide sprayed, personnel contamination and time spent per acre. Fine fuels reduction was achieved with the use of gas powered line trimmers. A section of FBS was considered complete, needing only intermittent maintenance, when it had been cut and sprayed as well as complying with the 10-20-30 standard.

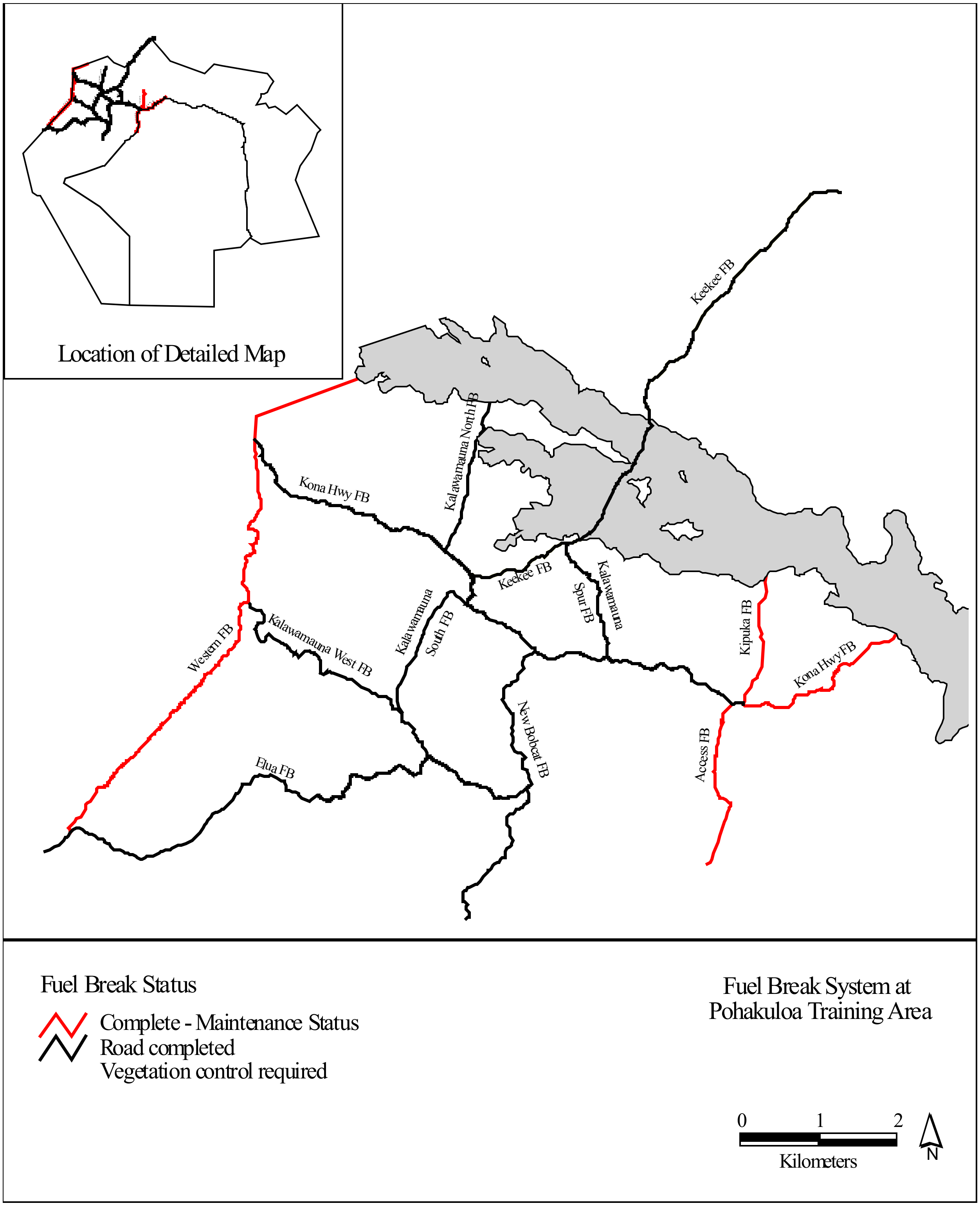


Figure 2.4-2. Status of Fuel Break System in Western PTA.

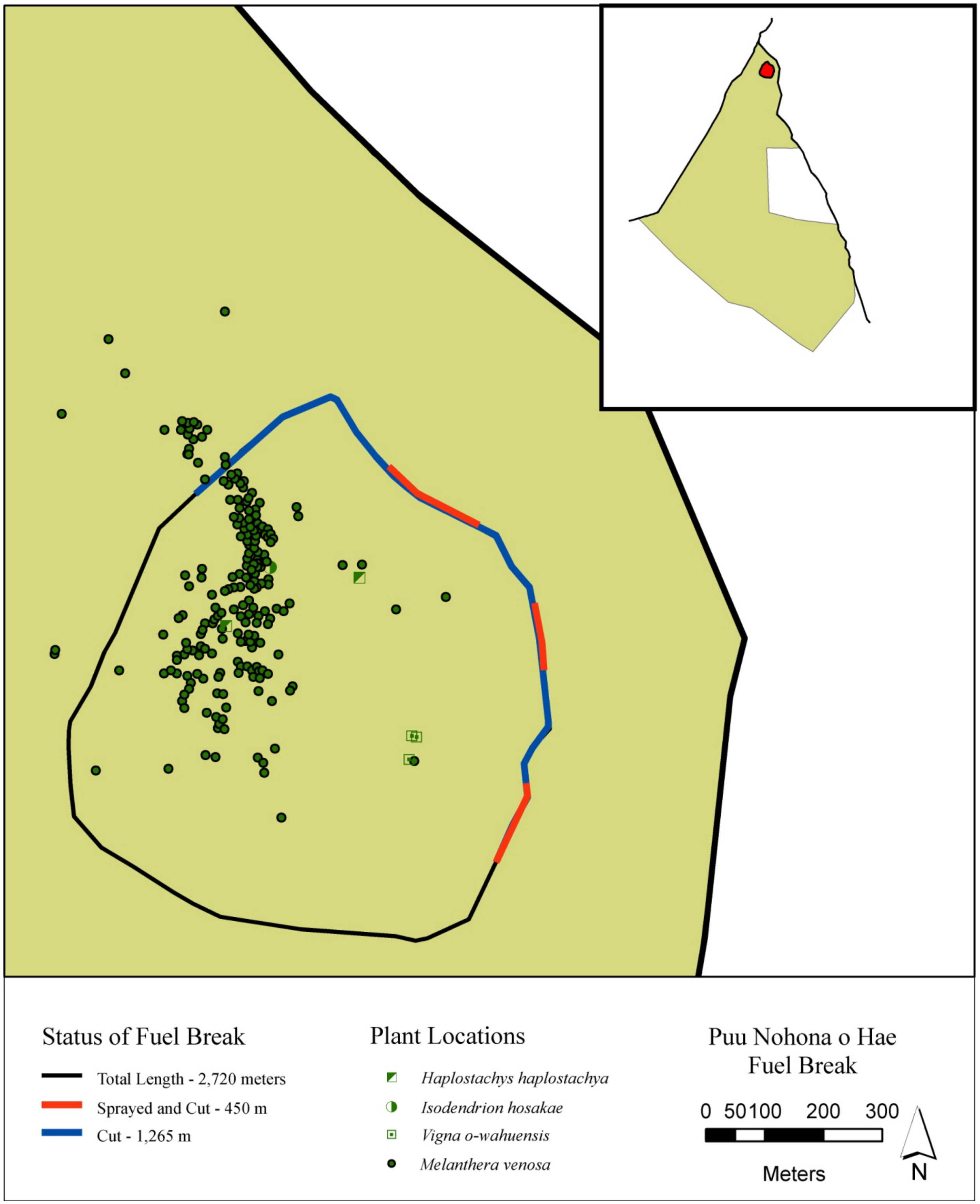


Figure 2.4-3. Status of Pu'u Nohona o Hae Fuel Break in KMA.

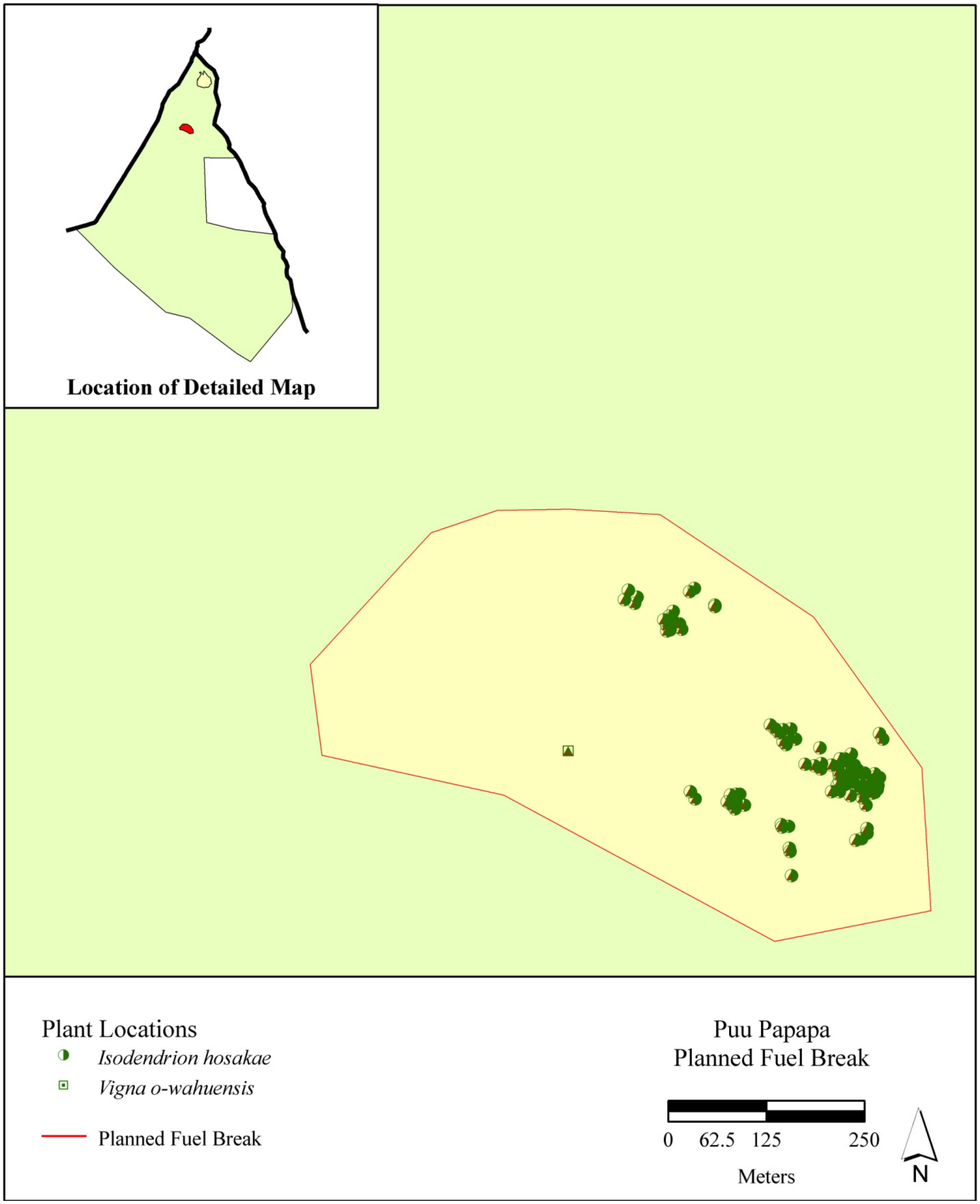


Figure 2.4-4. Planned Pu'u Pāpapa Fuel Break in KMA.

Discussion

Progress on the Fuel Break System is summarized in Table 2.4-1.

Table 2.4-1. Progress on the Fuel Break System for PTA and KMA.

Fuel Break	Length	Fuels Reduction*	Spray Application*	Status
Western FB	9,160	Completed	Completed	Complete/Maintenance Status
Access / Kīpuka FB	4,064	Completed	Completed	Completed/Maintenance Status
Kona Hwy FB	11,048	2,850 (26%)	2,850 (26%)	Vegetation Control/Fuels Reduction
Pu'u Nohona o Hae	2.720	1,265 (47%)	450 (17%)	Vegetation Control/Fuels Reduction
Pu'u Pāpapa	2,080	0	0	Vegetation Control/Fuels Reduction
Ke‘eke‘e FB	7,595	0	0	Vegetation Control/Fuels Reduction
‘Elua FB	6,350	0	0	Vegetation Control/Fuels Reduction
Kālawamauna West FB	5,443	0	0	Vegetation Control/Fuels Reduction
Kālawamauna South FB	2,015	0	0	Vegetation Control/Fuels Reduction
Kālawamauna North FB	2,007	0	0	Vegetation Control/Fuels Reduction
Kālawamauna Spur FB	1,768	0	0	Final Dressing, Pending
New Bobcat FB	4,398	0	0	Vegetation Control/Fuels Reduction
Flow Fuel Corridor	4,513	0	0	Aerial Herbicide, Pending
Total:	58,361	14,336, (24.6%)	14,945, (25.6%)	

* Lengths are reported in meters and parenthetical is percentage completed.

Efforts have focused on the three highest priority FBs: the Western Boundary FB, the east end of the Old Kona Highway FB, as well as the Kīpuka and Access Road FBs (Figure 2.4-2). These FBs can be thought of as primary or exterior FBs, as they are between the two most common areas of wildfire ignition and many of the endangered plant ASRs.

The overall average rate of fuels reduction for 2008 was 6.7 meters/ hour, with an overall average rate of herbicide application of 27.3 meters/hour. Progress from the Access / Kīpuka FB (FB 310) is not included in this calculation because primary fuels reduction occurred on the East side of the roads in 2006-2007 and fuels were already greatly reduced and in some places absent.

The rate of progress and the final date of compliance will depend on future staffing for the FB program. Current priorities, methods and planning should be reevaluated to maximize efficiency and production if and when additional personnel are hired. FB expansion in the KMA and the new alignment of Saddle Road will influence future management priorities and allocation of human and material resources. Reevaluation of FBS priorities is recommended, when KMA expansion is implemented and new sections of Saddle Road are completed.

Bringing the roads around the bases of Pu‘u Pāpapa and Pu‘u Nohona o Hae to the 10-20-30 standard commenced in 2009. Because of the high potential for fire at Pu‘u Nohona o Hae and the vulnerability of the endangered plant populations found on the pu‘u, it is recommended that the fuel break be brought up to 10-20-30 standard as soon as possible.

Deterioration of fire access roads, especially in the more remote sections of the FB network, will continue until protocol to improve these areas is more formally established. The development of a maintenance schedule is recommended.

3.0 ENDANGERED BIRDS/MAMMALS, RODENTS, AND INVASIVE ARTHROPOD PROTOCOLS

Figure 3.0-1. Nēnē at Range 01.

Introduction

As part of the BO (USFWS 2003; USFWS 2008), the Army was required to assess the status of three endangered bird species: ʻIo, Nēnē and ʻuaʻu. From past incidental sightings, it is known that ʻIo occasionally use PTA (CEMML 2006), though it is unclear how dependent the species is on habitats at PTA or the level of their use. Nēnē have also been incidentally observed on PTA for many years without an understanding of their patterns of use (CEMML 2006). Beginning in the 2007 flocking season, Nēnē observations have been more consistent during both flocking and breeding seasons, prompting new monitoring and management protocols. ʻUaʻu is an elusive seabird and surveys in the past have yielded very few observations (CEMML 2006). It is not certain that ʻUaʻu currently use PTA.

The PIP endangered bird surveys are designed to provide a basic understanding of which species are present, and if present, which habitats they occupy. This information is used to determine and guide management strategies for enhancing the populations and their associated habitats. Because each species requires different monitoring techniques, a detailed description of the PIP protocols are described in the following species-specific sections.

3.1 ‘Io Survey Protocol

Figure 3.1-1. Hawaiian Hawk

Species Status at PTA

The Hawaiian Hawk or ‘Io (*Buteo solitarius*) is not common at PTA. From historical sightings, Banko (1980) concluded that ‘Io are not common on the arid plains between Mauna Kea and Mauna Loa and on the Western Flank of Mauna Kea. In 1998, USFWS contracted an island-wide ‘Io survey including the road network at PTA (Klavitter 2000). No ‘Io were detected at PTA, however an ‘Io density map was created, including PTA, by extrapolating observations of ‘Io in various habitat types across the Big Island. According to these extrapolations, portions of western PTA, KMA, and Kīpuka ‘Alalā (southwest) were classified as having the potential to support sparse to dense ‘Io populations.

There have been few incidental sightings at PTA in the past 10 years. ‘Io were seen on PTA in 1998, 2003, 2006 (CEMML 2007), 2008 and 2009 (unreported data). All individuals were transient and did not remain in the area for more than a few days. Birds were observed perching in trees and soaring on thermals. Because of incidental observations, the presence of potential habitat, and BO requirements, ‘Io surveys were initiated in 2004. ‘Io require large trees for nesting and perching, so areas within PTA with large stature trees were selected for surveys. PTA was divided into three main study areas (Figure 3.1-2): Training Area (TA) 22, TA 23 (Kīpuka ‘Alalā) and TA 1-4 (PCH).

Methods

Survey transects with evenly spaced survey points were created using ArcGIS. Transects run through forested habitat and survey stations are spaced a minimum of 800 m apart to prevent overlapping ‘Io territories and recounting birds (Klavitter, 2000). Data collected at each survey station includes wind speed, cloud cover and rain. Each station is surveyed for a total of 10 minutes, using broadcast ‘Io calls and one observer. During the 10 minute sample period, the ‘Io calls are broadcast for two, 1-minute periods during the first and eighth minutes (Klavitter 2000).

Observers watch the surrounding sky and trees for ‘Io activity. If a bird is sighted, the observer records the survey location, UTM coordinates, time, approximate distance of the bird, weather conditions, and the type of activity (e.g., soaring, perched etc.). Each station in each study area is sampled by one observer, quarterly for one year.

Results/Discussion

No ‘Io were seen in the three study areas during the quarterly surveys conducted from 2004 to 2006. Because the ‘Io surveys required a significant allocation of personnel hours, it was decided to stager surveys in the three study areas. In Kīpuka ‘Alalā, ‘Io surveys were conducted from 2004 to 2005. Surveys in Training Area 22 and Palila Critical Habitat were conducted from 2005 to 2006.

Because no ‘Io were observed during the surveys, techniques developed by Reed (1996) and Mackenzie *et al.* (2006) were used to determine, with a given level of confidence, that our lack of ‘Io observations reflected the true absence of ‘Io and were not due to “false absences” (see Detection Probability for Endangered Birds at PTA).

In summary, based on Reed’s formula (1996), Klavitter’s test-surveys (2000), and the lack of any ‘Io observed during the course of the three years of surveys we are able to state with 95% confidence that there were no ‘Io present in the PTA study area at the time of survey, after visiting each of the survey points four times.

Detecting no ‘Io during the surveys indicates that it is unlikely that there is a breeding or resident population at PTA. ‘Io are highly visible, territorial birds and the low number of incidental sightings at PTA as well as the lack of ‘Io presence recorded in historical range data support the assumption that ‘Io do not prefer the habitat at PTA (Banko, 1980).

Since the results of the 2004-2006 surveys, survey frequency has been reduced to quarterly surveys, in each of the three study areas, conducted once every five years. If more than five incidental ‘Io observations are recorded within a single study area in an intervening year, quarterly surveys will be initiated immediately within that study area to determine any nesting or breeding activity. By maintaining a quarterly survey effort, the same 95% confidence level as described above may be applied to subsequent survey efforts assuming no ‘Io are observed.

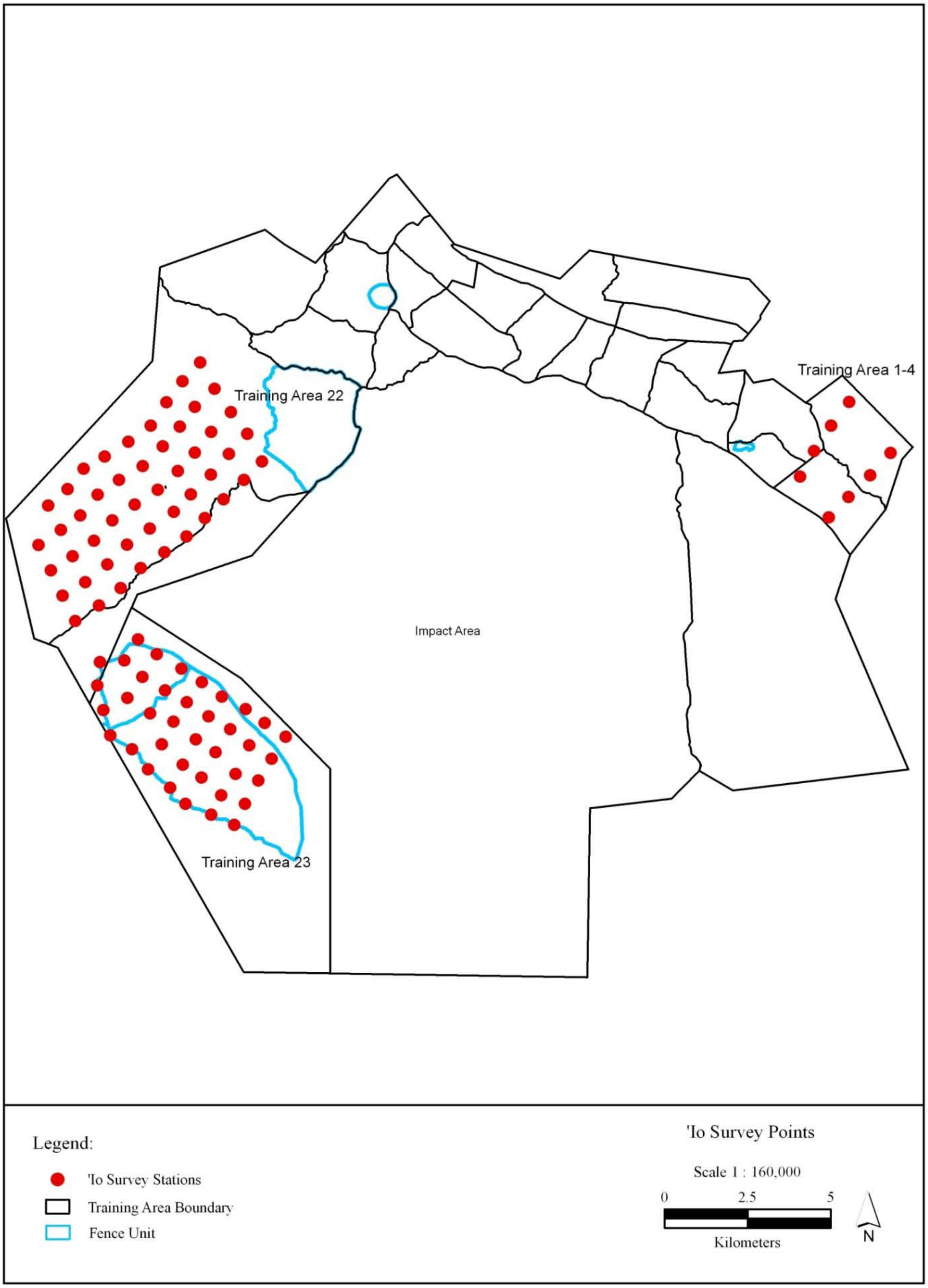


Figure 3.1-2. Map of ‘Io Survey Transects at PTA.

3.2 Nēnē Survey Protocol

Figure 3.2-1. Nēnē at Range 1.

Species Status

The Nēnē or Hawaiian goose (*Branta sandvicensis*) is a federally listed endangered ground-nesting avian species. Nēnē have between 6-7 different populations on Hawai'i Island that are actively managed (USFWS 2004). Of these, Hakalau Wildlife Refuge, Pu'u Wa'a wa'a and Keauhou have been the source populations for Nēnē sighted on PTA, based on records from banded birds (Figure 3.2-2. During flocking season (March-September), individuals from the above identified breeding populations migrate to areas of higher elevation and areas of greater food availability (Banko *et al.* 1999). It is during this time that individuals from the Pu'u Wa'a wa'a , Hakalau National Wildlife Refuge, and Keauhou populations have been seen on PTA in large numbers (more than 20 birds at one sighting), specifically at Range 1 (Figure 3.2-3).

Historically, Nēnē have been infrequently, incidentally sighted at PTA, and never during Nēnē surveys, which were conducted between 2004 and 2006. Beginning in the 2007 flocking season, however, Nēnē were observed with some regularity visiting Range 1 and the first breeding pair was recorded in the KMA during the 2007-08 breeding season. Nēnē breeding season is one of the longest of any wild geese (USFWS 2004). Most Nēnē lay eggs from October to March with a nesting peak in December, and most goslings hatch in December and January (USFWS 2004).

Nēnē mate for life and remain close to each other throughout the year. They are known to have high nest site fidelity, meaning that they return to the same area to nest from year to year (Banko1988; Banko *et al.* 1999). Female offspring return to their natal fledging sites to nest, while males disperse (Banko and Manuwal 1982; Woog 2000). After breeding, Nēnē will rejoin with larger family groups during flocking season. During post-breeding season and pre-breeding season Nēnē flocking activity increases (Hu, pers. comm. 2005). Nēnē have adapted to a terrestrial life and as such, do not need wetlands in their habitat. Their preferred habitat includes grasslands, shrub lands and dryland forests. Some community types such as high-elevation sparsely vegetated lava flows and open native alpine shrubland-woodland that Nēnē inhabit are found at PTA (USFWS 2004). Little is known regarding habitats Nēnē use at PTA and how important those habitats are for the Nēnē population.

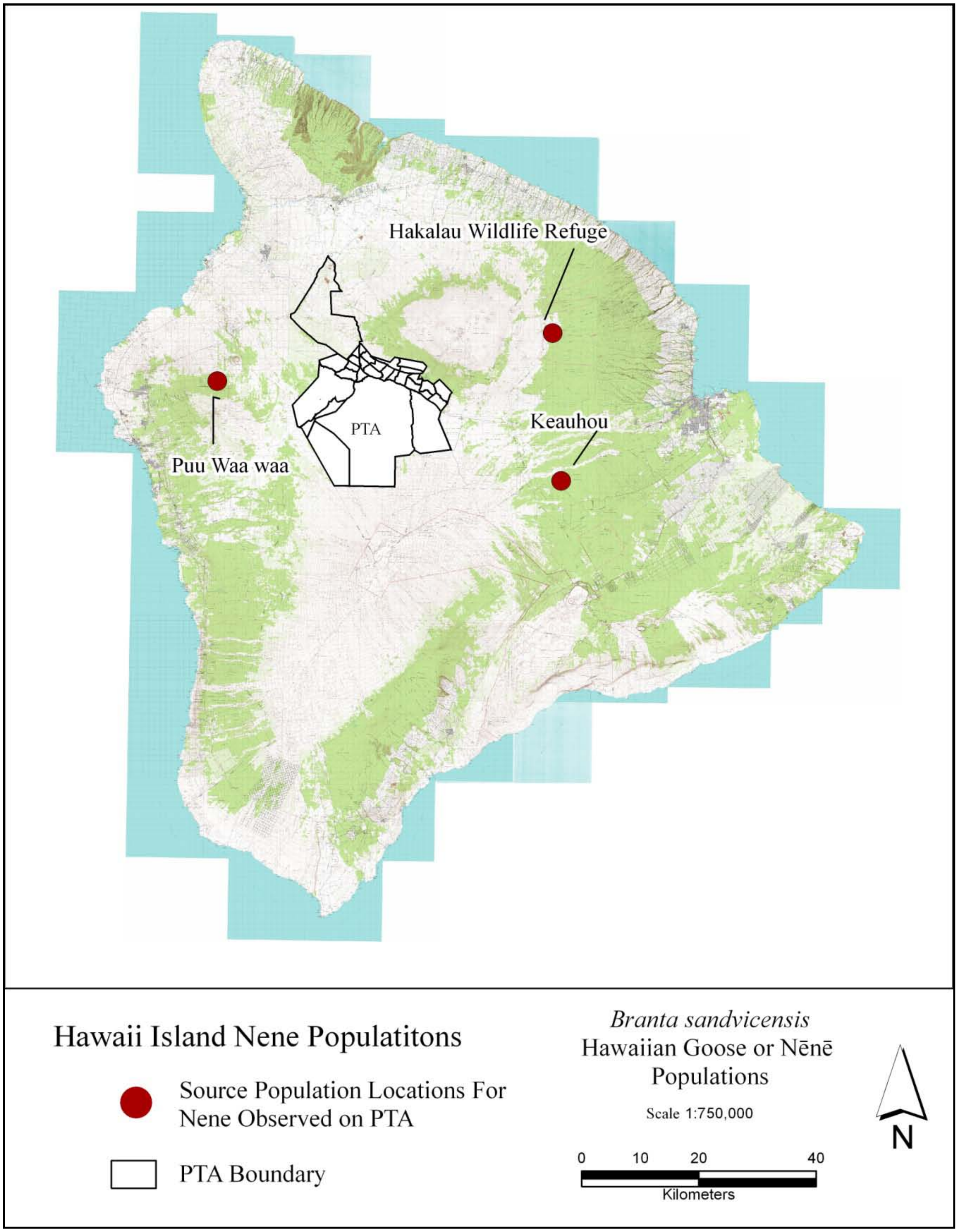


Figure 3.2-2. Source Populations for Nēnē on PTA.

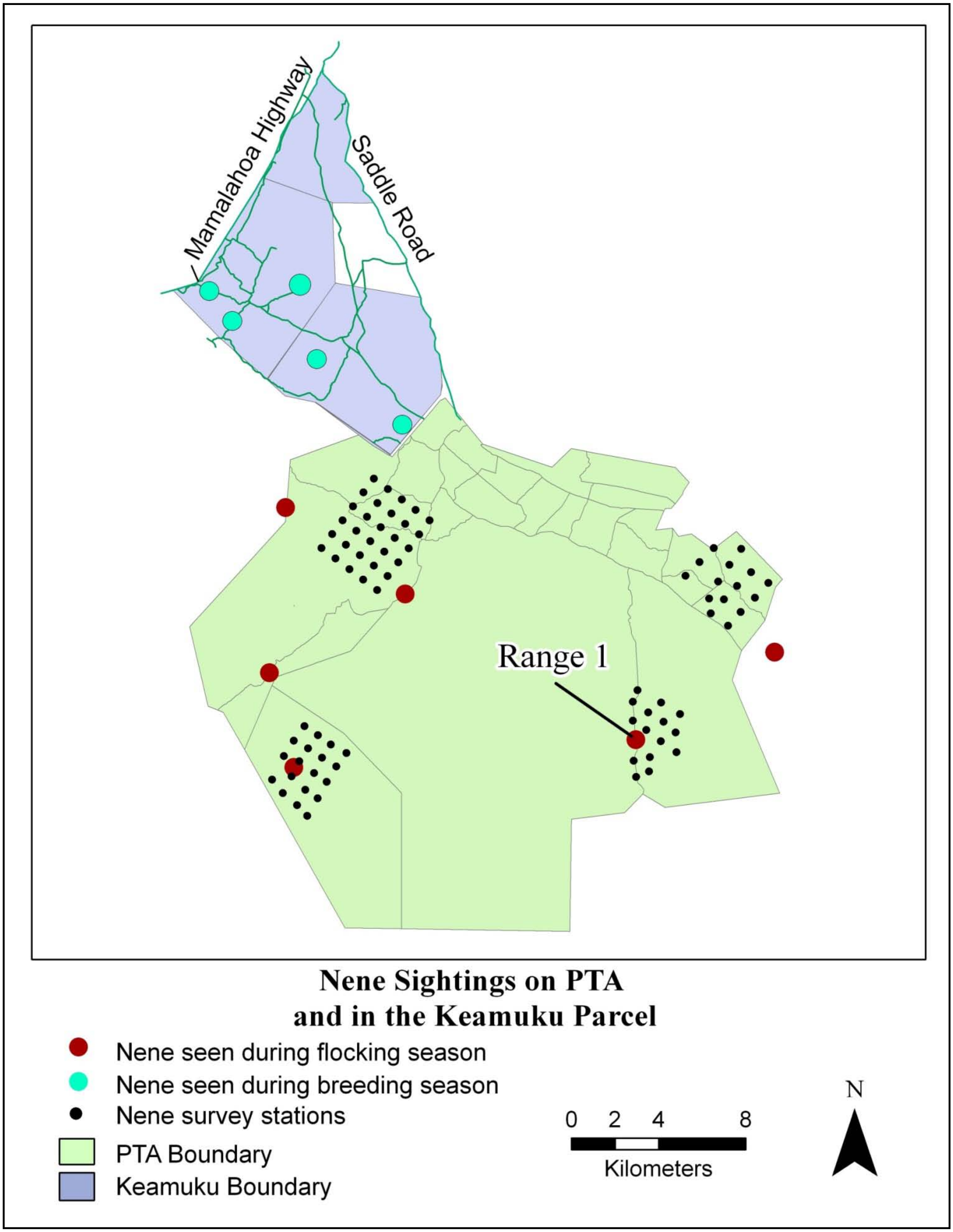


Figure 3.2-3. Nēnē distribution at PTA.

Methods

FLOCKING SEASON

Currently there is not an established method for surveying for flocking Nēnē in areas of unknown occupancy. Since Nēnē presence at PTA has not been predictable, frequent, or for extended periods of time, new surveying methods have been piloted and adjusted over the past several years.

The initial approach for Nēnē surveys in 2005, used recorded Nēnē calls that were broadcast at 800 m intervals along transects of varying length also located in Training Areas 1-4, 21, 22 and 23 (Figure 3.2-3). These locations correspond with areas where Nēnē had been sighted incidentally. Each three minute Nēnē call broadcast was followed by two minutes of observation and then repeated to complete a ten minute observation period. In addition, personnel attempted to observe Nēnē departing or returning to roosting locations located on high vantage points. Two observation points were located in PCH throughout TAs 1-4, and two each in TAs 21. Observations were conducted for one hour after sunrise when Nēnē are departing from roosting locations. This approach was abandoned after 2 days of observations due to scheduling and difficult logistics to accomplish this task.

After the first survey method yielded zero Nēnē sightings, a second two-part method was used to survey for Nēnē in 2006 and 2007. First, a variety of recorded Nēnē calls were broadcast from survey points monthly along transects in TA 1-4, 21 and 23 to elicit a response from Nēnē. For the second approach, observers broadcast Nēnē calls from pre-determined road-side locations weekly and watched for signs of Nēnē.

For the first approach, sampling stations were located 800 m apart in a grid-like fashion. At each station, observers conducted 10-minute surveys with two minutes of playing Nēnē calls followed by three minutes of observation then repeated. These surveys were conducted once a month during the pre and post breeding seasons (i.e., October to November and May to July)

For the second part, Nēnē calls were broadcast in the manner described above at road-side survey locations. During the pre and post breeding seasons each road-side point was visited weekly.

No Nēnē were seen during surveys from 2005 to 2007, but birds were being reported from various areas of the installation. From 2005, flocking groups of Nēnē were reported on Range 1 and in during the 2007-2008 breeding season one nesting pair was observed in KMA.

Because no Nēnē were ever detected during formal surveys, a new approach to monitoring Nēnē was initiated. In 2007, NRO began consistently monitoring Range 1 for Nēnē utilizing the range for foraging, resting and socializing during flocking season (March-October). Anecdotes indicate that Nēnē have been using the area as far back as 1992. After Range one was identified as a historical stop-over for Nēnē, surveying and monitoring efforts were focused exclusively in that area. In order to capture a baseline understanding of Nēnē use and distribution at Range 1 and the surrounding habitat, systematic surveys for Nēnē sign were conducted in the fall of 2008. The sign surveys confirmed that the small area of trees at Range 1 where Nēnē had been observed was the epicenter of Nēnē activity in the area. PTA NRO has now targeted this area with two remote sensing cameras, weekly visits by biologists and a video camera on a tower (coming in the 2009 flocking season). These monitoring efforts are conducted throughout the flocking season to collect information on Nēnē behavior, visitation patterns and specific individual identification. Monitoring is conducted on a weekly to daily schedule when there is military training at Range 1 and when Nēnē are consistently present.

In September 2008, the Army produced a BA describing training at Range 1 and Nēnē use patterns. USFWS rendered a BO in December 2008 and concluded that routine military training and SBCT Transformation training and the conservation measures identified by the Army in its BA would not jeopardize the threatened or endangered species found within the AA or adversely modify critical habitat. The conclusion of no jeopardy and no adverse modification was based on certain restrictions to military training which are outlined in the following section.

- The two remote sensing cameras that were installed on Range 1 in January 2008, to record the hot spots of Nēnē activity, will by checked by the NRO on a weekly basis for the next three years. Information on the number of birds, their band ID, the time of their visit and their behavior will be recorded.
- The NRO are researching the possibility of having a video camera (possibly live-feed) installed on the range that has a wider view. If the live-feed option proves feasible, it can be checked remotely by the biologists.
- Starting with the 2009 flocking season, the NRO will monitor Range 1 for Nēnē presence, in person, on a weekly basis. If Nēnē are seen, NRO will conduct follow-up surveys on the days following the first observation until no Nēnē are seen for two consecutive days. Information on the number of birds, their band ID, the time of their visit and their behavior will be recorded using standard NRAG data sheets. If this weekly scheduled is found to be either inefficient use of time or not providing good data, the NRO will work with the USFWS to revise the schedule (i.e. go to biweekly surveys). These surveys will be conducted for 3 years after which point (2012) the USFWS and the NRO will use the data to determine the best management for the future to minimize conflict on Range 1.
- NRO will be present during all training events at Range 1 while Nēnē are present.
- NRO will have one staff person “on call” during all training events at Range 1. This person will be available to respond immediately if Nēnē fly into the range during training.
- A biologist will accompany the military unit while they sweep the range from the firing point out to the left and right limits to the farthest objective to search for live or dead birds before live-fire training initiates. If Nēnē are seen within the line of fire, no-live fire will be allowed until the Nēnē are behind the line of fire. If a dead bird is found, NRO will collect the bird to be sent for a necropsy study and inform USFWS within 48 hours.
- The range sweep will take place within the hour preceding training. Surveyors will be spaced 3 to 5 m apart and move in parallel lines across the range to systematically sweep for Nēnē. In addition, the area between the Known Distance (KD) Range and the Nēnē survey area will be surveyed by a biologist using a spotting scope mounted on a vehicle on Red Leg Trail or another high vantage point.
- If units are training and Nēnē fly into the area, the unit will call a cease fire and call the NRO who will proceed to the range to monitor the situation.

- If Nēnē are present in the SDZ, no live-fire training can occur.
- If 6 or fewer Nēnē are in the Nēnē survey area, units can continue to train as long as Nēnē are not within the SDZ as long as the 60 day requirement (see below) has not been exceeded. If more than 6 birds are on Range 1 behind the line of fire, training will not be allowed to commence until the number of Nēnē reduces to 6 or fewer. Only after the number of Nēnē on the range is 6 or fewer will live-fire training be allowed.
- If more than 60 bird days (days where 1 to 6 birds are seen on the range and training takes place unhindered) occur within a calendar year, starting in January 2009, the Army will amend its policy to not allowing any live-fire training to take place while any number of Nēnē are anywhere on the range for the remainder of that calendar year.
- If at any time during or before a training event, Nēnē start to wander into the line of fire, an immediate cease fire will be called. A biologist will watch the geese and allow training to recommence once the biologist sees the geese leave the line of fire.
- When Nēnē are present forward of the first firing point, the line of departure will be moved further into the range, if possible, to allow training to continue uninterrupted.
- NRO will minimize the likelihood that Nēnē will habituate to human presence by maintaining a minimum distance of 30 m from the Nēnē while monitoring them at Range 1. Exceptions to this can be made if the observer must approach closer than 30 m to avoid a training hazard, but the observer will move away again as soon as it is safe to do so.
- Based on regular observations of Nēnē on Range 1, the Army assumes that Nēnē don't roost on the range. Biologists have seen Nēnē consistently depart the range between 6:30 and 6:45pm, and not return until 6:20 am at the earliest arrival. No birds were seen flying over the range once they departed for the night. During 3 separate night observations using night vision goggles (7.5 hours total) no Nēnē were seen. While training at night, at least one spotter will be required to observe the training with night vision goggles to look for Nēnē in the area.
- Day-time restrictions associated with the number and location of Nēnē on the range will also apply at night.
- In the event that military units are conducting night training but no training the following day, a biologist will sweep the range to look for dead Nēnē the following morning.
- Every military unit that will use Range One is briefed on the issues associated with Nēnē in the area and provided with a pamphlet that outlines the Army's responsibility under the Endangered Species Act.
- Range control staff will check the area after each training event ends to ensure that the areas used by the Nēnē are clear of all refuse.
- Siebert stakes have been installed around the areas of high Nēnē use to warn soldiers to stay out.
- A sign educating soldiers about the Nēnē has been installed by NRO on Range One.

- Range Control and the military units will be briefed on the requirement to alert the NRO if a dead Nēnē is found. Every military unit using Range 1 will be required to report dead Nēnē to the NRO found during their pre-training sweeps of the Range.
- If a Nēnē is found dead, the bird will be collected by NRO and submitted to Dr. Thierry M. Work at the National Wildlife Health Center, Honolulu Field Station (USGS-BRD) for a necropsy. USFWS will be notified within 48 hours of finding the dead bird.
- The NRO will make field observations on the reaction of Nēnē on Range 1 to noise disturbances generated by military training. These observations will help the Army determine if there are any risks to Nēnē associated with noise which were not anticipated by USFWS at the time of their consultation for the 2008 BO.
- Military units will only be allowed to bivouac at the designated bivouac site located across Red Leg Trail while training at Range 1. Bivouacking will not be allowed in the Range 1 complex as it has been in the past.
- The NRO has developed sighting cards to be used by Range Control and Range Maintenance to track goose observations while they perform standard range duties. These tracking cards will be given to the NRO at the end of each day that Nēnē are seen.
- Vehicles will be driven 15 mph unless troops are present, at which time the speed limit will decrease to 5 mph.
- In an effort to reduce the number of geese that utilize the areas used for live-fire training at Range 1, an alternative site that may be suitable for foraging and socializing was identified and is denoted on Figure 3.2-4. It has some of the same physical features such as mineral soil, rather than lava rock, and has a relatively level terrain for a clear line-of-site. In addition, it is in close proximity to Range 1 and should be visible to Nēnē as they fly into Range 1 from any direction. However, the site lacks mature trees that could serve as a source of shade.
- Beginning in January 2009, NRO began to improve the site to make it attractive to Nēnē. In order to prevent the site from attracting additional Nēnē to PTA, which could hinder training, regular monitoring and adaptive management (in coordination with the USFWS) of the site will be implemented.
- Native trees have been planted to provide shade. The trees will be covered with shade cloth structures in the beginning to protect them while they grow and to provide shade for Nēnē.
- Several methods will be employed to increase the initial attractiveness of the alternative site. A water source and flats of turf grass have been placed in the fenced areas. Decoys resembling Nēnē have also been placed inside the fenced enclosure. NRO will monitor the site and collect pertinent Nēnē data and enter it into a spreadsheet. When Nēnē are present at the alternative site, Nēnē elsewhere on the Range 1 complex will also be monitored to assist in determining if attraction away from Range 1 is successful. Abundance of Nēnē at Range 1 when birds are present at the alternative site will be noted.

- In coordination with the USFWS, the water and turf grass will be removed from the alternative site after Nēnē are determined to be consistently using the area. NRO will then monitor this site on the same schedule as Range 1 (weekly) to confirm the presence of Nēnē.
- If, after the removal of the water source and grass, Nēnē are no longer observed at this site, in coordination with the USFWS additional methods will be explored to increase the attractiveness of the area as a loafing site.
- In order to increase understanding of Nēnē use of PTA and throughout the island of Hawai‘i, natural resource staff will support an ongoing satellite transmitter study conducted by the USGS-BRD and the NPS. Dr. Steve Hess is the project lead for the USGS-BRD and is working with NPS biologist with Kathleen Misajon. The Army will purchase 10 transmitters to be placed on Nēnē known to use Range 1. The Army will coordinate with the project leads to target specific birds for study in either 2009 or 2010.
- The NRO will work with the Nēnē Working Group to determine the potential for using deterrent or habitat alteration to deter Nēnē from training areas.

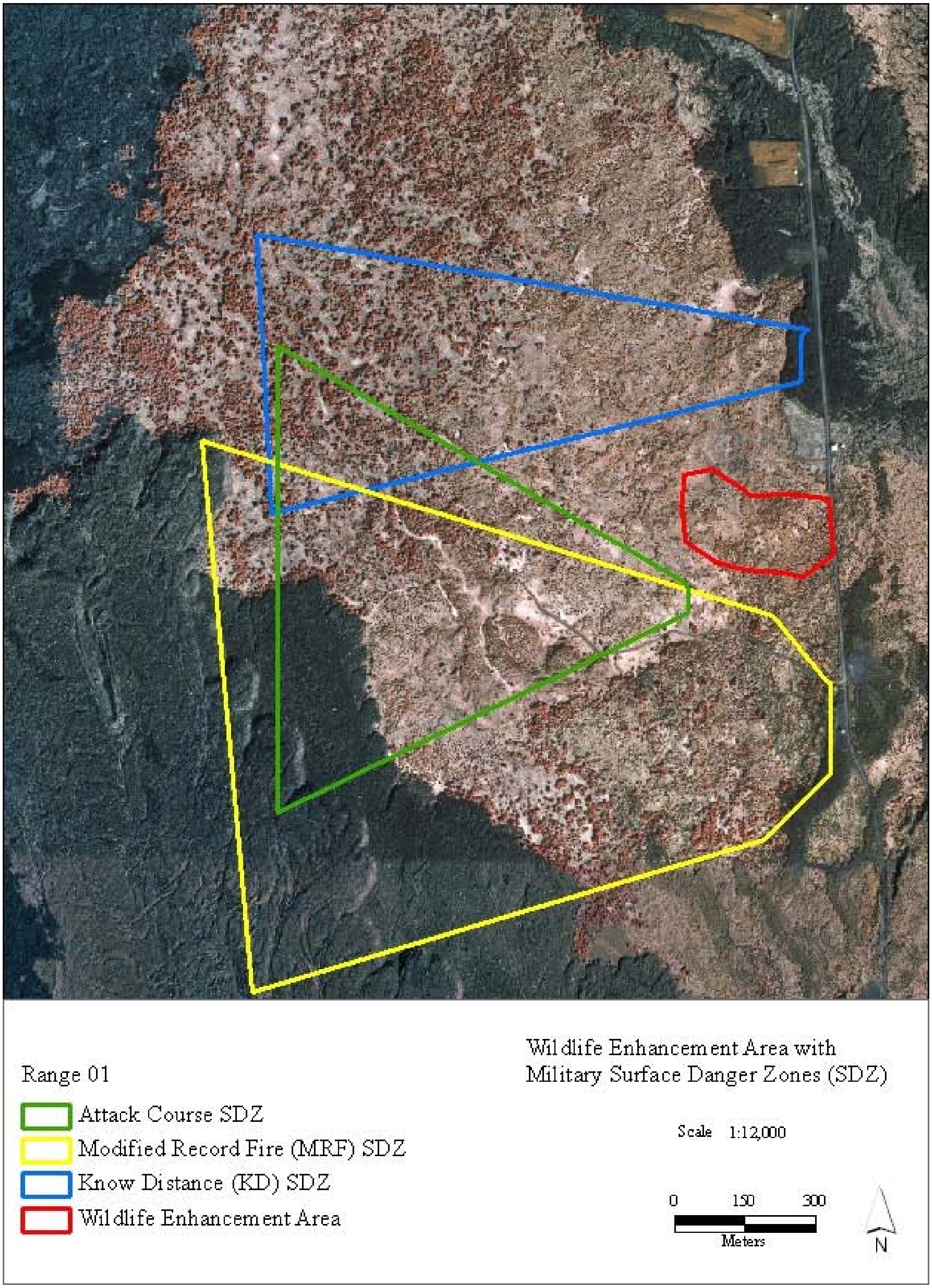


Figure 3.2-4. Range One Nēnē habitat restoration area and range surface danger zones (SDZ)

BREEDING SEASON

After the first nesting Nēnē pair was observed in the KMA in January of 2008, planning for future breeding season surveys were initiated. The KMA is approximately 9,074 ha (22,422 ac). The parcel is located between PTA proper, the Māmalahoa Highway (SH 190), and Saddle Road (Figure 3.2-5). The area will be used as a maneuver area to support training for the Stryker Brigade Combat Teams and Legacy forces. Within the KMA, aviation drop-zone and brigade task force maneuver training areas have been proposed. This area is also currently being used as pasture land for Parker Ranch cattle as it has been for over 100 years and as a result is almost exclusively grassland habitat. It was determined that Nēnē prefer areas with both shorter grass species for food and mobility and taller fountain grass clumps as cover for nest sites. Nēnē were also reported being associated with cattle trough areas that had hutches similar to structures used during Nēnē captive breeding efforts on the island. Using this information, NRO developed a survey strategy for the KMA (Appendix 2.0). Each potential Nēnē site is surveyed once a month during the breeding season. Surveys are scheduled for one day a week and take three to four weeks a month to complete. Cattle water troughs that have been identified as survey target areas due to Nēnē preference for the remnant hutch structures in these areas and the mixed grass matrix often associated with these areas. To identify sites with high potential for Nēnē, 400 meter buffers were created around these areas. NRO divided the KMA into Priority areas 1 (highest), 2 (medium) and 3 (lowest) based on locations of past Nēnē sightings and appropriate Nēnē habitat and grass cover (Figure 3.2-5). Priority areas 1 and 2 are surveyed on foot by biologists with binoculars through areas of suitable Nēnē habitat within the 400 Meter buffers. Priority area 3 is surveyed from a vehicle using binoculars because this area is a monoculture of short grass or dirt with no suitable nesting locations. To help minimize possible impacts to the geese in this parcel the Army proposes to:

- The NRO will conduct intensive surveys for nests during the 2008-2009, 2009-2010, and 2010-2011 breeding seasons. A detailed survey protocol will be developed and provided to USFWS by January 2009 (Appendix 2.0).
- If a nest is found, the NRO will control threats around any nesting Nēnē to include rodent control, mongoose/cat trapping and, if possible, pig and feral dog trapping. The nest area will be protected from cattle grazing and efforts to prevent goat and sheep disturbance will be further investigated (i.e. emergency electric fences around nest buffer areas). Threat determination and abatement will occur on a nest by nest basis. Orange snow fencing will not be used, as it has the likelihood of disturbing nesting birds.
- The objective of nest monitoring is to determine hatch date or the cause of nest failure. Nests will be monitored twice weekly in a manner that minimizes disturbance to nesting birds. Nest checks will include the following: assess whether the male is onsite and guarding; obtain a visual observation of the female from the maximum distance possible using binoculars and/or a spotting scope to determine whether she is present and if she is incubating; if there are egg shells visible outside of the nest, if there are goslings, etc. If a pair is not present, inspect the nest area more closely to determine whether or not the nest has failed. If the nest has not failed, assume the pair is on nest break and reassess the nest on the next visit.
- Natural resource staff will not disturb active nests or touch eggs.

- Cameras and other monitoring equipment will be serviced during nest checks to minimize disturbance. Nest checks will be completed in the shortest amount of time possible and should not exceed 5 to 10 minutes. Camera placement will be determined in coordination with the USFWS, based on the type of equipment to be used.
- When a nest is located, the USFWS shall be notified within 48 hours and relevant information such as the location of the nest and pair information will be provided.
- To assist in determining hatch date or causes of nest failure, nests will be monitored from blinds or with remote sensing cameras to minimize disturbances.
- Nest will be monitored for hatching and fledging success and a report will be submitted to the USFWS at the end of each nesting season.
- Natural resource staff will develop a "no-go" area to include the nest site plus a 200 m (600 ft) buffer in all directions around the nests. The buffer area will be marked with Seibert stakes. No training will be allowed in these no-go areas. The airspace above the 200 m (600 ft) buffer will also be off-limits to helicopter training. If there is a road adjacent to the nest that bisects the no-go area, the road will be off limits to all traffic until the birds have left the area. Natural resource staff will develop and distribute maps that clearly show the no-go areas and educate incoming military units of the no-go areas during the nesting season.
- All nest failures will be reported to the USFWS within 48 hours.
- Natural resource staff will monitor the nests for hatching success. If hatching occurs, the USFWS shall be notified immediately and the family will be moved by a biologist with Nēnē handling permits to a more appropriate location if possible. (See Nēnē brood translocation below for additional details on coordination).
- To reduce mortality of Nēnē on roads, the natural resource staff will work with the USFWS and Nēnē managers on the island of Hawai'i to develop and install Nēnē deterrents along road edges within the KMA once the roads are in place, starting in 2009.
- Natural resource staff will work with Nēnē managers on the island of Hawai'i to implement the GPS tracking study developed by the USGS-BRD and the NPS. Equipment, such as satellite transmitters, tracking equipment, and staff time for on-the-ground tracking of Nēnē at PTA can be incorporated as part of the on-going study through coordination with the USGS-BRD and the NPS.
- If families are not captured and relocated from the KMA, natural resource staff will work with USFWS to develop an additional no-go buffer area around the brood sites.
- The natural resource staff will be active members of the island of Hawai'i Nēnē working group starting immediately.

Nēnē Brood Translocation

- In an effort to reduce future breeding efforts in the area from offspring hatched in the KMA, natural resource staff will notify USFWS who will coordinate translocation efforts of hatched broods with island of Hawai'i Nēnē managers.

- Because translocations involve extra time, and effort, they must be coordinated well in advance. In addition to informing the USFWS of nests that are found, natural resource staff will provide bi-weekly updates of nest checks and possibly hatching dates to the USFWS
- Banding of adults and goslings (of appropriate age/size) onsite will be done by biologists with permits to handle Nēnē and coordinated with the USFWS.

Reporting

- Natural resource staff will send the USFWS an email summarizing the nest survey effort and results on a monthly basis or notify us within 48 hours of finding an active nest.
- After the first season of nest surveys and monitoring, natural resource staff will provide a report detailing all pertinent biological information including a summary of all survey efforts, breeding activity, banding, and Nēnē translocations. The report will be provided to the USFWS no later than July 1, 2009.
- The USFWS may make further recommendations based upon the number of Nēnē nesting at the KMA. If no changes are recommended, survey, nest monitoring, and translocation protocols will remain the same in the second year.
- Natural resource staff will provide a final report to the USFWS no later than July 1, 2010, that summarizes all activities conducted (and their results) during both breeding seasons.

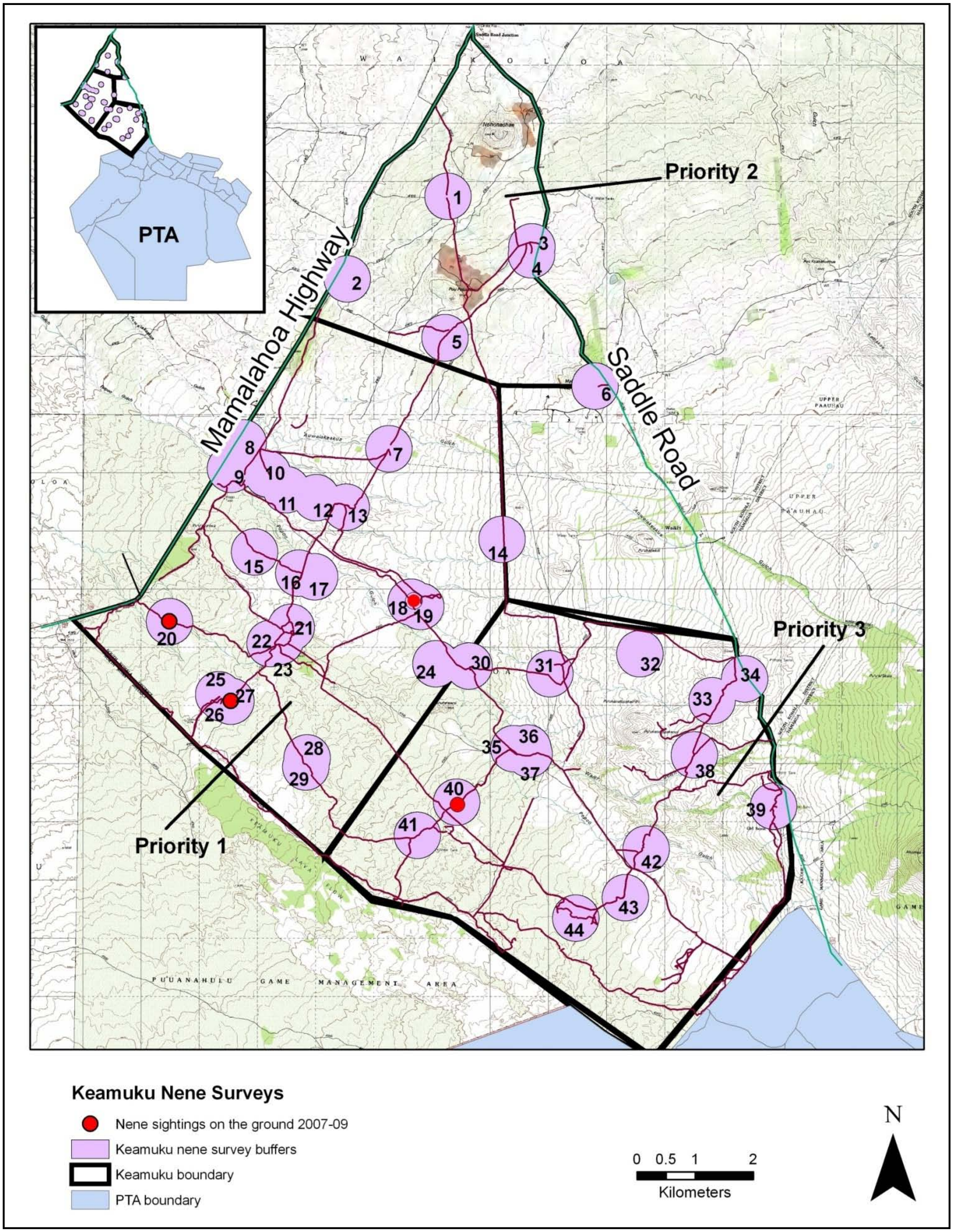


Figure 3.2-5. Nēnē survey buffers and priority areas in the Ke‘āmuku Maneuver Area.

Results/Discussion

It is still unclear how Nēnē are using the resources at PTA as occasional visitors during flocking season. Now that Range 1 has been identified as a historical flocking stop-over and the NRO have targeted it for Nēnē surveys and monitoring, it is hoped that specific information about Nēnē family groups and their breeding ground origins can be collected. This information will be helpful in understanding which birds are visiting PTA and will also help in selecting individuals for the GPS tracking project. Once the GPS tracking project is initiated, NRO will have much needed information about Nēnē movement patterns over all of PTA as well as help locating any unknown stop-over or roosting locations at PTA. It is possible that the GPS tracking project will also eliminate the need for future Nēnē transect surveys across PTA by identifying other consistently used, manageable Nēnē areas.

A permanent, sustainable solution for de-conflicting the military and Nēnē at Range 1 is increasingly necessary as the population of Nēnē on the island increases along with the use of Range 1 for training. Any success in luring Nēnē off of Range 1 over to the adjacent habitat restoration area will aid in reducing the conflict. A more active approach of herding Nēnē to safe areas may be necessary if passive luring methods do not result in Nēnē permanently using the habitat restoration area instead of Range 1.

The 2008-2009 breeding season was the first time that the KMA was systematically surveyed for nesting Nēnē. At this time, it seems that the proposed survey method will be a successful one. While no nesting activity was observed in the KMA in the 2008-2009 breeding season possibly because of poor habitat conditions related to weather. Several pairs of Nēnē were observed during surveys. All observations on the ground were associated with cattle water trough areas as anticipated by the survey design. Based on Nēnē nest site fidelity behavior, the NRO anticipates being able to target known nest locations in the future as the primary method for nest searching in combination with systematic trough buffer surveys to locate new nesting pairs.

Because a more consistent Nēnē presence on PTA and in the KMA is a recent discovery, the Army has initiated as part of the 2008 BO a three year period in which to gather as much information regarding Nēnē behavior, habitat use, movement patterns, nesting habits, predatory threats and military conflicts as possible to inform more permanent management in the future. During this time, a variety of management strategies should be tested to protect the Nēnē and to test different techniques for success.

3.3 ‘Ua‘u Survey Protocol

Figure 3.3-1. Hawaiian Petrel

Species Status

Hawaiian Petrels or ‘Ua‘u (*Pterdroma sandwichensis*) are a federally listed species that ranges across the tropical Pacific, but nests only in the Hawaiian Islands (Simons 1998). Hawaiian petrels were once common in the Pōhakuloa plain as evidenced by the multitude of bone found within archaeological middens and lava tubes (Athens *et al.* 1991, Banko 1980), but the over harvesting by Polynesians (Olson 1982a) and the introduction of alien predators (dogs, pigs, rats, cats and mongoose) to the islands reduced the population to only a few colony sites in the higher elevations of their breeding range. Historically there are no records of the birds at PTA, except for an unconfirmed sighting of a nestling in 1990. A radar survey was conducted in 1994 and three Hawaiian petrels were detected flying over the eastern portion of PTA (Cooper *et al.* 1996). Additional observer based surveys conducted on PTA have not detected the species (RCUH 1998; RCUH 2000; RCUH 2002); however, sites that appeared to contain old inactive burrows were found (RCUH 2002). These sites were in human modified pits in TA 23, but they were never confirmed by more experienced biologists.

Although it appears that the birds may have been extirpated from PTA, small or relict colonies can be difficult to find (Carlile 2003). Therefore, continued monitoring is reasonable. In addition, it takes five to six years for birds to mature to breeding age and return to their fledging colony (Mitchell *et al.* 2005). Immature birds that may have fledged from PTA could potentially still be in the population but currently undetectable.

Methods

The 2003 BO requires PTA NRO to conduct surveys for Hawaiian Petrels using marine radar to determine if there are any active colonies at PTA. Radar; however, was deemed of limited value for seabird surveys at PTA because of problems with target identification (Cooper *et al.* 1996; David, pers. comm. 2006). Therefore, a new survey approach is warranted.

The study sites in TA's 21 and 23 are remote and access is confounded by the possibility of unexploded ordnance and a High Hazard rating for TA 23. Because of this, remote automated recording equipment is an ideal method for surveying for Petrel presence. Cornell University's bioacoustics lab leases ARU that can acoustically census the study area everyday, for a pre-determined amount of time, over the entire breeding season. The same type of sampling intensity is not possible using human observers.

Most nesting activity in Hawai‘i has been reported at elevations from 2,000 to 3,000 m on Mauna Kea, Mauna Loa and Kilauea (Banko 1980, Conant 1980). This range indicates that, while there is a high density of invasive predators at PTA's upper elevations, petrel habitat on PTA between 2,000 and 2,600 m should be relevant for present day nesting colonies. Eight random locations were selected within suitable habitat, which consists of open pāhoehoe lava with lava tubes and blisters for nesting sites (Figure 3.3-2). The study site is approximate 3 square kilometers of non-contiguous habitat surrounded by barren lava flows. The study area is in both TA 21 and TA 23. There are a total of 12 ARU survey sites and 6 biologist observation based survey sites. Without Marine radar or thermal imaging, the most effective method to sample for Hawaiian Petrels is auditory. The individuals in the Petrel population, that this study targets, are the non-breeding adults because these individuals come back to the colony during breeding season and vocalize while flying overhead (Simons 1985). Simons (1985) had observed some individuals vocalizing at lower elevations while traveling to colony sites, but most calling is done over colony sites. Simons (1985) also noted that breeding individuals in the population spend all of their time, at the colony, inside their burrows and have only been observed vocalizing when they were disturbed, making breeding adults very difficult to detect. Non-breeding adults are both highly detectable due to their vocalizations and consistently present in flight above the colony site making this demographic a suitable survey target. Non-breeding adult Petrels congregate and vocalize at the colony site steadily from May to mid August when they depart for the season (Simons 1985).

In 2008, ARU deployment in TA 23 was scheduled to capture the intra-seasonal variation in the visitation patterns of breeders. These individuals are present at the colony more consistently for the first half of the sampling period than they are for the second half of the sampling period. For the first quarter of the breeding season, in TA 23, the ARUs were deployed at four of the eight survey sites. The units were then transferred to the next four sites one quarter of the way through the sampling period and batteries were replaced. The ARU's remained at the second locations for the second and third quarters of the breeding season to capture the intra-seasonal variation in breeding Hawaiian Petrel activity. Finally the ARUs were returned to the first four locations for the final quarter of the sampling period to complete the sampling equally among all of the sites. Units were collected at the end of August when non-breeding birds have departed and calling virtually stops (Simons 1985).

While breeding individuals are the ultimate criteria for an active nesting colony, these individuals are functionally undetectable using remote acoustic recording technology. By continuing to rotate ARU sampling sites to capture breeders' intra-seasonal variation, some survey sites may be unequally sampled for non-breeding individuals' intra-seasonal variation. As non-breeders return to the colony site in May, their calling intensity is likely to build as the month progresses, and as the non-breeders leave for the season in mid August their calling intensity is likely to taper off leading up to the final individual's departure. In future surveys, altering the rotation schedule to accommodate non-breeding individuals may be more appropriate for this survey technique and technology.

Sites in TA 21 are also monitored using an ARU on a rotation during the breeding season, but because this area is more accessible, the rotation used for these survey sites is functional for both breeding and non-breeding individuals' intra-seasonal variation. Four randomly selected Petrel habitat sites away from road-sides are surveyed using a single ARU (Figure 3.3-2). The ARU is moved every two weeks to a new location, from May through August, to capture intra-seasonal variation in Petrel calling intensity at each of the survey sites.

Because Training Area 21 is also accessible via roads, additional observational surveys are conducted by PTA NRO. Six survey sites along Red Leg Trail are monitored from May to August, the peak calling time of the Hawaiian Petrel breeding season. Each of the six sites is monitored a minimum of two times during the sampling period by biologists. The observers arrive at the sampling site ten minutes prior to sundown and remain at the sampling site until 21:00 hr. The observers listen for Hawaiian Petrels' wing beats and calls and scan the sky for silhouettes of high flying birds.

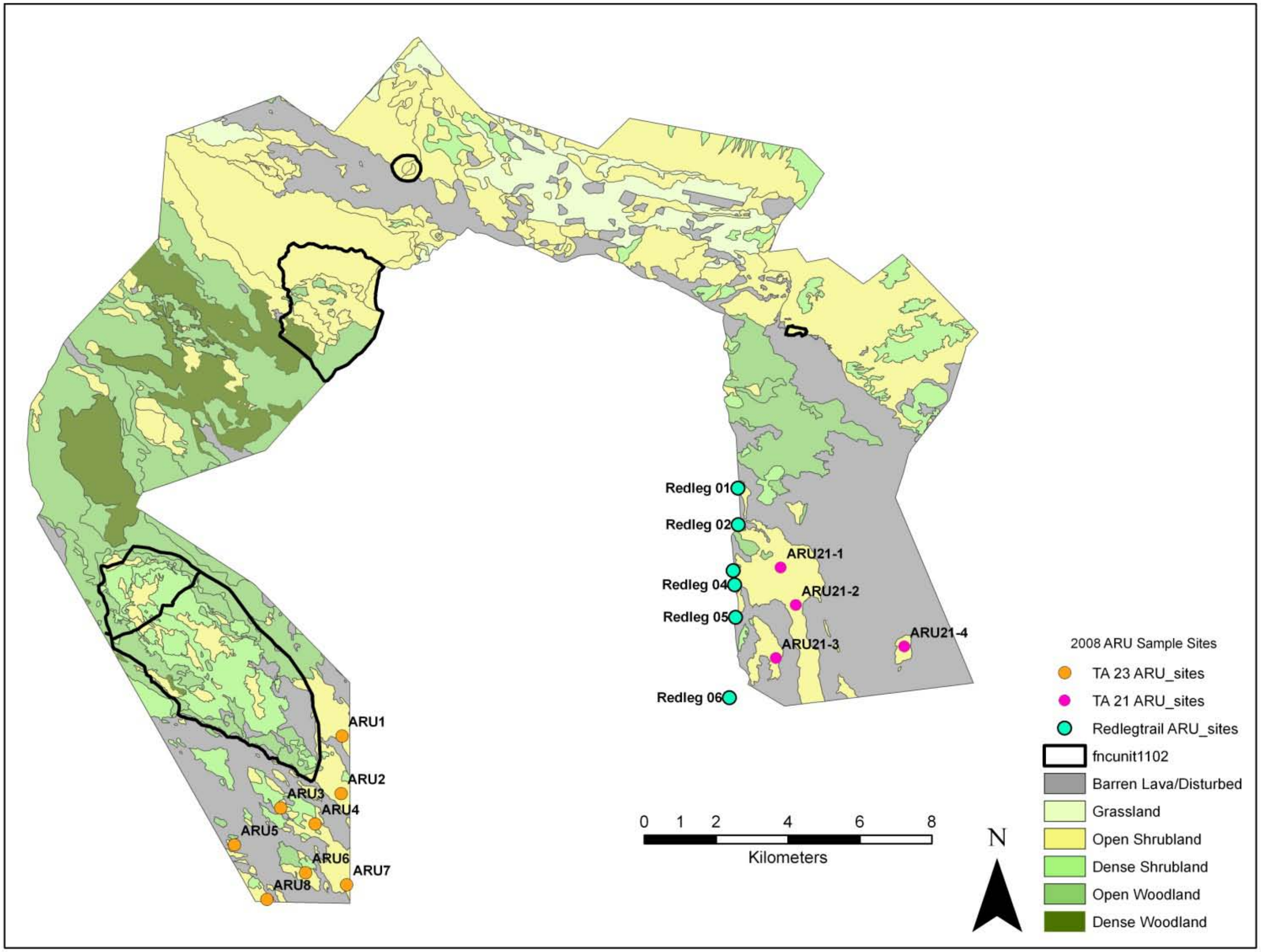


Figure 3.3-2. Hawaiian Petrel survey locations.

Results/Discussion

Audio survey data from the ARUs will be analyzed using techniques developed by Reed (1996) or Mackenzie *et al.* (2006) depending on the resulting data from the surveys and whether or not petrel detections were recorded. Both techniques provide a framework for assessing, with a given level of confidence, that we are not detecting false absences. If presence is detected, the unbiased occupancy of petrels at the survey locations potentially could be assessed using the same statistical framework.

Roadside observational surveys for Hawaiian Petrels will be conducted for two consecutive breeding seasons beginning in 2008. If no detections are recorded in 2008 and 2009, roadside surveys will be suspended, but passive auditory surveys using ARU's will continue until at least six years of data have been collected (2013). A six-year period is necessary to sample for immature birds that may still be in the pelagic population for the first five years of the study because they take six years to reach breeding maturity before returning to their natal fledging site (Simons 1998; Flint, pers. comm. 2007). If birds are detected with the ARU, additional methods such as ground surveys will be initiated to locate active burrows. If no Hawaiian Petrel detections are made during the entire six-year period, the Army will present the data and finding to USFWS and recommend discontinuing or highly reducing monitoring for this species. Since Hawaiian Petrels are highly philopatric, chances of a colony re-establishing without human intervention are extremely low (Harrison 1990; Flint pers. comm. 2007).

3.3.1 Detection Probability for Endangered Birds at PTA

'Io, Nēnē and 'Ua'u are either rarely present or thought to be completely absent from most or all of PTA. With "absence" being the most likely result of many of the individual survey efforts, power analysis was conducted in order to provide guidance as to the sampling effort required, to state with a given level of confidence, that a species was in fact absent (not just undetected, as in a "false absence") during a survey.

The statistical framework that was chosen for conducting power analysis and subsequent survey design for endangered birds at PTA was Occupancy and Detectability (hereafter referred to as Occupancy) (Reed 1996; Wintle 2004; and Mackenzie 2006). By conducting multiple visits to survey locations, Occupancy can be used to concurrently calculate a detectability estimate for a survey species while estimating the species' proportion of occupancy within the surveyed area. In this way, the method avoids the biases resulting from "false absences" and allows for estimating the likelihood of a true absence.

To estimate the number of repeat visits to each survey point which are required to infer the species' absence, the following model was used (from Reed 1996):

$$N = \ln(\acute{\alpha}\text{ level})/\ln(1- p)$$

In this formula, N represents the number of visits required to infer species absence, p is the "detection probability" of the species (i.e. what is the likelihood of observing an individual if it is present at the survey point), and the ά (alpha) level refers to the acceptable probability of a Type I error. The higher the detection probability of the species, the fewer repeat visits required to infer absence. The lower the alpha level, (i.e. higher confidence), the more visits required to infer absence.

Detection probabilities can be roughly estimated as low (0.2), medium (0.4), or high (0.8) (Reed 1996), or can be calculated using existing survey data involving repeated visits (Mackenzie 2006). Detection probabilities can also be estimated by surveying a population of known or tagged individuals, and calculating the proportion of individuals present which were in fact observed. The detection probability for each of the three target survey species (‘Io, Nēnē and Hawaiian Petrel) were estimated using one of each of the above methods in the following manner:

‘Io: Klavitter (2000) used radio tagged birds for his survey work with ‘Io on the Big Island of Hawai‘i to determine detection probabilities. During field trials using the same survey methods used in the proposed and current PTA ‘Io survey protocols, 28 of 50 radio-tagged ‘Io were observed, resulting in an estimated detection probability of 0.56.

Nēnē: Since no survey data yet has been recorded at PTA where Nēnē were successfully observed as present, the probability of detection had to be estimated for the species at PTA. Surveys are conducted using a system of Nēnē calls broadcast at each survey point. Nēnē have been observed while the calls were broadcast on three occasions. They appeared to respond strongest to non-flight calls and the responses most typically elicited were quite calling responses, therefore the detection probability of Nēnē was conservatively estimated as 0.4.

Hawaiian Petrel: The detection probability of Petrel will be estimated from data collected during field trials of the automated audio recording systems conducted at an existing Petrel colony within Volcano National Park. Analysis will be conducted using the Occupancy modeling program PRESENCE (Mackenzie *et al.* 2006).

Solving Reed’s (1996) formula above using each species probability of detection (‘Io : 0.56, Nēnē: 0.4), and an alpha level of 0.05 (95% confidence) results in N = 3.65 for ‘Io and N = 5.86 for Nēnē. Rounding up, four and six repeated survey visits to a survey point in which no ‘Io or Nēnē (respectively) were observed would be sufficient to infer with 95% confidence that the species was absent during the surveys at that location.

3.4 Hawaiian Hoary Bat Management Protocol

Figure 3.4-1. Hawaiian Hoary Bat

Introduction

The purpose of this document is to:

1. Provide a brief description of the current state of knowledge directly relating to the natural history of HHB at, or relevant to, PTA as of December 2008.
2. Outline important knowledge gaps which need to be addressed in support of monitoring and management at PTA in fulfillment of the listed legal obligations as described in the BO (USFWS 1998c).
3. Provide an organized plan and detailed protocols for addressing knowledge gaps, and concentrating especially on:
   - Monitoring of HHB Occupancy trends
   - Management of habitat
   - Directions for future research and cooperative efforts

Natural History

The endangered Hawaiian hoary bat or ʻŌpeʻapeʻa (*Lasiurus cinereus semotus*) is endemic to the State of Hawaiʻi where it is the only extant, native terrestrial mammal (Tomich 1986). It has been documented historically on the islands of Hawaiʻi, Maui, Molokai, Oahu, Kauai, and possibly Kahoolawe (Hawaiʻi Natural Heritage Program 1996). Resident breeding populations of HHBs are now found only on the islands of Hawaiʻi, and Kauai (Baldwin 1950, Tomich 1986, Kepler and Scott 1990; Jacobs 1994). Current and historical population numbers are unknown for the HHB, but the species is believed to have declined over the past 100 years. The primary factor limiting recovery is thought to be habitat loss, primarily the availability of roosting sites; suitable roosting habitat is particularly important to pregnant and lactating females and non-volant young (USFWS 1998d).

The bat population at PTA is an unknown proportion of the subspecies' distribution, for which there are no abundance estimates. The presence of HHBs has been officially documented at PTA since 1992 (Gon *et al.* 1993). Additional surveys have also documented HHB presence at PTA (Menard 2001; York in CEMML 2006; Jacobs 2007) as well as numerous unofficial accounts by PTA staff. The presence of HHBs at PTA may fluctuate throughout the year according to hypotheses proposed by Menard (2001). She proposed that the HHB population may engage in three partial seasonal migrations to different locations on the Big Island. Her records of bat occurrence suggest that during the

- **Breeding** season (May to August) HHBs move into the lowlands out of the eastern highlands
- **Post-lactation** season (September to December) some HHBs move to the eastern highlands and perhaps to PTA, from the lowlands.
- **Pre-pregnancy** season (January to April) more HHBs move to the eastern highlands from the lowlands and from the central highlands (PTA).

Under this scenario, HHB populations might be highest at PTA during Post-lactation, lowest during Breeding and possibly intermediate during Pre-pregnancy.

York's study (in CEMML 2006) was the first attempt to address the question of habitat selection by HHBs at PTA. York and the NRO conducted single-visit, presence/absence surveys for HHBs at 50 road-side locations throughout PTA from May to June 2005, and from November to December 2005 (CEMML 2006). The summer surveys conducted during the HHB breeding season detected a preference for "dense woodland habitat types." York's breeding season surveys detected no habitat preferences. Overall naïve occupancy during these surveys was estimated to be 52% in summer and 66% during the Post-lactation season (Jacobs 2007). These occupancy estimates have not been tested for significant differences, but do appear to mirror Menard's predictions.

In 2007, Jacobs executed a pilot study to test methods to be used in a long-term PTA HHB monitoring program (Jacobs 2007). Data were collected from January 1 to April 12, 2007. Five automated passive bat detectors were rotated through 30 survey locations, in five habitat classes, on a weekly basis. Sampling resulted in a total of 231 survey nights recorded during the Pre-pregnancy season. No difference was detected between habitat types. Overall occupancy was estimated to be 0.7573 with a se = (0.1189) representing an alpha level of 87%. Overall detectability was estimated to be 0.1980 with an se = 0.0350 representing an alpha level of 87%. The overall naïve estimate of occupancy (percent of sites with at least one detection) was 63%. HHB calls were detected from between one hour and ten minutes before sunset to as late as seven hours and fifty minutes after sunset. Weather did not appear to affect the detection rates or occupancy patterns of HHBs. York and Jacobs' combined data show HHBs detected at significant naïve occupancy levels, throughout a wide area of PTA, in all three breeding seasons.

Additional studies conducted by the USGS-BRD in the lowlands of Hawai‘i have also contributed to the pool of HHB natural history information which may be applicable to PTA. summarized his findings in an unpublished research proposal to the HHB research cooperative in 2006. He has mist netted and radio tagged 29 HHBs in lowland areas in the Hilo and Hāmākua Coast areas. Movements of HHBs of up to 12 miles and 5,000 feet in elevation were recorded within a single night during his study. So far his unpublished data supports the hypotheses of seasonal movements, with nearly all bats leaving the eastern lowlands from January to March. Home ranges varied in size from five to 150 ha, and contained multiple core feeding areas. Feeding areas usually were associated with vegetative edge areas such as roads or orchard rows. Bonaccorso found that the radio tagged bats used a wide variety of habitat types including native and agricultural areas, gulches, urban/suburban areas and coastal waters. Good habitat appears to be any area with "trees and edges, gaps and roads". HHB roosting site requirements can include nearly any tree species (12 species observed used), over 5 m in height, with moderate to large leaves to provide thermal cover and open areas below for a "drop-out" zone. Roost trees were located in forests, copses and isolated trees. While a bat may use several different roost sites, they exhibited high fidelity to those sites. Diet studies reveal moths, beetles and flying termites comprising 95% of a HHB's diet. Diet varied between the sexes, with females taking more large slow beetles, and males taking more fast moths.

Marcos Gorreson (2008) has collected occupancy data at numerous sites throughout the island of Hawai‘i. It is hoped that this data, in combination with PTA's occupancy data and occupancy studies planned by Volcanoes National Park will be useful for tracking the seasonal population movements of HHBs on the island of Hawai‘i.

HHB Management Outline

HHB management at PTA will focus on three general subject areas relating to HHBs:

- Population monitoring using seasonal occupancy estimates as an index
- Habitat management and monitoring
- Natural history investigations

Each subject area will have its own set of objectives, recommendations, and protocols where appropriate. All three subject areas are important for the effective management of HHBs at PTA. Management without monitoring the effects on the species can become misdirected and counter-productive. Without better knowledge of the natural history of the species to guide changes in management actions, the causes of population changes will not be fully understood, and therefore cannot be properly addressed by managers.

The following protocols and management recommendations are based on the current state of knowledge. It should be understood that a major objective of the HHB management plan is to not only improve that state of knowledge, but to use that improved knowledge to simplify and increase the effectiveness of the workload associated with the monitoring and management of HHBs at PTA. As such, these protocols and objectives will be modified using an adaptive management approach based on annual reviews of the program by the IT.

HHB monitoring and management is required by the BO both at PTA and on the KMA. The 2007 Pre-breeding season pilot study was conducted only on PTA proper, due to budgetary, personnel, and equipment limitations. Subsequent management and monitoring efforts will take place on both PTA and the KMA; focusing first on PTA, and then "phasing in" work on the KMA in 2009 as more equipment and personnel are acquired.

HHB Population Monitoring

HHB population monitoring at PTA and on the KMA will utilize automated passive echolocation detectors, following the protocols developed from recommendations generated by the 2007 pilot study (Jacobs 2007). These population monitoring protocols for both PTA and the KMA are described in detail in the various sections of this PIP. Monitoring at PTA began with a pilot study in January 2007, and is continuing. Monitoring in the KMA will began in 2009 with an initial pilot study effort. It is recommended that this year-round monitoring protocol be followed for a minimum of five consecutive years to create a baseline index of occupancy at PTA and the KMA. After the initial five years, the intensity and scope may be re-evaluated. The data collected over the first five years will be applicable to address the following questions of management concern:

- Does HHB occupancy at PTA change between seasons?
- During and after the first five years, is there an overall trend in HHB occupancy at PTA (increase, decrease, no change), and what is the level of intensity?
- Does HHB occupancy differ between habitat types?

Occupancy estimation does not allow for the estimation of absolute numbers of HHBs at PTA. However, since its results will be applicable to addressing the above questions, it provides comprehensive location and timing guidance for managers to minimize disturbance, and initiate habitat management. Monitoring trends in occupancy will also provide a surrogate for monitoring trends in actual numbers, due to the high correlation between the two. Occupancy data (in conjunction with other natural history data) can help guide the management of specific habitat types for the benefit of HHBs. With the continued development of the application of

Occupancy and Detectability data it is hoped that "use intensity" levels will soon be able to be calculated (Mackenzie, pers. comm., 2007)

Other methods of population tracking such as mist netting and tagging have been examined. However, when applied to population monitoring, these methods were deemed so labor intensive, expensive and involving such a high probability of failure, as to disproportionately consume limited budget and personnel hours which could otherwise be applied to habitat improvement and other natural history studies.

Habitat Management and Monitoring

Habitat Management: Habitat management for HHBs at PTA should focus on the maintenance and augmentation of habitats most likely to provide roosting habitat, and which are the most threatened by human activities. Second priority should be those habitats which provide the most productive feeding areas.

Tree and high shrub-land habitats are thought to be the most likely provide roosting sites based on Bonaccorso's unpublished work from 2006. He describes HHB roost sites as typically being located >5 m above the ground, in trees with drooping vegetation, with a clear drop-out zone below. Such potential habitats should be considered first priority and include those dominated by *Sophora*, *Myoporum* and *Metrosideros* species (Classes 4 and 5 in Table 3.4-1).

Management actions to protect HHB habitats are concurrent with other management efforts at PTA. These actions include:

- Construction and maintenance of ungulate exclusion fences around all forested habitats. These fences will protect existing trees from ungulate damage, and allow for their natural regeneration. Construction is being done in such a way to impact as little potential roosting habitat as possible.
- An intense and timely ungulate removal program, to render and maintain fenced areas "ungulate free".
- Construction of a system of fire-breaks to protect against the imminent danger of catastrophic wildfires. Construction is being done in such a way to impact as little potential roosting habitat as possible.
- Management of invasive species including those which directly threaten tree and shrub land habitats such as Banana Poka (*Passiflora molissima*) and German Ivy (*Senecio mikanoides*). Banana Poka densities are still low enough in Kīpuka ʻAlalā that it may be possible to eradicate it.
- Assisting in scheduling and planning the extent of potentially disruptive or destructive activities, such as construction or training; to limit their impacts on first priority HHB habitats and avoid peak seasons of HHB occupancy.

It is not likely that the biologist assigned to bat monitoring and management will directly supervise any or all of the five areas of management action listed above. However, it will be the responsibility of the bat biologist to help assure that these actions are actually implemented and that they are undertaken in such a way as to increase the HHB habitat quality and quantity at PTA.

It is also the responsibility of the bat biologist to investigate and possibly implement additional methods to increase the quality and quantity of HHB habitat at PTA. The natural history investigations will contribute greatly in assessing what qualities determine the quality of HHB habitat. However, current recommendations for increasing HHB habitat quality include:

- Decreasing potential predation on non-volant young (cats, rats, mongoose)
- Accelerating natural tree regeneration

Habitat Monitoring

Habitat monitoring should consist of tracking the percent cover of potential roosting habitat (i.e., trees >5 m in height) at PTA, as well as regenerating shrub and tree land habitats. While exact tree species are currently not thought to influence roost site selection, native species will be encouraged rather than non-native. Habitat monitoring at this level and scale will be accomplished most efficiently with remote sensing. In this way, percent cover by land-cover type can be tracked, and trends observed. Remote data will be collected a minimum of once every five years, beginning in 2009. Such data will also be useful to many other aspects of the environmental management program at PTA. Land-cover characteristics which may prove useful for gauging bat habitat quality include vegetation height and density.

Knowledge Gaps and Natural History Investigations

Pilot studies and concurrent lowland telemetry studies have been useful in generating initial data to guide the development of a HHB conservation plan at PTA. However, ongoing studies will need to be continued and new studies initiated to address many remaining questions. The following questions are currently thought to be important for providing additional guidance in refining HHB management and for reacting to future HHB population trends.

- What are the inter-seasonal and inter-annual changes in HHB abundance at PTA (on-going)
- What are the characteristics that best describe preferred roosting habitat at PTA?
- What are the HHB home range sizes at PTA?
- What is the potential prey availability at PTA, and are there seasonal trends in their abundance?
- What is the extent of predator impacts on HHBs at PTA?
- What are HHB's reactions to disturbance?

Answering these questions will require using additional, labor-intensive methods such as mist-netting HHBs and radio telemetry. Such studies will benefit from thorough literature searches to investigate methods and the results of relevant studies. Conducting such investigations at PTA will also likely require expanding cooperative efforts with other agencies on Hawai‘i such as those established with the USGS-BRD and NPS.

3.4.1 HHB Survey Protocols

HHB Occupancy and Monitoring Protocols for PTA

Project Objective**:** The objective of the Occupancy monitoring project at PTA is to use automated passive echolocation monitors to:

- Compare the occupancy rates of five general habitat types
- Quantify the seasonal and annual patterns of HHB occupancy at PTA

- Contribute to continuing cooperative efforts with USGS-BRD and NPS using meta-analysis of occupancy data to investigate big-picture natural-history questions

Methods

A bat habitat classification map of PTA was created using an existing ArcGIS coverage of PTA's 24 plant communities created by Shaw and Castillo (1997). Five PTA bat habitat classes were created by grouping together these 24 plant communities based on gross structural characteristics such as vegetation height, vertical structure and density (Table 3.4-1, Figure 3.4-2). Guidance in the bat-centric groupings of plant communities was provided through consultation with local bat researcher Dr. Frank Bonaccorso (IT Member).

120 potential survey point locations distributed throughout PTA were randomly generated using ArcGIS, and the Hawth's tools extension. Survey site locations were subject to the following parameters: Since Anabat II detectors have a sampling range of approximately 100 m (Bonaccorso pers. comm. 2007) survey points were located no closer than 200 m to each-other, and no closer than 100 m from a road or the edge of the sampled habitat patch the point is located within. Survey sites were also located no further than 1 km from a drivable road, and were not located within active bombing ranges or dud areas in order to facilitate safe access. Before a site was used for the first time it was visited and examined to make sure these requirements were met, and that it was in fact located in the proper bat habitat class. If the requirements were not met, an alternate site meeting the requirements was used instead. In this way, 75 total sites were produced, with between 10 and 19 sites located in each of the five bat habitat classes (Figure 3.4-2). Habitat was then quantified using a Braun-Blanquet vegetation cover-plot with a 5 m radius surrounding the survey point. Within the plot the percent cover of bare ground and each plant species present was categorized for four different zones of height of 0 to 2 m, 2 m to 3 m, 3 m to 5 m and >5 m. Percent cover categories were <5%, 5% to 25%, 25% to 50%, 50% to 75% and >75%. This classification system allows for the comparison of data with other areas outside of Shaw and Castillo's (1997) map, such as the KMA and USGS-BRD study areas.

The total number of sampling events and of locations was determined in part by logistical and budget constraints combined with the requirements of the statistical design (see below). Distribution of the number of survey points within each habitat class was based roughly on the proportion of PTA covered by each habitat type. However, additional points were moved to habitat class 4 in order for it to contain at least enough survey points to provide the potential of achieving an estimate of occupancy for that habitat type with an alpha level of 0.2. Since the objective of the monitoring is to create an index to track seasonal and annual changes in occupancy, as long as the same sampling scheme is repeated each year, valid comparisons can be made despite the in-exact proportion of sampling points in each habitat type. Habitat classes and their corresponding number of survey points are as follows: 1/26, 2/11, 3/12, 4/9, 5/17 (Table 3.4-1 for habitat class descriptions). Habitat may change over time due to fires or habitat management efforts resulting in a change in HHB occupancy at PTA; therefore it is important to maintain the sampling efforts within each habitat to assess if the overall changes in PTA HHB occupancy are the result of actual changes in the HHB population, or just the result of changing habitat availability.

Table 3.4-1. Five general habitat classes for HHB habitat selection sampling.

The 24 plant communities at PTA were grouped based on gross structural characteristics such as vegetation height and density (Barren Lava is not currently included for sampling)

Class Habitat	Percent of Sample Frame	Corresponding Plant Community Type
Barren Lava	9	Barren Lava
1) Low Shrub	29	Open *Dodonaea* Mixed Shrubland
		Dodonaea Mixed Shrubland
		Styphelia – Dodonaea Shrubland
		Styphelia Mixed Shrubland
		Pennisetum Grassland
		Eragrostis Grassland
		Disturbed
		Chenopodium Shrubland
2) Open High Shrub	**25**	*Myoporum* Shrubland
		Myoporum – Chamaesyce Shrubland
		Myoporum – Dodonaea Shrubland
		Sophora – Myoporum Shrubland with grass
3) Dense High Shrub	**11**	*Myoporum – Sophora* Mixed Shrubland
		Myoporum – Sophora Shrubland with forb
		Myoporum – Sophora Shrubland with grass
		Dense *Dodonaea* Shrubland
		Sophora- *Myoporum*- *Chamaesyce* Shrubs
		Sophora - *Myoporum* Shrubland with forb
4) Treeland w/Grass or lava	**7**	Sparse *Metrosideros* Treeland
		Chamaesyce Treeland
5) Treeland w/tall Shrub	19	Open *Metrosideros* Treeland with shrub
		Open *Metrosideros* Treeland & dense shrub
		Intermediate *Metrosideros* Mixed Treeland

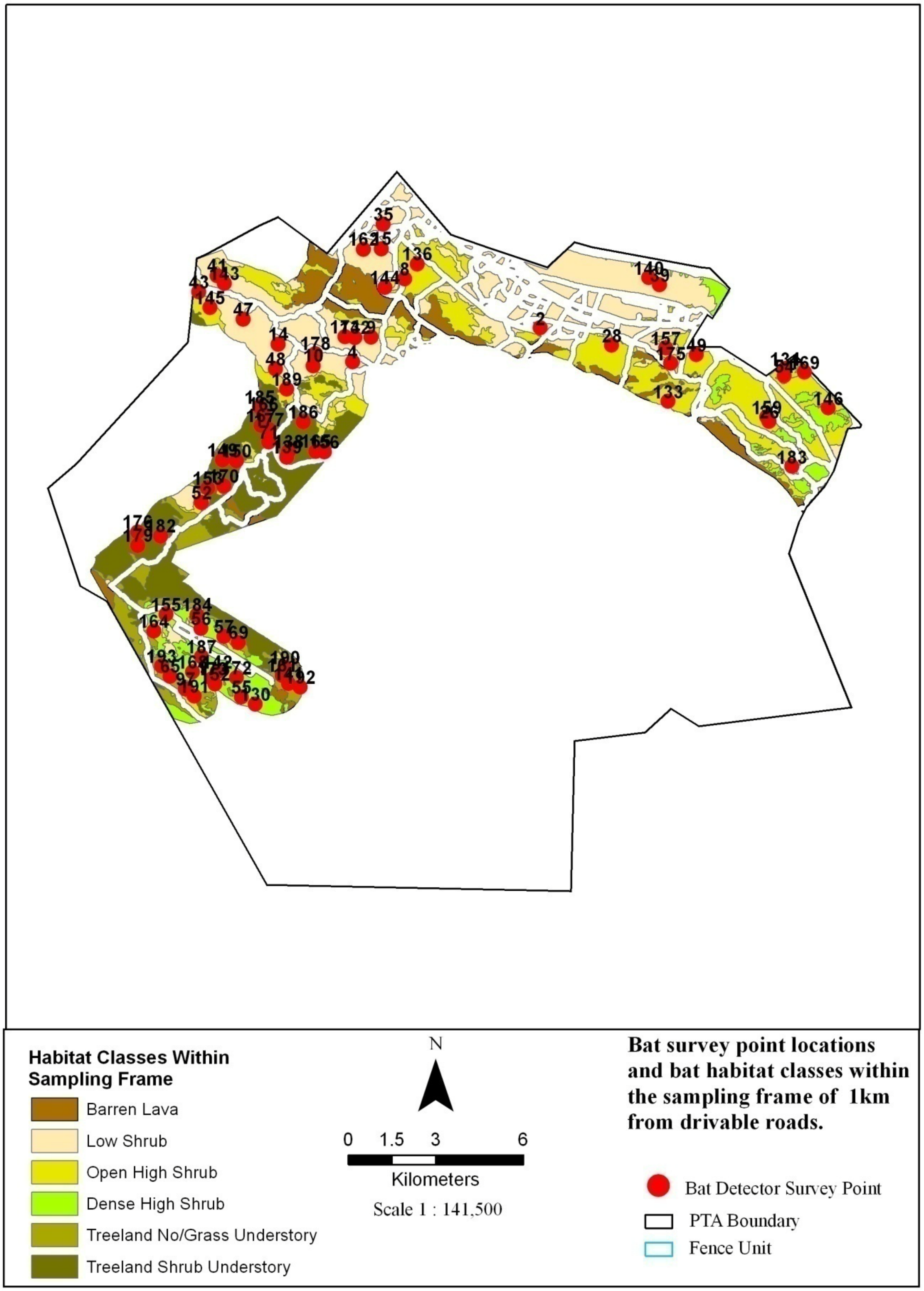


Figure 3.4-2. HBB occupancy sampling frame, locations and habitat type.

Unlike in the pilot study, no survey locations will be located off of Red Leg trail, in TAs immediately to the south of Saddle Road, or along the end of Bobcat Trail at the southern end of the Kīpuka ʻAlalā fence unit. These areas are not included in the sample frame because: they preclude reliable scheduling due to restricted and unpredictable use of ranges, presence of powerful lights (Red Leg Trail, and near Saddle Road), over-extend sampling efforts to far distant locations, and demand too much time to access due to low quality of roads (Southern Kīpuka ʻAlalā). Removing these areas from the sample frame increases the time available for the completion of work at other sites, decreases wear and tear on vehicles, and inter-seasonal/annual variance by allowing a more regular sampling schedule. Removing these areas from the sampling frame will have no deleterious effect on the extrapolation of the conclusions from the bat surveys.

Five Anabat II detectors combined with Anabat CF ZCAIMs (in combination referred to as a "detector") will be used to provide 7-day a week, automated data-collection (Figure 3.4-3). The weather-proof housing of the detectors was re-designed after the pilot study to decrease weight and set-up time. Microphone sensitivity was increased from five to six following the pilot study. Therefore, data from the pilot study cannot be reliably compared with the following seasons. The detectors will be programmed to record HHB calls from 16:00 hr until 06:00 hr the following morning.

Each detector will be deployed for a week at a time at one of the 75 survey points. Detectors will be re-deployed to survey a new point each week. Points have been scheduled for surveying randomly within each habitat class resulting in at least three of the five different habitat classes being surveyed each week. Detectors will be deployed in a consistent 15 week sampling schedule as described in detail in Table 3.4-2**.** This schedule of deployment will be repeated at the same locations, in the same order, each sampling season to reduce variance, and to thereby provide a consistent index for tracking inter-annual and inter-seasonal changes (Jacobs 2007). Sampling breaks of approximately two weeks between each season will provide time for maintenance, and data analysis and summary.

The three 15 week seasonal sampling periods of January to April, May to August, and September to December were determined by the constraints of the occupancy model, equipment limitations and the natural history of the species. Occupancy calculations require a closed population without significant emigration or immigration (Mackenzie *et al.* 2006). It is hypothesized that HHB engage in seasonal altitudinal migrations during the three reproductive time periods of Pre-pregnancy (January to March), Breeding (April to August) and Post-lactation (September to December) (Menard 2001). It is currently thought that during any of these three periods there is not significant movement between populations and altitudes. The scheduled sampling breaks will decrease the potential of sampling during periods when the population may be actively engaged in altitudinal migrations.

Figure 3.4-3. HHB Automated Detector with Weather-proof Housing Design

Table 3.4-2: Regular weekly sampling schedule by survey point, dates given for Pre-pregnancy and Breeding seasons 2009.

Week	Date	Survey Points				
1	12-31-08	43	47	97	184	165
2	1-7-09	136	2	185	182	155
3	1-14-09	17	153	178	190	55
4	1-21-09	156	41	191	15	187
5	1-28-09	157	189	193	134	179
6	2-4-09	28	143	130	176	57
7	2-11-09	186	192	56	159	140
8	2-18-09	48	177	132	26	142
9	2-25-09	10	150	144	65	173
10	3-4-09	169	4	152	161	167
11	3-11-09	146	39	69	139	54
12	3-18-09	145	174	71	149	164
13	3-25-09	166	49	9	183	172
14	4-1-09	8	14	35	138	172
15	4-8-09	170	162	133	141	52
1	4-29-09	43	47	97	184	165
2	5-6-09	136	2	185	182	155
3	5-13-09	175	153	178	190	55
4	5-20-09	156	41	191	15	187
5	5-27-09	157	189	193	134	179
6	6-3-09	28	143	130	176	57
7	6-10-09	186	192	56	159	140
8	6-17-09	48	177	132	26	142
9	6-24-09	10	150	144	65	173
10	7-1-09	169	4	152	161	167
11	7-8-09	146	39	69	139	54
12	7-15-09	145	174	71	149	164
13	7-22-09	166	49	9	183	172
14	7-29-09	8	14	35	138	172
15	8-5-09	170	162	133	141	52

The sampling effort allocation of approximately 15 sites per habitat type, sampled for seven nights each, was derived by considering the occupancy and detectability estimates generated by the pilot study within the sampling plan and power analysis framework outlined by Mackenzie *et al.* (2006). This framework provides a study design compatible with analysis in a single species, multiple season model analysis in the program PRESENCE. PRESENCE was developed be Mackenzie *et al.* (2002) and is available as freeware at http://www.proteus.co.nz. Because the probability of detecting a HHB's presence during a survey is not 100%, repeated sampling of survey locations will be used to estimate a detection probability as described by Mackenzie *et al.*

(2006). This detection probability can then be used to provide an unbiased estimate of actual occupancy.

Under Mackenzie *et al.*'s (2006) framework, the optimal number of surveys to conduct at each site (K) was indicated by using a table based on the pilot study's estimates of occupancy versus the estimated detection probability of HHB at PTA. Based on these estimates, each site should be surveyed seven nights. A maximum of 75 points can be surveyed given the restrictions of five detectors, each surveying one site every seven days over the course of 15 weeks.

Power analysis was conducted using the following formula (from MacKenzie *et al.* 2006) given the limitations of 75 points, a seven-day sample period, and the pilot study's estimations of occupancy and detectability:

$$S = \psi/Var(\psi)[(1-\psi)+(1-p^*)/(p^*-KMA\{1-p\}^{k-1})]$$

Where S = the optimal number of sites to survey, ψ = estimated occupancy, p = detection probability, K = Number of surveys per site, and $p^* = 1-(1-p)^k$ and $Var(\psi)$ = 91% confidence.

Differences in habitat occupancy will be compared by calculating and comparing HHB occupancy and their associated standard errors within surveyed locations. Comparisons of occupancy between the five habitat types (and later, between seasons and years) will be performed by direct comparisons and by using AIC and other model selection tools within PRESENCE.

The report on the results of the pilot study (Jacobs 2007) provides a comprehensive discussion of the study design recommendations which resulted in the development of many of the specific methods described above.

HHB Occupancy and Monitoring Protocols for the KMA

Project Overview: The protocols developed for HHB occupancy monitoring as described above have been adapted and applied to a similar study design on the KMA. Sampling will focus on the 15 week reproductive season, starting with the 2009 pre-pregnancy pilot study season. A total of 75 survey points were randomly generated in ArcGIS using Hawths Tools. Each point is no farther than 600 m and no closer than 200 m from a road, or 100 m from another point to prevent sampling along roadways that may be used as flight corridors or overlapping a sample area. Because of the extensive trail network in the KMA, survey points are fairly uniformly distributed over the entire parcel (Figure 3.4-4). Due to the low quality of the current land-cover map for the KMA, the distribution of survey points will be important in scouting the terrain for habitat classification. It is likely that a significant re-working of survey points will be required following the pre-pregnancy 2009 pilot season after the habitat classifications have been made.

During the pilot project, bat call data was collected at survey points and the vegetation quantified using the same Braun-Blanquet vegetation cover-plot with a 5 m radius surrounding the survey point methods as was used on PTA. It is important to use the same methods in order to allow for direct comparisons and pooling with PTA data. Survey point distribution is random within rough strata based on vegetation height and density characteristics as was done on PTA proper. Altitude is also being recorded as a covariate, but sample size may not be large enough for formal analysis if its impact is not dramatic.

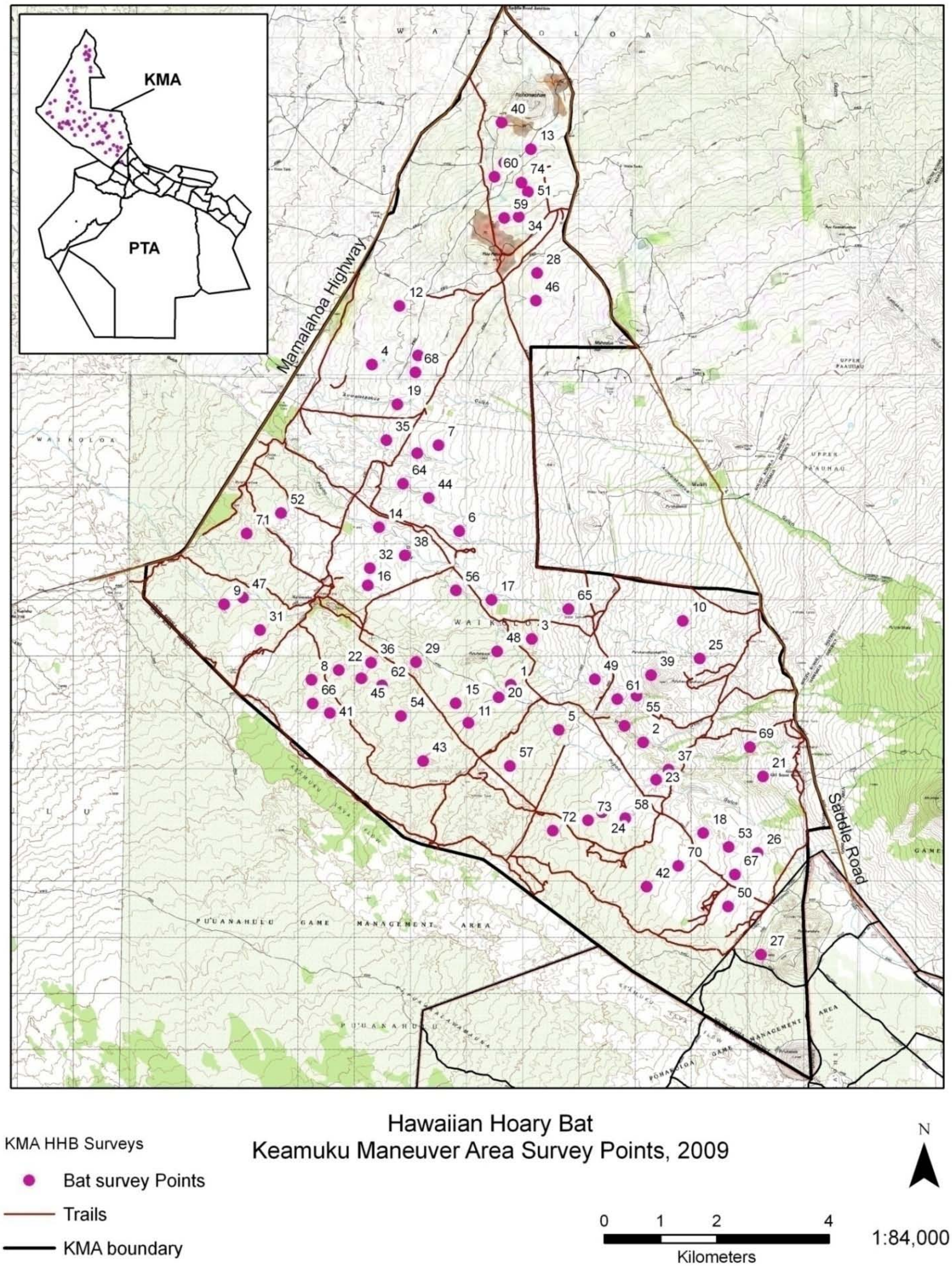


Figure 3.4-4. HHB KMA 2009 survey locations

3.5 Rodent Control Protocol

Figure 3.5-1. Replacing bait within the rodent control area.

Current Rodent Control Program

Introduced rodents are known to impact native plant species by consuming fruits, seeds and seedlings (Sugihara 1997). Although rodents damage native plants by browsing foliage and eating seeds and seedlings, their impacts on plants are poorly understood (Cole *et al.* 2008). In 2004 at PTA, rodents severely damaged and killed several seedling of the endangered *Neraudia ovata* by gnawing through their stems. In 2006, rodents gnawed the stems of *Solanum incompletum*. The fleshy, juicy fruits of S. *incompletum* and *N. ovata* as well as many other native plants are a potential source of moisture and nutrition for rodents (Clark 1982; Sugihara 1997).

Because of observed and potential rodent damage to *N. ovata* and *S. incompletum*, rodent control is conducted around most the naturally occurring and some outplants of these two species as required by the BO (Figure 3.5-2). Rodent control has not been initiated for a new population *S. incompletum,* which was discovered in 2007 in TA 18. At this time there are no plans to establish rodent control and may be a good opportunity to assess the impact of rodents to this species. The following two methods are used to remove rodents from the control areas.

Snap Trapping

Traps designed to kill rodents are used when it is imperative to remove rodents as quickly as possible from a sensitive resource (i.e., endangered plant seedlings). Traps are set in a grid or randomly to provide the most effective and efficient protection for the resource. Traps are baited with peanut butter or coconut. Dead animals should be removed from the trap using gloves and buried on site or double bagged in plastic and disposed of in the sanitary landfill.

Poison Baiting

Currently the poison blocks used to control rodents are Ramik® minibars because they are the only product registered for conservation use. The concentration according to the manufacture's label is 0.005% diphacinone, an anticoagulant. The bait blocks are placed inside Protecta® bait stations, which are all marked with our contact information in accordance with the Special Local Needs (SLN) label for using this restricted pesticide in natural areas of Hawai'i . In accordance with the SLN label, all control areas are marked with appropriate warning signs.

According to studies conducted at PTA, the best placement of bait stations to control both mice and rats is 25 m. In areas where rats are the main target species, box spacing can be moved to 50 m. To comply with the SLN label requirements, bait stations are placed around the resource in a grid. Bait stations and bait are secured according to the specifications on the SLN label.

Bait station are checked bi-weekly or monthly, depending on the remoteness of the control site, to ensure a continuous supply of bait is available to the rodents. The number of bait blocks is adjusted depending on the bait take during various seasons and control sites. Sixteen blocks is the maximum bait allowed by law. The number of bait blocks placed in each bait station is recorded using the appropriate field form. All SLN label requirements pertaining to personal protective equipment and handling instructions will be adhered to without exceptions. Dead animals inside the bait boxes should be removed using gloves and buried on site or doubled bagged in plastic and disposed of in a sanitary land fill. If buried on site, other non-target animals must not be able to access the carcass to prevent secondary poisoning. LIVE ANIMALS SHOULD NOT BE HANDLED. Allow the animal to leave the bait station. If the animal is not capable of departing the bait station, close the lid and leave the animal without replenishing the bait.

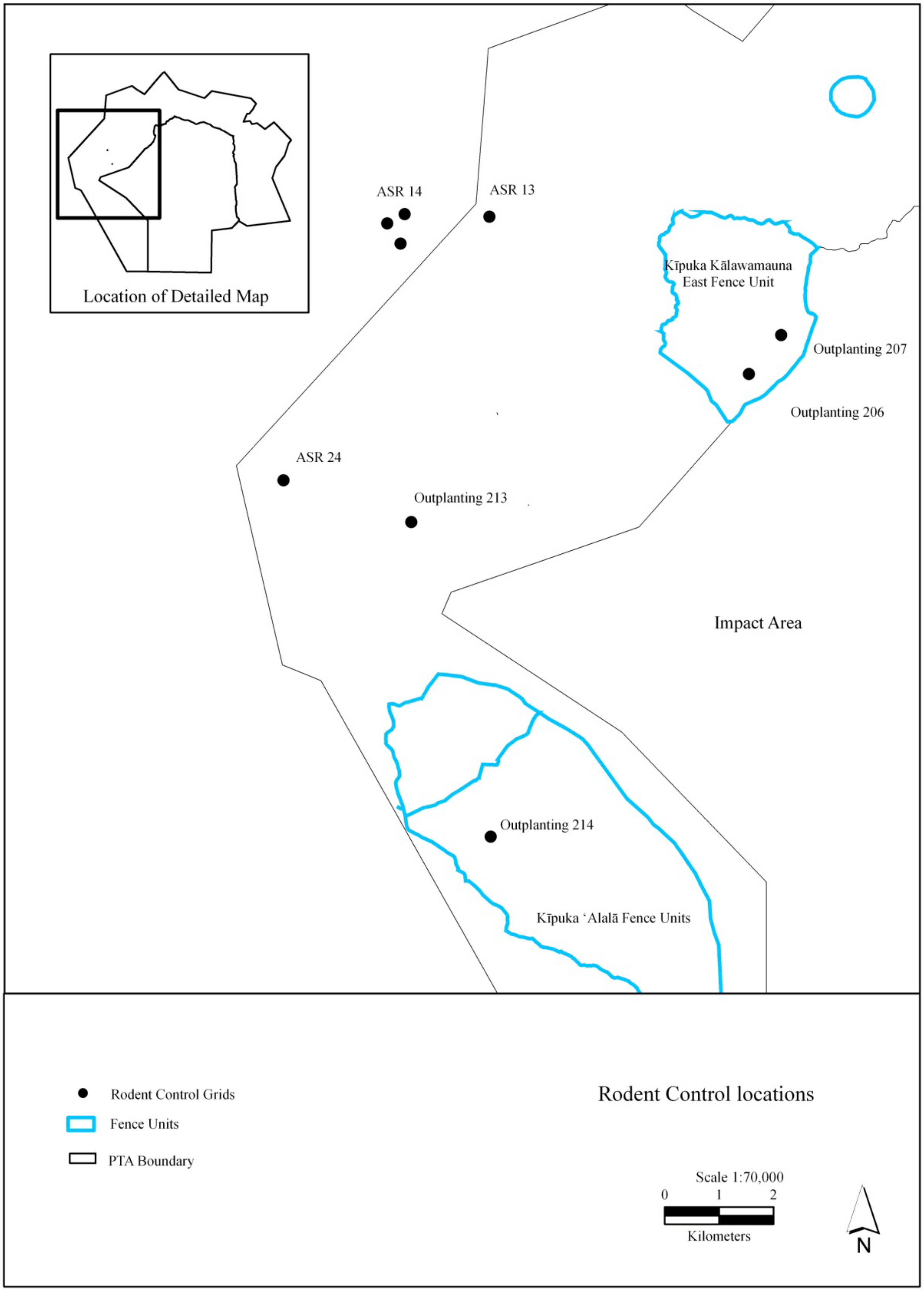


Figure 3.5-2. Current Rodent Control Sites

Additional Required Rodent Control:

In the 2003 BO, PTA NRO is required to control rodents around *Zanthoxylum hawaiiense*. Because *Z. hawaiiense* is widely distributed at PTA, designing a rodent control program will be challenging using conventional methods such as bait box application of rodenticide and snap trapping. A mouse was observed by Army Biologist Sean Gleason, with a *Z. hawaiiense* seed in its mouth in 2003 (Gleason, pers. comm. 2003). It is possible that rodents are having an adverse effect on germination and survival of young *Z. hawaiiense*. Before engaging in a large-scale rodent control program for *Z. hawaiiense*, more information is needed on the actual impact of rodents to this species.

PTA NRO plans to initiate a tracking study during 2009 around *Z. hawaiiense* females during their fruiting period to determine if rodents are consuming seeds. When such an individual tree is identified, fluorescent powder may be applied to the base of the tree, partway up the trunk, or on individual fruits if in reach of the ground, whichever methods are appropriate. This will occur within one week of identifying the individual fruiting female. Following application, use of a UV light at night to follow any rodent trails and look for seed caches or evidence of seed take in one to two weeks. This will involve intensive searching around the tree with the UV light and possibly excavation of seed caches. Trails can be followed one night, flagged with pin flags and seed caches excavated or investigated during daylight hours if it is very time consuming to follow powder trails. This initial study may determine if rodents are visiting or utilizing *Z. Hawaiiense*. Data collected will be observational and localized to whatever available opportunity though, and will not definitively prove or disprove potential impacts of rodents to the species. However, the information gained will be useful in developing a more systematic approach to monitoring potential impacts by rodents.

In conjunction with the rodent impact study, a study to learn more about *Z. Hawaiiense* will be initiated during 2009. More information is needed to understand the habits of this species to better determine management strategies. For example, the species is diocious yet only approximately 7% of the current known individuals have been sexed. Knowing the location of females is important to conduct studies on rodent impacts to seeds and seedlings. A subset of trees from the population will be selected based upon multiple criteria, which include location, substrate (Figure 3.5-3), density and phenology. These criteria will ensure a representative sample will be selected. Initially, an estimated 140 trees will be randomly selected (with the exception that the female tress already identified will be included in the sample).

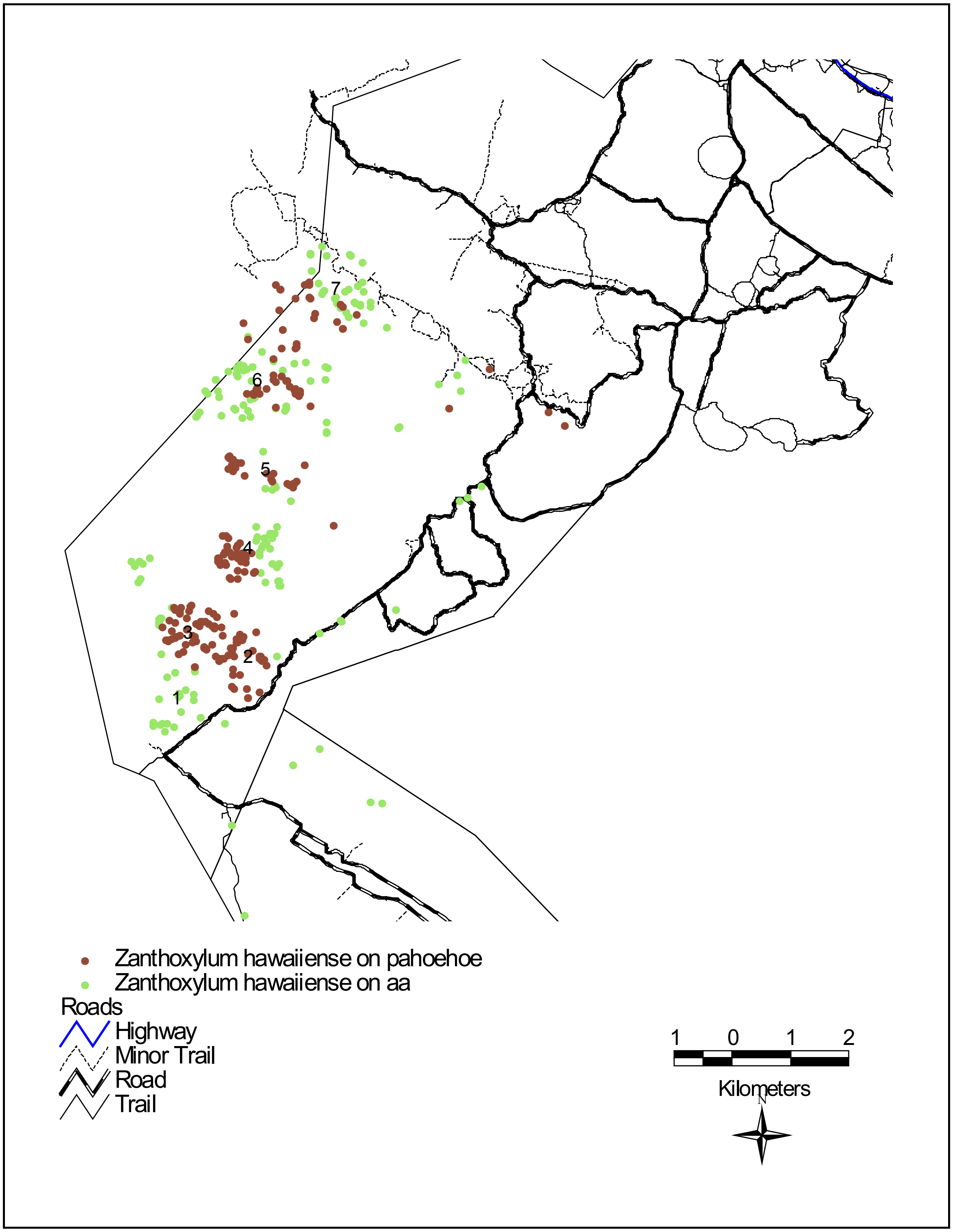


Figure 3.5-3. Location of *Z. hawaiiense* in West PTA.

The selected trees will be visited and basic data collected including: tree measurements such as diameter, height and canopy size; and phenological assessments such as vigor, sex, reproductive structures and counts, and browse. Locations will be added or individuals revisited until a representative sample of approximately 70 individuals are selected. This sample will be subject of regular (initially bi-monthly) monitoring and a subset of these will receive various management strategies, including combinations of fencing, weed control and further monitoring for rodent impacts.

If rodents are found to significantly impact *Z. Hawaiiense*, controlling rodents around a significant number of trees will be difficult using conventional control methods because this species is so widely distributed. PTA NRO has been investigating two alternative control methods. Recently approved broadcast rodenticide application methods may be useful for control around *Z. Hawaiiense* as well as several other rare species at PTA. PTA NRO is planning to conduct a small-scale broadcast of diphacinone in areas on the western side of PTA in order to assess the conservation benefits of broadcast versus bait box applications. Upon completing all necessary permitting documents, PTA NRO will conduct a limited broadcast in 2009. This initial broadcast will incorporate rodent population monitoring with broadcast areas of different sizes in order to determine site-specific methods for PTA.

Another promising technology that PTA NRO is investigating is predator proof fencing. A proposal to have an area with *Z. Hawaiiense* fenced using a technique which excludes rodents was submitted to the Island Conservation Legacy Funds Project, which has Legacy grant money for constructing predator proof fencing on Department of Defense lands. If the PTA site is chosen for construction, the effectiveness of predator proof fencing and continuous rodent control using rodenticide can be compared.

3.6 Invasive Invertebrate Monitoring and Control Protocol

Figure 3.6-1. Argentine ants infesting a *S. lanceolata* inflorescence

Introduction

Invasive invertebrate monitoring and management at PTA will focus on social insects of the *Hymenoptera* order (i.e. ants and wasps). Other invasive invertebrates may be present at PTA, however no management approaches or research priorities have currently been identified.

3.6.1 ANTS

There are no native ant species in Hawai‘i . Several ant species have been documented at PTA including *Cardiocondyla venustula, Hypoponera opaciceps, Linepithema humile* (Argentine ant), *Monomorium latinode*, *Pheidole megacephala* (big-headed ant), *Tapinoma melanocephalum* (tiny yellow house ant), and *Technomyrmex albipes* (Oboyski 1998; Oboyski *et al.* 2001). New ant species also continue to be introduced and colonize the Island of Hawai‘i . A new species, *Monomorium indicum*, was found by State entomologists at Kawaihae Harbor in early 2007. Invasive ant species are predators of other arthropods and *L. humile* and *P. megacephala* have been implicated in declines of native Hawaiian arthropods (Oboyski *et al.* 2001). *Linepithema humile* is known to colonize high elevation areas and has been shown to reduce populations of important native pollinators such as *Hylaeus* sp., ground nesting native bees (Cole *et al.* 1992). *Linepithema humile* have also been observed creating dead ant “bridges” across the sticky inflorescence of *Silene lanceolata,* potentially robbing nectar and damaging flowers.

Invasive ants may disrupt native ecosystem function and ultimately pose a significant threat to the health of native and endangered plant species. Ants are known to tend alien pests such as aphids and scale insects, which impact plant vigor and may serve as a vector for further spread of plant disease (Messing *et al.* 2007). Foraging ants may impact fruit development and seed set of endangered plants and indirectly affect pollination by attacking native arthropods. It is vital to monitor key entry points for incipient infestations and to map the current distribution of problematic ants such as Argentine and Big-headed ants. Once the extent of the infestation is determined, control can be considered both on a local scale around sensitive rare plant species and potentially on a landscape scale (if determined to be feasible). Additional research is currently needed to develop efficient and effective control methods for landscape scale management.

Monitoring for incipient ant invasions

It is recognized that invasive ant species pose a tremendous threat to the environment, commerce and even human health. Several organizations both in Hawai‘i and internationally, have recognized this fact and have made attempts to improve the prevention, early detection and response to incipient invaders (Pacific Ant Prevention Plan 2004; Hawaiian Ant Group 2007). Ants should be monitored on a semi-annual basis at key entry points to identify incipient ant species. Because most of the equipment used at PTA passes through Kawaihae Harbor, monitoring in this area is essential to detecting any new ant species. Bradshaw Army Airfield is another key entry point that should be considered, particularly if the airfield is expected to receive increased usage. Other monitoring locations should focus on areas where equipment is stored before being deployed to the field such as the main motor pool, Range Maintenance and Department of Public Work’s storage areas. Monitoring these sites is a valuable step towards developing a rapid response plan for early eradication of invasive ant species.

METHOD

Baiting cards (7.6 x 12.7 cm index card) with a mixture of corn syrup and tuna, will be placed in a grid pattern over the monitoring area every five meters (Hartley and Lester 2005). To maximize the chance of detecting ants that prefer carbohydrate heavy baits, such as the little fire ant (*Wasmannia auropunctata*), peanut butter bait will be used at every other bait card. It is important to target areas that ants will likely be found such as grassy or vegetated habitats, piles of equipment/supplies and trash bins. Cards will be left for one hour and vouchers collected with an aspirator (Hartley and Lester 2005). Specimens collected will be frozen and identified at PTA unless expert opinion is required. If an ant species cannot be identified it will be sent to the State Entomologist or other expert for identification. Incipient monitoring information will be kept in a database along with spatial data documenting monitoring locations.

Responding to incipient ant invasions

Although PTA already has two of the more problematic invasive ant species in Hawai‘i, the big-headed and Argentine ant, the most viable hope for limiting damage to PTA’s natural resources is catching incipient ant species early and eradicating them. Following the initiation of semi-annual monitoring at high-risk entry locations, the PTA natural resource program will assess the baseline of ant species present at these disturbed sites. Any species, such as the little fire ant, considered by the IT to be a risk to PTAs natural resources should be considered for immediate eradication if feasible. Future monitoring is intended to alert the natural resource program to any additional species that may be introduced. If an invasive ant species is detected, surveys utilizing the methods for mapping described below will be conducted as soon as possible. If the area infested is small enough and methods for eradication are feasible, than the natural resource program will treat the affected areas, upon consultation with Hawai‘i Department of Agriculture Pesticides Branch.

Mapping the extent of ant populations:

Before a comprehensive control strategy can be developed for PTA, the extant populations of Argentine and Big-headed ants should be mapped. Small-scale investigations of Argentine ants were conducted from 1997 to 2005 in Training Areas (TA) 2, 10, 11, 17, 19, 20, 22 and 23 (Oboyski 1998; Oboyski *et al.* 2001, PTA unpub. data). Work delineating the Argentine ant population in TA 23 was last done in 2004. In 2008, an infestation in TA 22 was mapped in the context of control trials described below (PTA unpub. data). Argentine ants are suspected of covering several square kilometers or more at PTA. To more clearly delineate the area infested, initial surveys using bait cards should be conducted road-side for ease of access and efficiency.

METHOD

Bait cards (as described in above methods) will be placed every 500 m along main PTA roads. If possible, mapping should begin in spring when ant numbers are increasing from the winter. Once presence has been documented along the main road network, surveys can begin to determine how far ant populations penetrate the surrounding habitat by placing baits along transects that traverse the habitat. Once the general distribution is determined, finer detailed surveys will take place along the invasion fronts as necessary. Bait station spacing will be reduced to 50 m (or finer) to get a more accurate delineation of the invasion front. Once the distribution is roughly mapped, appropriate control, containment or eradication methods can be planned and implemented. In 1998, Oboyski found Big-headed ants at three sampling sites in TAs 4 and 16. Subsequently, big-headed ants have been found during incidental collections in a number of other sites including TAs 21, 22, 23 and on Pu‘u Pāpapa within the Ke‘āmuku Parcel (PTA unpub. data). Additional survey effort should be applied in these areas to document the spread of this problematic and aggressive ant species (Oboyski 1998).

Small-scale ant control:

Because landscape scale techniques to control ants are not effective at eradicating ants at this time, current control efforts should focus on small-scale areas around sensitive natural resources.

METHOD

Starting in late May 2008, prior to a targeted application of Maxforce Fine Grain - Granular Ant Bait (hydramethylnon), each plot within TA 22 to be used in control trials was monitored for foraging ant activity using the method of Krushelnycky and Reimer (1998). Four 30 x 45 m plots were treated at random to compare with four untreated plots. All plots were spaced at least 60 m from each other. In place of fermented fish bait, a four cm^2 patch of corn syrup and tuna bait as described in methods above, was utilized. Monitoring cards were placed near plot center in shaded or vegetated locations and left for approximately 60 minutes. Several digital photographs were taken; cards were then retrieved and placed in a ziplock bag. Foraging ants at the baiting card were enumerated from the digital photograph and vouchers positively identified under magnification. Three days of bait card monitoring over six days was used to estimate diurnal variation and establish a baseline estimate for the number of foraging workers near plot center.

After the three initial days of monitoring, no additional specimens were collected - as repeated collection appeared to be decreasing local foraging ant activity at all plots.

After initial monitoring, Maxforce was applied using a spinning disk type spreader at a rate of 2.25 kg/ha (Krushelnycky and Reimer 1998). For even toxicant application throughout the plot, meter tapes were stretched from plot corners and center stakes. Using the tapes as a guide, Maxforce was spread in a radius at 18 evenly spaced locations throughout the plot. Following treatment, all plots were monitored with bait cards as above, after one and two weeks. Monitoring then continued each month thereafter for a total of four months. Excellent control lasted for at least 42 days after application of toxicant and reduced foraging ant numbers were still apparent after 106 days at control plot locations.

3.6.2 *VESPULA PENSYLVANICA* MONITORING AND CONTROL

Vespula pensylvanica are widespread and abundant at PTA and may be particularly abundant in *Metrosideros polymorpha* forests (Oboyski 1998; Oboyski *et al.* 2001). In Hawaiʻi , *V. pensylvanica* have been documented feeding on insects from nine orders and about 2/3 of the prey insects were endemic (Gambino *et al.* 1987). It is probable that *V. pensylvanica* are having a detrimental impact on the native arthropods at PTA.

Vespula Monitoring

A road-side monitoring program will be established in conjunction with USGS-BRD. Using protocols developed by the USGS-BRD traps baited with heptyl butyrate will be hung from ʻŌhiʻa trees or other vegetation along road-side every 60 meters. A total of 10 traps will be placed in each of five monitoring areas. Traps will be checked and re-baited once a month and queens identified and counted. Data will be store in a database and compared with USGS-BRD monitoring to better gauge the relative magnitude of wasp abundance at PTA compared to sites with long-term monitoring data from Hawaiʻi Volcanoes National Park.

Vespula small-scale control

Because *V. pensylvanica* are drawn to water, they are often a safety concern around campsites and outplanting areas where water is used extensively. Simple water funnel traps or traps with heptyl butyrate will be used at these sites to reduce the number of foragers and reduce the risk of personnel being stung. If possible traps will be placed up to two weeks prior to work commencing in the areas.

A pilot control study will be set up in the *Metrosideros polymorpha* forests in TA 22 within *Hedyotis coriacea* habitat. Traps using heptyl butyrate will be placed in a grid pattern over the plant population. Stations will be placed every 160 meters and cover 128 acres (51 hectares). Thirty traps will be required to cover this area. Trapping will begin in May to trap as many queens as possible and continue through October. The traps will be visited monthly. If traps are full, more frequent trips will be made to ensure trap success. Trap success increases when heptyl butyrate is released slowly over time (Landolt *et al.* 2003). If feasible, heptyl butyrate will be placed on a paper wick inside a microcentrifuge tube. Between July and September, observations will be made once a month within the control perimeter to locate additional nests. If nests are located, they will be treated with Delta Dust according to the product label, which usually kills the nest in dry habitat in a single application (Foote pers. comm. 2007).

Research at Cornell University has shown that traps at the center of a plot with perimeter traps usually capture fewer wasps than traps at the center of a plot without perimeter traps (Baraband 2007). The numbers of wasps in the perimeter traps will be compared to the traps in the central portion of the grid to determine if there is a difference in the number of wasps caught. Population monitoring will also be established in adjacent habitat for comparison.

4.0 LARGE-SCALE FENCING, FIRE BREAK SYSTEM, AND UNGULATE REMOVAL

Figure 4.0-1. Fence Crew clipping wire mesh to T-posts.

4.1 Introduction

Hawai‘i’s remaining dryland forest ecosystems have been severely fragmented and degraded by deforestation, land development, fire, nonnative ungulate grazing, and invasions by alien plant species. In Hawai‘i, reducing or completely removing grazing ungulates from native ecosystems through the use of large-scale fencing and ungulate removal is often considered a key first step toward promoting the recovery of native vegetation (Cabin *et al.* 2000). Continued grazing by feral ungulates often destroys native vegetation and increases ecosystem vulnerability to alien species invasions. In fact, direct browsing by ungulates and/or habitat destruction caused by ungulate presence is listed in the recovery plans as the primary threat for all of the federally listed plant species at PTA (USFWS 1993; 1994; 1996a; 1996b; 1997; 1998a; 1998b; and 1999). Fencing is listed as a priority 1 task within the recovery plans. Priority 1 tasks are those that the USFWS considers necessary to prevent the extinction of a species or to prevent the species from declining irreversibly.

The control of ungulates at PTA is also a top management priority for the Army. Where ungulate numbers are relatively high, such as the māmane/naio (*Sophora/Myoporum*) forests, trees have a distinct browse line. Additionally, sheep and goats impact fragile cave resources, transmit weeds, and disturb soil layers. Feral pigs are also found in many areas of PTA. Pigs impact native and endangered plants through browsing, trampling, and rooting (RCUH 2003). Fifteen endangered and threatened plant species still survive at PTA, many of which are not currently known to occur elsewhere in the world. Because many native plant species have lost "predator defenses" such as thorns and chemicals, they are preferentially selected by ungulates as forage (RCUH 2003).

In addition to the ungulates' direct impact on native and endangered species, there are also long-term effects to the prolonged existence of ecosystems. Ungulates impact not only individual plants, but the life cycle of the species as well. The continued presence of ungulates impacts young plants, preventing them from reaching maturity, and eliminating them from contributing to the seed bank. The only inputs to the seed bank are from aging, mature plants. Once these mature plants reach the end of their life cycle and die, the contributions to the seed bank are reduced. Over time fewer plants are contributing to the seed bank, those seeds that germinate are consumed by ungulates, and eventually there are no seed producing plants, effectively removing the entire species from the ecosystem. Native woody plants tend to be replaced by invasive grass or forb species, leading to a general degradation of the vegetative community. This has been repeatedly confirmed by field research in Hawai‘i's dry communities (Scowcroft and Giffin 1983; Scowcroft and Sakai 1983; Stone *et al.* 1992; Scowcroft and Conrad 1992; and RCUH 2003). Multiple exclosure experiments have demonstrated strong beneficial effects to native flora and fauna due to ungulate exclusion, and have also demonstrated that heavily degraded ecosystems recover very slowly while those not severely damaged show good recoveries (Baker and Reeser 1972; Loope and Scowcroft 1985; Cabin *et al.* 2000; and RCUH 2003). It is therefore essential to stop the degradation of unique PTA ecosystems in order to enhance the opportunity for their recovery.

Evidence from both Hawai‘i Volcanoes and Haleakalā National Parks indicate that damaged ecosystems can show notable recovery after 10 to 50 years of protection from feral animals. Scowcroft and Conrad (1992) conducted a study on the effects of recovery of vegetation following removal of feral sheep on the subalpine woodland of Mauna Kea. This study demonstrated that release from ungulate browsing benefited native plant species, such as *Sophora chrysophylla*, *Chenopodium oahuense*, *Triserum glomeratum*, and *Agrostis sandwicensis*, which became reestablished and spread in spite of the presence of alien plants, provided that the areas were not fully occupied by alien plant species. They found a similar response with removal of the introduced Mouflon sheep. Stone *et al.* (1992) and Loope and Scowcroft (1985) reported a similar recovery of māmane and the native bunchgrass (*Deschampsia nubigena*) at high elevation with goat/pig exclusion. Loope and Scowcroft (1985) summarizing exclosure four studies statewide concluded that feral ungulates have had an "overwhelming" influence on Hawaiian vegetation. Stone *et al.* (1992) concluded that feral pigs and goats are major stresses on native ecosystems and their exclusion usually results in recovery of native species, especially where alien plant cover is low.

Feral ungulates are considered one of the major threats to threatened and endangered species at PTA. The foraging activities of ungulates have been observed to disturb and degrade habitats, which consequently contribute significantly to the spread of alien weeds. Once an area has been disturbed, alien weeds can become established and often out-compete native species. At PTA, weedy species tend to be highly combustible and, as a result, their spread further threatens native ecosystems by increasing the risk of fire. One of the top priorities in the recovery plans for PTA species is the protection from ungulates in conjunction with weed and fire control. Most of the recovery plans state that the species included in the plans cannot afford to wait for the protection from ungulates.

An effective method for providing protection from introduced ungulates in Hawai'i is fencing of management units, accompanied by the removal of ungulates from within the fenced areas. Although this approach is costly, it does work as demonstrated at Hawai'i Volcanoes and Haleakalā National Parks, Hakalau Forest National Wildlife Refuge, and existing fence units on, and adjacent to, PTA.

Recovery plans usually recommend large-scale fencing for long-term protection of a species. Large fence units protect not only individual plants, but also the habitat and resources on which they depend. In contrast, small-scale fencing or constructing exclosures around individual plants do not provide long-term protection because they do not allow for any protected natural regeneration and should only be used to protect those populations under immediate threat from ungulates while longer-term, large-scale fencing projects are being undertaken. Additionally, fencing of individual plants could inadvertently have detrimental effects as the resources on which it depends are slowly degraded to the point at which the resources are no longer adequate to meet the needs of the individual.

Ungulate exclusion fences have been established at several locations on PTA. In April of 1999, a 33 acre (13.5 ha) fence unit was completed in TA 3 to Protect *Silene*. In May of 1999, monitoring plots were established on both the inside and outside of the fence unit to assess the effects of ungulate exclusion on this species. The initial monitoring in 1999 served as a baseline to which subsequent years of monitoring were compared. Four years after fence completion, monitoring and analysis demonstrated that in 2002 the average plant height was greater inside of the fence unit than it was outside. In addition, average plant heights inside the fence unit in 2001 and 2002 increased from the baseline average in 1999. During the same time period, the average height for plants outside the fence unit remained relatively unchanged. These differences were attributed to higher browse frequencies on plants outside the fence unit. The lack of protection for plants outside the fence unit leaves them vulnerable to ungulates. The study has shown that the reduction of ungulate pressures on this species can have significant positive effects in a relatively short period of time (RCUH 2003).

Other fence units on PTA include the Kīpuka Kālawamauna East Fence Unit that is located in the northwest portion of PTA is 1,971 acre (798 ha); Kīpuka 'Alalā Fence Units, consisting of a combined 5,074 acre (2,053 ha) in the southwest portion of PTA; Pu'u Ka Pele Fence Unit, consisting of 111 acre (45 ha) of which one-third is on Army land; and the 33 acre (13.4 ha) *S.* Fence Unit located close to the old Saddle Road. Vegetation monitoring plots and transects have been established for rare plant populations that occur both inside and outside of the fence units. Because these fence units have not been in place long enough, long-term data are not available to make statistically sound conclusions regarding the effects of fencing and ungulate removal on rare plant populations at PTA. However, the monitoring data for *S.*, gathered from 1999-2002, provides evidence of the positive effects of fencing and ungulate removal. In addition, māmane (*Sophora chrysophylla*), 'akoko (*Chamaesyce olowaluana*) and other native trees are rapidly regenerating inside the Kīpuka 'Alalā Fence Units, further demonstrating the ability of the native ecosystem to recover in the absence of ungulate pressure.

The fencing of large areas of land will allow the Army to manage lands at PTA through an ecosystem approach. An ecosystem management approach is considered by the Army to be a more sustainable and effective method to protect threatened and endangered plants, rather than constructing exclosures around individual plants. Ecosystem management is a planning and implementation process that seeks to conserve ecosystem processes and function while acknowledging the importance of human needs (US Army, Hawai‘i 2002). The proposed fencing would significantly reduce the further decline of the native ecosystem on PTA and promote the conservation of the listed species that depend on this ecosystem. An ecosystem management strategy enables the Army to conduct military training at PTA while conserving the natural resources upon which that training ultimately depends, as well as to comply with all applicable laws and regulations. Maintaining functional ecosystems ultimately supports sustainable training since ecosystems that lose key ecological functions become degraded and loss of training realism follows.

Summary of Biological Assessment and Opinion Requirements

The following is a summary of the large-scale fence units required in the 2003 and 2008 Biological Assessments and Opinions.

Western Fence Units: The Army shall construct fence units on the western portion of PTA to minimize threats to federally listed plants and the Hawaiian hoary bat. This will be in addition to the 7,166 acres (2,900 ha) of existing fence units at PTA. The size of the fence units will total approximately 21,500 acres (8,700 ha) but exact acreage will depend upon the final positioning of the fence boundaries.

They will be constructed to encircle most of the plants present in the western section of the installation and the southern corner of the Ke‘āmuku Parcel and will incorporate the remaining areas that contain the highest densities of listed plants. They will connect with the northern section of the existing Kīpuka ‘Alalā Fence Units. Specifically, they will encircle TAs 19, 22, and parts of TA 17 and 20.

In addition, fence units will be constructed around all known occurrences of *Zanthoxylum Hawaiiense* and all individuals of *Hedyotis coriacea, Neraudia ovata*, and *Solanum incompletum* will be included in the western fence units unless they are located on non-Army lands. This provision will require the construction of a fence unit in TA 23, north of the current Kīpuka ‘Alalā Fence Units.

The fence units will include a 75 m buffer from listed plant occurrences, unless otherwise approved by the Implementation Team. The fence unit shall be completed by December 2008, and may be constructed in phases, but with demonstrable progress accomplished by the end of each year. All ungulates shall be removed from the new fence units by 2010. Fence units around Pu‘u Pāpapa and Pu‘u Nohona o Hae will be maintained ungulate free. An annual aerial survey of each fenced area shall be conducted after 2010 to ensure that ungulates have not returned to the fence units. Ground surveys will ensure the fence lines are intact. If ungulates are observed, appropriate hunts or snaring shall immediately commence to remove these animals. Complete removal of ungulates may be difficult to maintain at all times due to the size, topography and/or density of vegetation within the various exclosures, however, the goal is to have all fence units as ungulate free as practicable. The *H. haplostachya* plants on Pu‘u Ka Pele will be protected from off-road maneuvers by an existing fence that shall remain post-Transformation.

Haplostachys haplostachya Fence Unit: A permanent fence will be constructed around a grouping of *H. haplostachya* near Pu‘u Ahi where currently only a single-strand “people” fence exists.

S. Fence Unit: A sixth fence, in the eastern area of PTA that encloses several *S.* plants, will be maintained.

Per the 2003 BO, all *Solanum incompletum* on PTA were to be fenced. The newly discovered individuals will be enclosed within the proposed conservation fence for the area.

To minimize the impact of existing barbed wire to Hawaiian hoary bats, the army will implement the following actions: The Army maintains all existing Natural Resource Program fences. Many of these fences are in need of upgrades, repairs, or replacement. As the Army modifies these fences, they will remove any existing barbed wire; No new barbed wire will be installed; The fencing modification will be completed by 2018.

Eastern Fence Units: The Eastern Fence Units identified in the 2003 BO have been superseded by requirements in the 2008 BO with the fencing of Training Area 21.

Conservation fencing will be installed at Training Area 21 to protect *Asplenium peruvianum* var. *insulare* and *Silene*. The fencing will also protect the majority of the 300 caves in Training Area 21 that are believed to have potential habitat for *A. peruvianum* var. *insulare*

Ke‘āmuku Parcel Fence Units: Two fence units with 75 m buffers will be constructed around Pu‘u Pāpapa and Pu'u Nohona o Hae in the Ke‘āmuku Parcel. The fence units will protect *Isodendrion hosakae*, *Melanthera venosa*, and *Vigna o-wahuens*is and all training activities will be prohibited within these two fence units. A 75 m buffer shall be included in the Ke‘āmuku fence units to reduce indirect effects of Army training (off-road maneuver) and maintenance of fuel modification areas on plants near the base of the cinder cones.

4.2 Large-scale Fence Unit Construction

Figure 4.2-1. Drilling post-holes in rock.

In 2006, NEPA requirements were fulfilled and construction of large-scale fence units at PTA was initiated. Significant milestones accomplished include the hiring of a Fence Coordinator, determination of the PTA boundaries where fence lines are proposed for construction, development and completion of the Programmatic Environmental Assessment and Finding of No Significant Impact for the Construction of Large-Scale Fences at PTA, natural and cultural resource surveys along the majority of all fence lines, hiring four fence crew leaders and 15 fence crew members, and acquiring equipment, materials and supplies necessary for completing approximately 25 miles of fence line.

Requirements identified for large-scale fence units in the Biological Opinion (USFWS 2003, 2008) and progress toward their satisfaction are summarized in Table 4.2-1. Initiation of Section 7 Consultation in 2008 resulted in a Biological Assessment and Biological Opinion. New requirements for fence units requires the construction of the *Solanum incompletum* Fence Unit, redesign of the five Pu‘u Koli Fence Units into a single and much larger Pu‘u Koli Fence Unit, replacement of the pre-existing four-foot fence material with six-foot fence material, and removal of barbed wire from pre-existing fence lines. To date approximately 37.3 km (23.51 mi) of the planned 64.5 km (40.1 mi) of fence unit. The status and specific linear distance of each fence unit segment for 2008 can be found in Table 4.2-1 and Figure 4.2-3.

Figure 4.2-2. Fence Crew aligning and setting posts.

Table 4.2-1. Summary of regulatory and construction issues related to large-scale fence units.

Fence Unit	Area/ Perimeter*	Surveyed**	SHPO Completed	UXO Clearance Completed	Fence-line Preparations	Corner Posts/Braces Set*	Wire fabric Attached*	Completion Date/Anticipated Completion
Haplostachys haplostachya	165 ac 2.0 mi	Yes	Yes	NA	Yes	Yes	Yes	Completed 2006
Hedyotis coriacea	975 ac 6.4 mi	Yes	Yes	Yes	3.5 mi	5.5 mi	2.6 mi	Mid 2009
Kīpuka Kālawamauna West	3,361 ac 13.2 mi	Yes	Yes	NA	6.2 mi	6.2 mi	4.7 mi	Late 2010
Kīpuka Kālawamauna North	5,342 ac 12.9 mi	Yes	Yes	NA	Yes	Yes	10.4 mi	Completed 2009
Mixed Tree	5,157 ac 12.2 mi	Yes	Yes	Yes	7.8 mi	6.4 mi	6.4 mi	Late 2009
Nāʻōhuleʻelua	4,086 ac 11.6 mi	Yes	Yes	Yes	No	No	No	Late 2010
Puʻu Koli	11,650 ac 19.9 mi	No	No	2008	No	No	No	2012
Puʻu Nohona o Hae	205 ac 2.2 mi	Yes	Yes	NA	No	No	No	Late 2009
Puʻu Pāpapa	71 ac 1.4 mi	Yes	Yes	NA	Yes	Yes	Yes	Completed 2008
Solanum incompletum	287 ac 3.2 mi	Partial	No	NA	No	No	No	Late 2009
Upgrade/Barbed wire removal	Miles/Mile s							
Kīpuka ʻAlalā North	1.4/5.5 mi	TBD	TBD	TBD	NA	No	No	By 2018
Kīpuka ʻAlalā South	9.4/11.4 mi	TBD	TBD	TBD	NA	No	No	By 2018
Kīpuka Kālawamauna West	2.5/7.6 mi	TBD	TBD	TBD	NA	No	No	By 2018
Silene	1.0/1.0 mi	TBD	TBD	NA	NA	No	No	By 2018

* Includes previously installed fence lines and common boundary fence lines.
**Surveyed for cultural and natural resources.

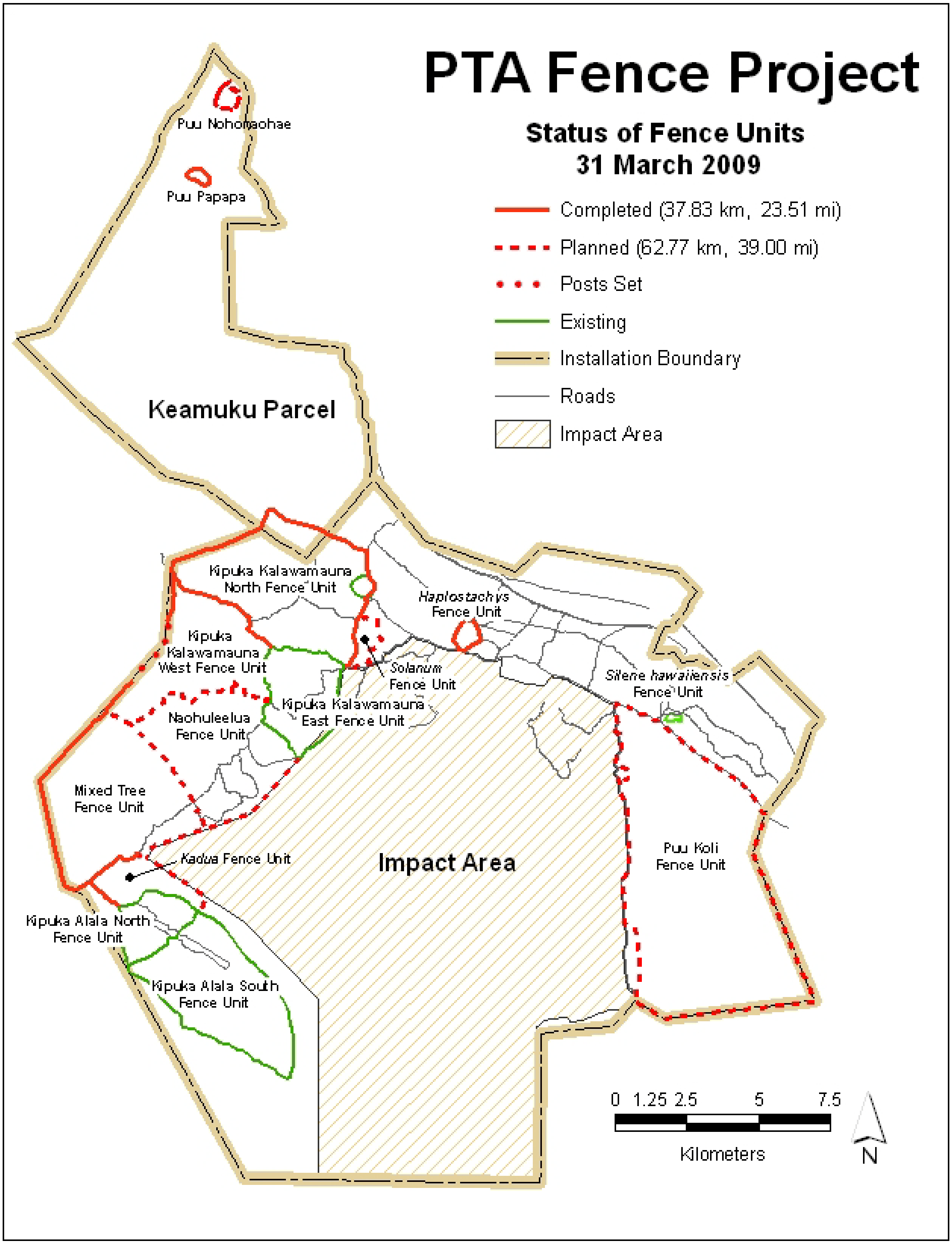


Figure 4.2-3. Status of the construction of large-scale fence units at PTA.

4.3 Feral Ungulate Removal and Monitoring

Figure 4.3-1. Goats at PTA.

Feral ungulate monitoring and removal are ongoing activities, which are contracted by the Army to a professional animal control company. Because sheep and goats have strong herding instincts, animals ("Judas") are fitted with radio-transmitters mounted on collars and released inside completed fence units. Currently one animal with a radio collar is inside the Kīpuka ʻAlalā North and South Fence Units, as well as the Kīpuka Kālawamauna Fence Unit. Detections of non-Judas animals inside fence units by NRS and other PTA personnel are reported to contract hunters who then follow up and take action to remove the animals.

Several juvenile goats were seen inside the *H haplostachya* Fence Unit in late 2008 and were removed in early 2009. The perimeter of the *H. haplostachya* Fence Unit was inspected and no damage to the fence or other obvious point of infiltration was noticed. This unit is currently ungulate free. No other fence units have been closed at this time so ungulate removal efforts are not currently required. NRO is currently working on a plan to involve the public hunters to remove animals from fence units as they are completed. The proposed plan will allow public hunters to remove animals for the first four months after the fence is completed, then professional aerial and ground hunts will remove the remaining ungulates.

5.0 SUMMARY OF IMPLEMENTATION SCHEDULE AND BUDGETS (20 YEARS)

Figure 5.0-1. Sunset on Mauna Kea.

5.1 Total Expenditures for twenty-year life of the PIP:

Full implementation of the PIP is estimated to cost $4.51million for the first year, and up to $9.19 million for the twentieth year. Estimated total programmatic costs are $136 million over 20 years. This figure is subject to change depending on timing of implementation of actions. It should be noted that the PIP is subject to the availability of funds and nothing in this plan should be interpreted to violate the Anti-deficiency Act. The Army intends to fund the program through its operating funds each year. By taking an active role to determine the best available practices and the highest priority threat management needs, the Army's conservation efforts will be in the forefront of species conservation in Hawai‘i . Successful implementation of the PIP assures that the Army will be in compliance with the Endangered Species Act and still accomplish its training mission.

Table 5.0-1. Summary - Pohakuloa Implementation Plan Estimated Personnel and Program Support Costs (20 years)

		Annual Cost by Year (000s)																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total (000s)
PERSONNEL																						
(by Program area; includes wages and benefits; all positions through contracting agency)																						
Implementation Plan Manager	(1)	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	1,920
Botanical Program	Program Manager (1)	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	1,580
Rare Plant Monitoring	Coordinator (1)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	1,200
	Crew leader (1)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	1,000
	Crew (5)	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	4,200
Rare Plant Outplanting	Coordinator (1)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	1,200
	Crew leader (1)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	1,000
	Crew (3)	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	2,520
Rare Plant Survey and Protection (shared staff with Rare Plant Monitoring)	Coordinator (1)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	1,200
Invasive Plants Control Program	Program Manager (1)	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	1,580
Fire/Fuel Breaks	Coordinator (1)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	1,200
	Crew leader (1)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	1,000
	Crew (6)	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	5,040
Rare Plant Weed Control	Coordinator (1)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	1,200
	Crew leader (3)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	3,000
	Crew (15)	630	630	630	630	630	630	630	630	630	630	630	630	630	630	630	630	630	630	630	630	12,600
Incipient Weed Control (shared fucntion with Rare Plant Weed Control)																						

Table 5.0-1. Summary - Pohakuloa Implementation Plan Estimated Personnel and Program Support Costs (20 years)

		Annual Cost by Year (000s)																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total (000s)
Wildlife Program	Program Manager (1)	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	1,580
Hawaiin Hoary Bat	Coordinator (1)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	1,200
Nene	Coordinator (1)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	1,200
General (hawk, petrel, forest birds, ferals control)	Crew leader (1)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	1,000
	Crew (7)	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	5,880
(crew leader and crew multifunction for all Wildlife Program)																						
Administraive Program	Program Manager (1)	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	1,580
	Aministrative assistant (1)	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	840
	Operations assistant (1)	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	840
GIS / Database Program	Program Manager (1)	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	1,580
	GIS / Database technician (1)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	1,000
Fence Insp/Maint Program	Coordinator (1)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	1,200
	Crew (2)	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	1,680
Fence Const/Upgrade Program	Coordinator (1)	0	60	60	60	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	240
	Crew (17)	0	714	714	714	714	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,856
FACILITIES																						
Plant Propagation Facility maintenance/repairs		1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	35
PROGRAM SUPPORT SYSTEMS																						
Helicopter Support		40	40	40	35	35	40	35	35	40	35	35	40	35	35	40	35	35	40	35	35	740
(sling loads, remote access, surveys, ungulate control)																						
Feral Ungulate Control		100	100	100	0	0	35	0	0	35	0	0	35	0	0	35	0	0	35	0	0	475
(years 1-3 removal; years 4-20 maintenance)																						
UXO Escort Services		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	200
Cornell Acoustics Laboratory (petrel study, years 1-4)		11	6	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Vehicles (purchases, repairs, maintenance)		16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	320

Table 5.0-1. Summary - Pohakuloa Implementation Plan Estimated Personnel and Program Support Costs (20 years)

	Annual Cost by Year (000s)																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total (000s)
TECHNOLOGY SUPPORT																					
Computers (purchase, hardware, software)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	240
Network and peripherlas (server, printers, ploters, faxes)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
Computer Systems maintenance/repair (IT contractor)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	240
Database development and implementation	12	12	12	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	87
Field Systems (GPS, PDAs, Juniper system)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100
EQUIPMENT AND SUPPLIES																					
Field Communications and Service (phones, radios)	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	280
Field Equipment (e.g., mowers, trimmers, saws, tools)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	300
Field supplies (e.g., pesticides, flagging, stakes, temporary fencing, other consumables)	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217	4,340
Permanent Fencing (6-foot woven wire, posts, anchors, etc.)	0	194	194	194	194	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual PPE Allowance for Field Staff	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	520
Office Furniture, Office Supplies	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	700
Plant Propagation Facility Annual Supplies	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	60
Printing, Freight, Postage	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	300
STAFF TRAINING and RECRUITMENT																					
Annual Safety Trainings (e.g., first-aid, CPR, heli-ops, power tool use)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	300
Professional Development (conferences, seminars)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	800
Communications	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100
GIS	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	60
Recruitment (advertizing, relocation)	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	220
RESEARCH																					
Mamane regeneration study for Palila critical habitat	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40
IMPL TEAM PROGRAM REVIEW (annual)																					
Implementation Team meetings and program review	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
Annual Report preparation and production	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100

Table 5.0-1. Summary - Pohakuloa Implementation Plan Estimated Personnel and Program Support Costs (20 years)

	Annual Cost by Year (000s)																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total (000s)
Sub-total - PERSONNEL	3051	3825	3825	3825	3825	3051	3051	3051	3051	3051	3051	3051	3051	3051	3051	3051	3051	3051	3051	3051	64,116
Sub-total - FACILITIES	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	35
Sub-total - PROGRAM SUPPORT SYSTEMS	177	172	172	67	61	101	61	61	101	61	61	101	61	61	101	61	61	101	61	61	1,764
Sub-total - TECHNOLOGY SUPPORT	56	56	56	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	967
Sub-total - EQUIPMENT AND SUPPLIES	325	519	519	519	519	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	7,276
Sub-total - STAFF TRAINING	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	1,480
Sub-total - RESEARCH	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	200
Sub-total - IMPL TEAM PROGRAM REVIEW	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	120
PROGRAM TOTAL	4,515	5,917	6,154	6,244	6,485	5,367	5,520	5,741	6,037	6,209	6,457	6,791	6,984	7,264	7,639	7,856	8,171	8,593	8,837	9,191	135,972

(includes 17.5% contracting agency overhead, 4.5% contracting agency technical assitance, and 4% annual wage increase and inflation factor after year 1)

5.2 Annual Schedules

Table 5.2-1. Annual Schedule for Wildlife and Botanical Programs

Priority	January	February	March	April	May	June	July	August	September	October	November	December
1	Bat Pre-pregnancy PTA 2pers, 1xweek	Bat Pre-pregnancy PTA 2pers, 1xweek	Bat Pre-pregnancy PTA 2pers, 1xweek	Bat Pre-pregnancy PTA 2pers, 1xweek	Bat Breeding PTA 2pers, 1xweek	Bat Breeding PTA 2pers, 1xweek	Bat Breeding PTA 2pers, 1xweek	Bat Breeding PTA 2pers, 1xweek	Bat Post-Lactation 2pers, 1xweek	Bat Post-Lactation 2pers, 1xweek	Bat Post-Lactation 2pers, 1xweek	Bat Post-Lactation 2pers, 1xweek
1	Bat Pre-pregnancy Ke'amuku 2pers, 1xweek	Bat Pre-pregnancy Ke'amuku 2pers, 1xweek	Bat Pre-pregnancy Ke'amuku 2pers, 1xweek	Bat Pre-pregnancy Ke'amuku 2pers, 1xweek	Bat Breeding Ke'amuku 2pers, 1xweek	Bat Breeding Ke'amuku 2pers, 1xweek	Bat Breeding Ke'amuku 2pers, 1xweek	Bat Breeding Ke'amuku 2pers, 1xweek	Bat Post-Lactation Ke'amuku 2pers, 1xweek	Bat Post-Lactation Ke'amuku 2pers, 1xweek	Bat Post-Lactation Ke'amuku 2pers, 1xweek	Bat Post-Lactation Ke'amuku 2pers, 1xweek
1			Nēnē flocking (PTA) Range One, 2Pers, 1X week	Nēnē flocking (PTA) Range One, 2Pers, 1X week	Nēnē flocking (PTA) Range One, 2Pers, 1X week	Nēnē flocking (PTA) Range One, 2Pers, 1X week	Nēnē flocking (PTA) Range One, 2Pers, 1X week	Nēnē flocking (PTA) Range One, 2Pers, 1X week	Nēnē flocking (PTA) Range One, 2Pers, 1X week	Nēnē flocking (PTA) Range One, 2Pers, 1X week	Nēnē flocking (PTA) Range One, 2Pers, 1X week	Nēnē flocking (PTA) Range One, 2Pers, 1X week
1	Nēnē Breeding (Keam.) 4 pers, 1 X week	Nēnē Breeding (Keam.) 4 pers, 1 X week	Nēnē Breeding (Keam.) 4 pers, 1 X week							Nēnē Breeding (Keam.) 4 pers, 1 X week	Nēnē Breeding (Keam.) 4 pers, 1 X week	Nēnē Breeding (Keam.) 4 pers, 1 X week
1	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month	Nēnē Camera Rng 1 2 pers 1X month

1				Petrel survey TA 23 4 pers, 1x/6 wks	Petrel survey TA 23 4 pers, 1x/6 wks	Petrel survey TA 23 4 pers, 1x/6 wks	Petrel survey TA 23 4 pers, 1x/6 wks	Petrel survey TA 23 4 pers, 1x/6 wks				
1				Petrel survey TA 21 2 pers, 1x / 2 weeks	Petrel survey TA 21 2 pers, 1x / 2 weeks	Petrel survey TA 21 2 pers, 1x / 2 weeks	Petrel survey TA 21 2 pers, 1x / 2 weeks	Petrel survey TA 21 2 pers, 1x / 2 weeks				
1				Petrel survey Red Leg 3 pers, 1 x/ 2 weeks	Petrel survey Red Leg 3 pers, 1 x/ 2 weeks	Petrel survey Red Leg 3 pers, 1 x/ 2 weeks						
1											Forest Bird Survey Calibration 3 pers, 1x week	Forest Bird Survey 6 pers, 4 x week
1	Spe haw monitoring			Spe haw monitoring			Spe haw monitoring			Spe haw monitoring		
1		Hed cor monitoring 112 hrs										
1		Sch haw monitoring 171 hrs										
1			Tet are monitoring 141 hrs									
1				Iso hos monitoring 160 hrs								

1				Mel ven monitoring 20 hrs								
1				Vig owa monitoring								
1					Sil lan monitoring 281 hrs							
1						Sil haw monitoring 171 hrs						
1							Tet spp 1 monitoring					
1								Hap hap monitoring 345 hrs				
1									Sol inc monitoring 18 hrs			
1									Por scl monitoring 24 hrs			
1									Ner ova monitoring 38 hrs			
1									Ste ang monitoring			
1										Asp per monitoring 6 hrs		

1											Zan Haw monitoring	
2	‘Elepaio Breeding Rodent bait 3 pers, 1xmonth	‘Elepaio Breeding Rodent Bait 3 pers, 1xmonth	‘Elepaio Breeding Rodent Bait 3 pers, 1xmonth	‘Elepaio Breeding Rodent Bait 3 pers, 1xmonth	‘Elepaio Breeding Rodent Bait 3 pers, 1xmonth	‘Elepaio Breeding Rodent Bait 3 pers, 1xmonth						
2	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month	Rodent Bait O.P 2 pers, 1x month
2	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month	Rodent Bait ASR 24 5 pers, 1x month
2	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month	Rodent Bait ASR 13/14 2 pers, 1x month
2	KMA Cat Trapping	KMA Cat Trapping									KMA Cat Trapping	KMA Cat Trapping
2	KMA Rodent Control 1X Month	KMA Rodent Control 1X Month								KMA Rodent Control 1X Month	KMA Rodent Control 1X Month	KMA Rodent Control 1X Month
2	KMA Nēnē fence										KMA Nēnē fence	KMA Nēnē fence

2			Vegetation Monitoring Plots	Vegetation Monitoring Plots								
2				Vegetation control plots monitoring	Vegetation control plots monitoring	Vegetation control plots monitoring	Vegetation control plots monitoring	Vegetation control plots monitoring	Vegetation control plots monitoring	Vegetation control plots monitoring	Vegetation control plots monitoring	Vegetation control plots monitoring
2				Argentine and control at Sil lan 2 pers 1 X month	Argentine and control at Sil lan 2 pers 1 X month	Argentine and control at Sil lan 2 pers 1 X month						
3	‘Elepaio Monitoring 2pers, 1x week	‘Elepaio Monitoring 2pers, 1x week	‘Elepaio Monitoring 2pers, 1x week	‘Elepaio Monitoring 2pers, 1x week	‘Elepaio Monitoring 2pers, 1x week	‘Elepaio Monitoring 2pers, 1x week						
3			‘Io Surveys Quarterly Surveys in each Training area		‘Io Surveys Quarterly Surveys in each Training area			‘Io Surveys Quarterly Surveys in each Training area		‘Io Surveys Quarterly Surveys in each Training area		
3		TA 23 Cat trapping 2pers 2 X month	TA 23 Cat trapping 2pers 2 X month	TA 23 Cat trapping 2pers 2 X month	TA 23 Cat trapping 2pers 2 X month	TA 23 Cat trapping 2pers 2 X month	TA 23 Cat trapping 2pers 2 X month	TA 23 Cat trapping 2pers 2 X month	TA 23 Cat trapping 2pers 2 X month			
3			Wasp Monitoring 2 pers 1 X month	Wasp Monitoring 2 pers 1 X month	Wasp Monitoring 2 pers 1 X month	Wasp Monitoring 2 pers 1 X month	Wasp Monitoring 2 pers 1 X month	Wasp Monitoring 2 pers 1 X month	Wasp Monitoring 2 pers 1 X month	Wasp Monitoring 2 pers 1 X month	Wasp Monitoring 2 pers 1 X month	Wasp Monitoring 2 pers 1 X month
3		Invertebrate incipient			Invertebrate incipient			Invertebrate incipient			Invertebrate incipient	

3		Ungulate removal	Ungulate removal	Ungulate removal	Ungulate removal	Ungulate removal	Ungulate Removal	Ungulate removal	Ungulate removal	Ungulate removal	Ungulate removal	Ungulate removal
3		Vertebrate incipient			Vertebrate incipient			Vertebrate incipient			Vertebrate incipient	
3	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)	Military Activity (Range one, airport, construction)
4		Zan haw seed predation study	Zan haw seed predation study	Zan haw seed predation study	Zan haw seed predation study	Zan haw seed predation study	Zan haw seed predation study	Zan haw seed predation study	Zan haw seed predation study	Zan haw seed predation study	Zan haw seed predation study	Zan haw seed predation study
4	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits	Ant survey as time permits
4	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits	Botanical Surveys as time permits
5	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study	Aerial Rodent baiting study
5	Wasp control	Wasp control	Wasp control	Wasp control	Wasp control	Wasp control	Wasp control	Wasp control	Wasp control	Wasp control	Wasp control	Wasp control

Table 5.2-2 Annual Schedule for Vegetation Control

Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ASR	5	4	14	5	3	4	5	6	12	4	3	7
	8	6	16	7	6	11	8	7	15	5	6	11
	12	13	18	8	12	24	16	19	29	8	13	19
	15	24	29	19	13	25	18	13		20	16	40
	20	25		20	15	44	20	31		24	18	
	22	31		21	30		22	40		25	30	
		44		40	31					44	31	
OP	212	209	206	200	217	215	212	209	206		217	215
		213	207					213	207			
			208						208			
			211						211			
			214						214			
Fence Unit			90			95,96			90			95,96
SK	72	308	71	72	308	71	72	308	71	72	308	71
PT	524	524	524	524	524	524	524	524	524	524	524	524
ASR with Vegetation Control	3,4,5,7,8,11,12,13,14,16,18,19,20,21,22,24,25,28,29,30 (on Hold),31,40,44											
	206, 207, 208, 209, 210 (HC), 211, 212, 213(41), 214, 215 (28)											

SK=Russian thistle 6,71,72,308 71,72@Ke‘āmuku 308=FB PT=Banana poka control

6.0 LITERATURE CITED

Abella, S. and Covington, W. 2004. Monitoring an Arizona Ponderosa pine restoration: sampling efficiency and multivariate analysis of understory vegetation. Restoration Ecology 12 (3). pp 359-367.

Alvarez, M. 1997. Management of Cape-ivy (*Delairea odorata*) in the Golden Gate National Recreation Area. Proceedings of the California Exotic Plants Pest Control Council 1997.

Arnett, M. 2002. Report of Survey for Rare Plants on the Keʻāmuku Parcel, Island of Hawaiʻi. Center for Ecological Management of Military Lands, Department of Forest Services, Colorado State University, Fort Collins, CO 80523.

Athens, S.J., M.W. Kaschko and H.F. James. 1991. Prehistoric Bird Hunters: High Altitude Resource Exploitation on Hawaiʻi Island. Bishop Museum Occasional Papers 31: 63-84.

Baldwin, P.H. 1950. Occurrence and behavior of the Hawaiian bat. Journal of Mammalogy, 31:455-456.

Baker, J.K. and D.W. Reeser. 1972. Goat management problems in the Hawaiʻi Volcanoes National Park: A history, analysis, and management plan. *Natural Resources Reports*, no. 2. U.S. National Park Service.

Banko, W.E. 1980. CPSU/UH Avian History Report 6A History of Endemic Hawaiian Birds Part 1. Population Histories---Species Accounts: Sea Birds: Hawaiian Dark-rumped Petrel (ʻUaʻu). University of Hawaiʻi at Manoa.

Banko, P.C. 1988. Breeding biology and conservation of the Nēnē, Hawaiian goose (*Nesochen sandvicensis*). Ph.D. dissertation, University of Washington, Seattle, WA.

Banko, P.C. and D.A. Manuwal. 1982. Life history, ecology, and management of Nēnē (*Branta sandvicensis*) in Hawaiʻi Volcanoes and Haleakalā National Parks. Final Report to the National Park Service, Cooperative Park Studies Unit, University of Washington, Seattle, WA. 153 pp.

Banko, P.C., J.M. Black, and W.E. Banko. 1999. Hawaiian Goose (Nēnē). *The Birds of North America*, No. 434, A. Poole and F. Gill (editors). The Birds of North America, Inc., Philadelphia, PA.

Baraband, L. 2007. New York State Integrated Pest Management Program [Internet]. Ithaca, New York:: Cornell University; <http://nysipm.cornell.edu/publications/yj_trapping/default.asp?metatags_Action=Find('PID','4')> Accessed on August 3, 2007.

Baskin, C.C. and J.M. Baskin. 2001. Seeds. Academic Press, San Diego, CA.

[BISC] Big Island Invasive Species Committee. 2008. Target Species List. URL:www.Hawaiʻiinvasivespecies.org/isc/biisc> Accessed on March 23, 2009

Bonaccorso, F.J. 2006. Habitat occupancy and detectability of the Hawaiian hoary bat using an automated system of bat detectors. Unpublished research proposal to the Hawaiian bat research cooperative.

Bossard and Benefield. 1996. War on German Ivy- Good News from the Front. Proceedings of the California Exotic Plants Pest Control Council 1997. pp. 63-64

Cabin, R.J., S.G. Weller, D.H. Lorence, T.W. Flynn, A.K. Sakai, D. Sandquist, and L. Hadway. 2000. Effects of long-term ungulate exclusion and recent Non-native species control on the preservation and restoration of a Hawaiian tropical dry forest. *Conservation Biology* 14: 439-453.

Carlile, N., D. Priddel, F. Zino, C. Natividad and D.B. Wingate. 2003. A Review of Four Successful Recovery Programs for Threatened Sub-Tropical Petrels. Marine Ornithology 31: 185-192.

Carroll, R., C. Augspurger, A. Dobson, J. Franklin, G. Orians , W. Reid, R. Tracy, D. Wilcove, and J. Wilson. 1996. Strengthening the use of science in achieving the goals of the Endangered Species Act: an assessment by the Ecological Society of America. Ecological Application 6:1-11.

[CEMML] Center for Environmental Management of Military Lands. 2006. Report for the Ecosystem Management Program Pōhakuloa Training Area, Island of Hawaiʻi July 2003 to December 2005. Prepared for the U.S. Army Garrison, Hawaiʻi by the Center for Ecological Management of Military Lands, Colorado State University.

_____. 2007 Implementation of the 2003 Biological Opinion, Pōhakuloa Training Area, Hawaiʻi, January - December 2006. Prepared for the U.S. Army Garrison, Hawaiʻi by the Center for Ecological Management of Military Lands, Colorado State University.

Christman, M. 2000. A review of quadrat-based sampling of rare, geographically clustered populations. Journal of Agriculture, Biological, and Environmental Statistics 5 (2). pp. 168-201

Chumley, J. and H. Klausner. December 2005. Non-native plants of the Kenai Peninsula: summary of a two-year roadside inventory. Final Report for the USDA Forest Service.

Clark, D.A. 1982. Foraging behavior of a vertebrate omnivore (*Rattus rattus*): meal structure, sampling, diet breadth. Ecology 63(3): 736-772.

Cole, F.R., A.C. Medeiros, L.L. Loope, and W.W. Zuehlke. 1992. Effects of Argentine Ants on Arthropod Fauna of Hawaiian High-Elevation Shrubland. Ecology 73(4) pp. 1313-1322.

Cole, R.F., L.L Loope, A.C. Medieros, C.E. Howe, and L.J. Anderson. 2000. Food habits and Impacts of Introduced Rodents in High Elevation Shrubland in Haleakalā National Park, Maui, Hawaiʻi. Pacific Science 54: 313-329.

Conant, S. 1980. Recent records of the ʻUaʻu (Dark-rumped Petrel) and the ʻaʻo (Newell's Shearwater) in Hawaiʻi. ʻElepaio 41: 1-3.

Cooper, B.A, R.E. David, R.J. Blaha. 1996. Radar and Visual Surveys of Endangered Seabirds and Bats in the Pōhakuloa Training Area, Hawaiʻi during Summer 1995. Prepared for R.M. Towill Corporation 420 Waiakamilo Road, Honolulu HI, 96817-4941.

Cordell, S. and D.R. Sandquist. 2008. The impact of an invasive African bunchgrass (*Pennisetum setaceum*) on water availability and productivity of canopy trees within a tropical forest in Hawaii. Functional Ecology. 22: 1008-1017

Cuddihy, L., J. Davis and S. Anderson. 1983. A Botanical Survey of Twelve Cinder Cones in South Kohala, Island of Hawai‘i . Endangered Plant Species Program, DOFAW, DLNR, Hilo, HI. Unpublished Report.

Daehler, C. and J. Denslow. 2007. List of Invasive and Potentially Invasive Species in Hawai‘i and the Pacific. URL:<http://www.botany.Hawai‘i.edu/faculty/daehler/WRA/default2.htm>. and Hawai‘i Exotic Plant Evaluation and Protocol URL:<http://www.botany.Hawai‘i.edu/faculty/daehler/WRA/hepep_background.htm>. Accessed on 4/20/09.

Dytham, C. 1999. *Choosing and Using Statistics: A Biologist's Guide*. Blackwell Science Ltd., Oxford, England.

Ellstrand, N.C. and D.R. Elam. 1993. Population genetic consequences of small population size: implications for plant conservation. Ann. Rev. Ecol. Syst. 24:217-242.

Elzinga, C.L., D.W. Salzer and J.W. Willoughby.1998. *Measuring and Monitoring Plant Populations*. Rep. No. BLM/RS/ST-98/005+1730. U.S. Department of the Interior, Bureau of Land Management, Denver, Colorado.

Falk, D., C. Millar, and M. Olwell, editors. 1996. Guidelines for developing a rare plant reintroduction plan. In *Restoring Diversity: strategies for reintroduction of endangered species*. D. A. Falk, C. I. Millar and M. Olwell, eds. Island Press. Washington D.C.

Gambino, P., A.C. Medeiros, L.L. Loope. 1987. Introduced Vespids Paravespula pensylvanica Prey on Maui's Endemic Arthropods Fauna. Journal of Tropical Ecology 3(2) pp. 169-170.

Geissler, P.H. 2006. Chapter 8. Sampling and Survey Design: *USGS Early Detection of Invasive Plants: A Handbook*. Draft, September 29, 2006.

Gon, S.M., L.C. Honigman, D. Zevin, W. Fulks, and R.E. David. 1993. Vertebrate inventory surveys at the multipurpose range complex Pōhakuloa Training Area (PTA) island of Hawai‘i. Unpublished report prepared for Hawai‘i Heritage Program, Honolulu, Hawai‘i.

Gorreson, M. 2008. Assessing bat detecability and occupancy with multiple automated echolocation detectors. Journal of Mammology 89(1):11-17.

Guerrant, E. O., Jr. 1996. Designing populations: demographic, genetic, and horticultural dimensions. In *Restoring Diversity: strategies for reintroduction of endangered species.* D. A. Falk, C. I. Millar and M. Olwell, eds. Island Press. Washington D.C.

Guerrant, E.O., Jr and P.L. Fiedler. 2004. Accounting for sample decline during ex situ storage and reintroduction. In *Ex situ Plant Conservation: supporting species survival in the wild.* E.O. Guerrant, Jr., K. Havens, and M. Maunder, eds. Island Press. Washington D.C.

Halward, T. and R. Shaw. 1996. Germination requirements and conservation of an endangered Hawaiian plant species (Silene *lanceolata*). Natural Areas Journal 16:335-343.

Harris, S., J. Brown and S. Timmins. 2001. Weed surveillance –how often to search. *Science for Conservation:* 175. Department of Conservation, Wellington, New Zealand.

Harrison, C.S. 1990. *Sea Birds of Hawai'i*. Cornell University Press, Ithaca, New York

Hartley, S and P. Lester. 2005. National Ant Surveillance Sensitivity Trial. School of Biological Sciences / Victoria Link, Victoria University of Wellington.

Hawaiian Ant Group. 2007. A Plan for the Prevention of Establishment of New Ant Species in Hawai‘i, with Special Attention to the Red Imported Fire Ant (*Solenopsis invicta*) and Little Fire Ant (*Wasmannia auropunctata)*. <http://www.Hawaiianantgroup.org/Hawaiiantplan> Accessed March, 2009

[HDOA] Hawai‘i Department of Agriculture, Division of Plant Industry. 20 October 2003. List of Plant Species Designated as Noxious Weeds. <http://plants.usda.gov/java/noxious?rptType=State&statefips=15>.

Hawai‘i Heritage Program. 1996. Natural diversity database on *Lasiurus cinereus semotus*. April 16, 1996. The Nature Conservancy of Hawai‘i, Honolulu, Hawai‘i.

Hawai‘i and Pacific Plants Recovery Coordinating Committee (HPPRCC). 1994. Minutes of the July 7 and 8, 1994, meeting of the Hawai‘i and Pacific Plants Recovery Coordinating Committee. Prepared for the U.S. Fish and Wildlife Service, Unpublished.

Imada, C., Frohlich, D., Lau, A., and Smith, R. 2007. Implementing Early Detection in Hawai‘i, Year One. Hawai‘i Biological Survey Report 2007-016.

Jacobi, J. D. 2003. Baseline Vegetation Survey and Long-Term Monitoring Strategy for the Kīpuka ‘Alalā Section of the U.S. Army’s Pōhakuloa Training Area, Island of Hawai‘i. U.S. Geological Survey, Pacific Islands Research Center, Kilauea Field Station. Hawai‘i National Park, Hawai‘i.

Jacobs, D.S. 1994. Distribution and abundance of the endangered Hawaiian hoary bat, *Lasiurus cinereus semotus*, on the island of Hawai‘i. Pacific Science 48(2): 193-200.

Jacobs, J.M. 2007. Pilot study of a monitoring program using automated passive bat detectors: assessing methods quantifying seasonal changes in occupancy, detectability and habitat use by the Hawaiian hoary bat (*Lasiurus cinereus semotus*) at Pōhakuloa Training Area, Island of Hawai‘i. Unpublished Report, Center for Environmental Management of Military Lands, Colorado State University.

Klavitter, J. L. 2000. Survey methodology, abundance, and demography of the endangered Hawaiian hawk: is delisting warranted? Master’s Thesis, University of Washington, USA.

Kepler, C.B. and Scott, J.M. 1990. Notes on the distribution and behavior of the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus)*, 1964-1983. ‘Elepaio, 50:59-64.

Korb, J., W. Conington, P. Fule. 2003. Sampling techniques influence understory plant trajectories after restoration: an example from ponderosa pine restoration. Restoration Ecology 11 (4). pp. 504-515.

Krushelnycky, P.D., and N.J. Reimer. 1998. Efforts at Control if the Argentine Ant in Haleakalā National Park, Maui Hawai‘i. Cooperative National Park Resource Studies Unit, University of Hawai‘i at Manoa. Technical Report 109.

Landolt, P.J., H.C. Reed and D.J Ellis. 2003. Trapping Yellowjackets (Hymenoptera: *Vespidae*) with Heptyl Butyrate Emitted from Controlled-release Dispensers. Florida Entomologist 86(3) pp. 323- 328.

Loope, L.L., and P.O. Scowcroft. 1985. Vegetation response within exclosures in Hawai‘i: a review. In *Hawai‘i's terrestrial ecosystems: preservation and management,* ed. C.P. Stone and J.M. Scott, 377-402. Univ. Hawai‘i Coop. Natl. Park Resource. Stud. Unit. Honolulu: Univ. Hawai‘i Pr.

Lubow, B.C. 1996. Optimal translocation strategies for enhancing stochastic metapopulation viabiability. Ecological Applications 6:1268-1280.

Ludwig, D. 1996. Uncertainty and the assessment of extinction probabilities. Ecological Applications 6:1067-1076.

Mackenzie, D.I., J.D. Nichols, G. B. Lachman, S. Droege, J. A. Royle and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248-2255.

Mackenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L.L. Bailey, and J.E. Hines. 2006. *Occupancy Estimation and Modeling.* Academic Press, San Diego, California, U.S.A.

Mangel, M. and C. Tier. 1994. Four facts every conservation biologist should know about persistence. Ecology 75:607-614.

Menard, T. 2001. Activity patterns of the Hawaiian hoary bat (*Lasiurus cinereus semotus*) in relation to reproductive time periods. M.S. Thesis. University of Hawai‘i Honolulu, U.S.A.

Messing, R.H., M.N. Tremblay, E.B. Mondor, R.G. Foottit and K.S. Pike. 2007. Invasive aphids attack native Hawaiian plants. Biological Invasions. 9: pp. 601-607.

Mitchell, C., C. Ogura, D.W. Meadows, A. Kane, L. Strommer, S. Fretz, D. Leonard, and A. McClung. October 2005. *Hawai‘i's Comprehensive Wildlife Conservation Strategy*. Department of Land and Natural Resources. Honolulu, Hawai‘i. 722 pp.

Morris, W.F., and D.F. Doak. 2002. *Quantitative Conservation Biology: Theory and Practice of Population Viability Analysis*. Sinauer Associates, Inc. Sunderland, Massachusetts.

Motooka, P., L Castro, D. Nelson, G. Nagai, and L. Ching. 2003. *Weeds of Hawai‘i's Pastures and Natural Areas; an Identification and Management Guide*. College of Tropical Agriculture and Human Resources, University of Hawai‘i at Manoa, Honolulu, HI.

Muttlak, H. and A. Khan. 2002. Adjusted two-stage adaptive cluster sampling. Environmental and Ecological Statistics. 9, pp 111-120.

Oboyski, P. 1998. Arthropod Survey at Pōhakuloa Training Area, Island of Hawai‘i, Hawai‘i . Prepared for the U.S. Army Garrison, Hawai‘i.

Oboyski, P.T., A.J. Gregor, L.B. Passerello, J.P. Weber, J.E. Hines, and P.C. Banko. 2001. Kīpuka ‘Alalā Terrestrial Arthropod Survey, Pōhakuloa Training Area, Hawai‘i. Prepared for the U.S. Army Garrison, Hawai‘i.

Pacific Ant Prevention Plan. 2004. Proposal prepared for the Pacific Plant Protection Organization and Regional Technical Meeting for Plant Protection. http://www.invasivespecies.net/database/species/reference_files/papp.pdf> Accessed March, 2009

Peet, R.K., T.R. Wentworth, and P.S. White. 1998. A Flexible Multipurpose Method for Recording Composition and Structure. Castanea 63 (3). pp. 262-274.

[PIER] Pacific Islands and Ecosystems at Risk. 2009. <https://www.hear.org/pier> Accessed on 4/21/09.

Platts, W. S., C. Armour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S Jensen, G.W. Lienkaemper, G.W. Minshall, S.B Monsen, R.L. Nelson, J.R. Sedell, J.S. Tuhy. 1987. Methods for evaluating riparian habitats with applications to management. General Technical Report INT-221. Ogden, Utah: USDA Forest Service, Intermountain Research Station.

Reed, J.M. 1996. Using statistical probability to increase confidence of inferring species extinction. Conservation Biology 10:1283-1285.

[RCUH] Research Corporation of the University of Hawaiʻi (RCUH). 1998. Annual Report for the Ecosystem Management Program, Pōhakuloa Training Area, Island of Hawaiʻi. Prepared for the U.S. Army Garrison Hawaiʻi by the Research Corporation of the University of Hawaiʻi, Manoa.

_____. 2000. Annual Report for the Ecosystem Management Program, Pōhakuloa Training Area, island of Hawaiʻi. Prepared for the U.S. Army Garrison Hawaiʻi by the Research Corporation of the University of Hawaiʻi, Manoa.

_____. 2002. Annual Report for the Ecosystem Management Program, Pōhakuloa Training Area, island of Hawaiʻi. Prepared for the U.S. Army Garrison Hawaiʻi by the Research Corporation of the University of Hawaiʻi, Manoa.

_____. 2003. Annual Report for the Ecosystem Management Program, Pōhakuloa Training Area, island of Hawaiʻi. Prepared for the U.S. Army Garrison Hawaiʻi by the Research Corporation of the University of Hawaiʻi, Manoa.

[SCC] Shoalhaven City Council. 2009. Noxious weeds. <http://www.shoalhaven.nsw.gov.au/Environment/weeds/naxious_weeds.asp> Accessed on 4/21/09

Scowcroft, P.G., and J.G. Giffin. 1983. Feral herbivores suppress māmane and other browse species on Mauna Kea, Hawaiʻi. /. *Range Manage.* 36(5):638-645.

Scowcroft, P. G. and C. Eugene Conrad. 1992. Alien and native plant response to release from feral sheep browsing on Mauna Kea. In *Alien plant invasions in native ecosystems of Hawaiʻi: Management and research,* ed. C. P. Stone, C. W. Smith, and J. T. Tunison, 625-65. Honolulu: Cooperative National Park Resources Studies Unit, University of Hawaiʻi at Manoa.

Scowcroft, P. G. and Howard Sakai. 1983. Impact of feral herbivores on māmane forests of Mauna Kea, Hawaiʻi: Bark stripping and diameter class structure. *Journal of Range Management* 36:495-98.

Shaw, R.B. and J.M. Castillo. 1997. Plant Communities of Pōhakuloa Training Area. Center for Ecological Management of Military Lands, Department of Forest Services, Colorado State University, Fort Collins, CO 80523.

Simons, T.R. 1985. Biology and Behavior of the Endangered Hawaiian Dark-rumped Petrel. The Condor 87(2): 229-245.

Starr, F.,K. Starr, and L.L. Loope. 2006. Roadside Survey and Expert Interviews for Selected Plant Species on Maui, Hawaiʻi . Hawaiʻi -Pacific Cooperative Ecosystems Studies Unit, University of Hawaiʻi at Manoa.

Staples, G. and D. Herbst. *A Tropical Garden Flora*. Bishop Museum. Honolulu. 2005.

Stone, C.P., C.W. Smith, and J.T. Tunison (eds.) 1992. Alien plant invasions in native ecosystems of Hawaiʻi: Management and research. Honolulu: University of Hawaiʻi Cooperative National Park Resource Studies Unit.

Stump, L.M., R.D. Laven, G.H. Aplet, R.B. Shaw. 1994. Three-Year Changes in Population Size and Structure in Three Rare Species of Hawaiian *Tetramolopium*: Implications for Conservation and Management. Center for Ecological Management of Military Lands, Department of Forest Services, Colorado State University, Fort Collins, CO 80523. Unpublished Report.

Sugihara, R.T. 1997. Abundance and diets of rats in two native Hawaiian forests. Pacific Science 51(2): 189-198.

Thompson, S. 1992. *Sampling*. Wiley Publishing. New York.

Tomich, P.Q. 1986. *Mammals in Hawaiʻi*. 2nd Edition. Bishop Museum Press. Honolulu, Hawaiʻi.

[USACOE] US Army Corps of Engineers. 2003. Programmatic Biological Assessment for Transformation of the 2nd Brigade 25th Infantry Division (Light) U.S. Army, Island of Hawaiʻi. Prepared by the Center for Environmental Management of Military Lands, Colorado State University, Fort Collins, Colorado. For the U.S. Army Corps of Engineers, Honolulu District, Hawaiʻi .

US Army 2002. Biological Assessment for Legacy Training.

US Army, Hawaiʻi . 2002. Makua Valley Implementation Plan. USAG-HI, Dept. of Public Works.

US Department of Agriculture. 2009. Invasive Plans. http://www.na.fs.fed.us/fhp/invasive_plants Accessed on 4/21/09.

[USFWS] US Fish and Wildlife Service. 1993. Draft Recovery Plan for *Haplostachys haplostachya* and *Stenogyne angustifolia*. US Fish and Wildlife Service, Portland, OR. 55pp.

_____. 1994. Recovery Plan for *Lipochaeta venosa* and *Isodendriion hosakae*. Portland, Oregon.

_____. 1996a. Recovery Plan for the Big Island Cluster. Portland, Oregon.

_____. 1996b. Recovery Plan for the Molokai Plant Cluster. US Fish and Wildlife Service, Portland, OR. 143 pp.

_____. 1997. Recovery Plan for the Maui Plant Cluster. US Fish and Wildlife Service, Portland, OR. 198 pp.

_____. 1998a. Big Island II: Addendum to the Recovery Plan for the Big Island Plant Cluster. US Fish and Wildlife Service, Portland, OR. 80 pages + appendices.

_____. 1998b. Recovery Plan for Four Species of Hawaiian Ferns. US Fish and Wildlife Service, Portland, OR. 78pp.

_____. 1998c. Biological Opinion of the US Fish and Wildlife Service for the Saddle Road Realignment and Improvement Project.

_____. 1998d. Recovery Plan for the Hawaiian Hoary Bat. U.S. Fish and Wildlife Service, Portland, OR. 50pp.

_____. 1999. Recovery Plan for Multi-Island Plants. US Fish and Wildlife Service, Portland, OR. 206 pages + appendices.

_____. 2003. Biological Opinion of the US Fish and Wildlife Service for Routine Military Training and Transformation of the 2nd Brigade 25th Infantry Division (Light), U.S. Army Installations, Islands of Hawai'i .

_____. 2004. Recovery Plan for the Nēnē or Hawaiian Goose (*Branta sandvicensis*). Region 1, US Fish and Wildlife Service. Portland, Oregon

_____.2008. Reinitiation of Formal Sections 7 Consultation for Additional Species and New Training Actions at Pōhakuloa Training Area, Hawaii.

Wagner, Warren, Herbst, D., and Sohmer, S., 1999. Manual of the Flowering Plants of Hawai'i. Bishop Museum, Honolulu.

Wintle, B. A., M. A. McCarthy, K. M. Parris, and M. A. Burgman. 2004. Precision and bias of methods for estimating point survey detection probabilities. Ecological Applications 14:703-712.

Woog, F. 2000. Ecology and behavior of reintroduced Hawaiian geese. Ph.D. Dissertation, University Hannover, Germany.

7.0 PERSONAL COMMUNICATIONS

Baskin, Carol. Professor, School of Biological Sciences, University of Kentucky, Lexington, KY 40506-0225.

Belfield, Thomas. Research Associate, USGS-BRD, Hawai‘i Volcanoes National Park, HI 96718. Ph: 985-6195.

Bonaccorso, Frank. Research Biologist, USGS-BRD, Hawai‘i Volcanoes National Park HI96718 Ph:(808)985-6126

Cordell, Susan. Research Ecologist, USFS, Institute of Pacific Island Forestry. 60 Nowelo St. Hilo, HI 96720. Ph: (808) 933-8121 ext. 128

David, Reginald. Biological Consultant, Rana Productions, P.O. Box 1371 Kailua-Kona HI. (808) 329-9141

Flint, Elizabeth, Wildlife Biologist, USFWS, Honolulu HI Ph: (808) 972-9400

Foote, David. Entomologist, USGS-BRD, Hawai‘i Volcanoes National Park, HI 96718. Ph:(808) 967-7396

Gleason, Sean. Former PTA Army Biologist (2003-2005). No current contact information.

Hu, Darcy. Ecologist and H-PI Research Coordinator Pacific West Regional Office, Honolulu c/o Hawai‘i Volcanoes National Park, P.O. Box 52 Hawai‘i National Park HI 96718. Ph:(808) 985-6092

Kiyabu, Brian. Horticulturist, Amy Greenwell Botanical Garden. Ph: 323-3318.

Mackenzie, Daryl.

Moller, Eric. Deputy Fire Chief, Pōhakuloa Training Area. Ph:969-2441.

Moriyasu, Patty. Research Associate, Volcano Rare Plant Facility. Ph: 895-4538.

Pence, Valerie. Director of Plant Research, Center for Conservation and Research of Endangered Wildlife, Cincinnati Zoo and Botanical Garden, 3400 Vine Street, Cincinnati, OH 45220.

Sugii, Nellie. Research Associate, Lyon Arboretum Micropropagation Facilities. Ph: 988-0470.

Weisenberger, Lauren. Research Associate, Army Environmental Office, Schofield. Ph: 656-8341.

Yoshinaga, Alvin. Research Associate, Lyon Arboretum Seed Storage Laboratory. Ph: 988-0469.

8.0 APPENDICES

8.1 Hawai‘i Rare Plant Recovery Group Collecting and Handling Protocol

General Information

WHAT DO I NEED TO PROVIDE TO THE PROPAGATION FACILITIES WHEN I SUBMIT MY SAMPLES?

1. Provide whenever possible the Rare Plant Field Data Form. If not, include with plant material sample descriptors such as:
    - Genus, species, subspecies, *etc.*
    - Collection organization
    - Collector
    - Date of collection
    - Collection site
    - Collection number
    - Type of material
    - Purpose of collection

    This is to ensure accurate documentation of the plant samples.
2. Label all samples legibly and unambiguously. Make sure all samples are tagged.
3. If any special or significant sampling methods were used, note what was done.
4. Note any pest problems associated with the parent plant at the time of collection.
5. If possible, make arrangements with the propagation facility before sample collection.
6. Submit samples to the propagation facilities as soon as possible! Delays may have deleterious effects on sample viability.

HOW DO I HANDLE MY PLANT SAMPLES AFTER I COLLECT THEM?

1. Insulate from heat. Keep at ambient to cool temperatures but do not freeze.
2. Try to cushion material so it won’t be crushed.
3. Do not pack samples with excessive moisture or allow samples to sweat in the bags for an extended period of time. This promotes fungal and bacterial growth and accelerates the decline to sample quality.
4. Send to propagative facilities as soon as possible.

Collecting and Handling of Seed Propagules

Seed quality is primarily dependent upon the seed collector’s methods and post harvest handling of material. Knowledge of timing and habit of natural seed dispersal is helpful (though not always available) in seed collection. Attention to inflorescence structure and their seed maturity patterns are also important in determining what to harvest.

LOSS OF SEED VIABILITY IS DUE TO

1. Excessive temperature.
2. Development of anaerobic conditions around the seeds caused by their own respiration. This is due to storing in plastic bags or tight packing.
3. Prolonged time interval from collection of samples to propagative facilities under conditions conducive to fungal and bacterial growth. Samples of fleshy fruit stored in plastic bags should be aerated intermittently in immediate delivery is not possible.

Dry dehiscent	Only available before it disperses. Try to harvest just before dehiscing.
Dry Indehiscent	Dependent upon when and how dispersed. For example, wind dispersed, by animals or insects, *etc.*

Recalcitrant Seed

Recalcitrant seeds cannot withstand any drying. Some have seed coats adapted to prevent excessive water loss while others have no such adaptation and are prone to rapid water loss post harvest.

In fleshy fruits, high seed moisture can be maintained by keeping the fruit intact. Seeds can be stored in impermeable plastic bags, but must be aerated by opening the bag intermittently to compensate for the restrictive gas exchange environment.

Insulate against heat and temperature extremes. Try to maintain a temperature as close to ambient as possible.

In mature fruit, indicate if picked off the ground or parent plant. Try not to collect from the ground if possible, unless it is known that they have recently fallen.

Orthodox Seed

In general, the desiccation tolerance of orthodox seed varies throughout its development. They tend to be intolerant of drying during early development and become more tolerant as the seeds mature.

If the fruits are immature, leave the seed within the fruit. Treat in the same manner as recalcitrant seeds.

Mature seeds from dry indehiscent or dehiscent fruits can be kept in permeable containers such as paper or cloth bags.

Collecting and Handling of Vegetative Propagules

Successful propagation of vegetative propagules is dependent upon many different factors such as the vigor of the parent, the collection date and even the environmental conditions at the time of collection. Correct handling of vegetative material is also important.

1. Vegetative materials deteriorate quickly post harvest and quick transfer from field to the propagative facility is imperative to ensure maximum viability.
2. Additional care must be taken during transport since they are easily damaged.

3. Place under cool conditions, such as a cooler with ice packs, as soon as possible after collecting and during transport to the propagation facility.
4. Try to collect samples that are insect and disease free.
5. Minimize damage during harvesting and transport.
6. In the case of vegetative cuttings, cut ends can be wrapped in damp towels or newspaper.

Vegetative Cuttings (Herbaceous)

The shoots harvested should be from the last mature flush of the plant. Cuttings should be long enough to allow for trimming and possible division.

If the plant species is known to be hard to propagate, small rooted plant suckers with some of the soil surrounding the roots could be taken if possible. Whole plants should not be removed at any time.

Vegetative Cuttings (Woody)

Propagation of mature trees is more difficult in general than their juvenile counterparts; but in many cases, juvenile forms are not available for collection. Whenever possible, the best material for propagation is the juvenile form. If only mature forms are available, material from their juvenile gradients may have a better chance of success.

Roots and Tubers

Timing of collection is important. The collection of immature or sprouting storage organs can result in significant losses in viability. In the case of plants that possess a dormant stage, a two-visit strategy may be required. One to identify individual clones and mark their location and another to collect the tubers or rhizomes once the top of the plant has died.

Fern Fronds

Fern fronds should be kept in plastic bags and not allowed to dry out during transport. If immediate delivery to the laboratory is difficult, place frond between 2 sheets of paper and allow to air dry flat within a plastic bag propped open. Spores will fall off frond as it dries. Seal the bag shut when completely dry and maintain a flat position to keep the spores on the paper surface.

Flowering Shoots

Some flowering shoots contain vegetative buds that do not develop but remain dormant. Sometimes the dormancy can be broken to produce juvenile vegetative shoots. Also, the immature flowers of a few tree species have been known to form adventitious shoots.

Root Cuttings

When lateral shoots are not available, such as in palms and other monocots, it is sometimes possible to produce vegetative shoots from root cuttings. Roots are often considered to be more juvenile in age than most of the tree. A juvenile gradient exists for roots, with the most juvenile material being closest to the trunk. Sprouts arising naturally from the roots of trees generally are juvenile in form. Store root cuttings in a moist sterile medium, such as peat moss.

Decontamination of Collecting Tools

Many of the Hawaiian endemic species have limited or non-existing *ex situ* collections, which necessitates the need for active *in situ* collecting. It is imperative that precautions be taken to keep the natural populations as disease free as possible. This is not only to maintain clean propagative stock material during collections, but also to ensure the integrity and overall health of the existing population and the surrounding flora. While absolute elimination of all pathogens is impractical and impossible, procedures should be directed toward preventing the introduction of serious foreign pathogens.

The risk of disease transmission of viral, fungal, or bacterial origin is a realistic possibility through the cutting implements used in collection of plant samples. Whenever possible, plant cuttings should be made with a new, unused blade. This can be accomplished by using an implement such as a box knife fitted with a disposable razor blade. The used blade can be changed before cutting the next sample.

Dr. Stephen Ferreira at UH Plant Pathology has also suggested that any cutting of plant propagules performed post collection should be done with disinfected tools. This is to prevent any disease contamination of the propagules before it goes to the propagation facility.

Decontaminate tools: Make a 5 % to 10% solution of household bleach (such as Clorox manufactured by The Clorox Co.) and soak tools. Let sit for 2-3 minutes then rinse well with water. Always use a fresh batch of bleach solution.

Literature Cited

Bonga, J.M. and P. Von Aderkas (1992) In Vitro Culture of Trees. Kluwer Academic Publishers, The Netherlands.

Falk, D.A. and K.E. Holsinger (1991) Genetics and Conservation of Rare Plants. Oxford University Press, Oxford, New York.

Guarino, L., V. Ramanatha Rao and R. Reid (1995) Collecting Plant Genetic Diversity-Technical Guidelines. CAB International, Oxon, UK.

8.2 Plant Propagule Collection Protocols; developed by the Makua Implantation Team and abridged and modified for the PTA Implementation Plan:

Introduction _ Benefits and costs of *ex situ* samples, and the context of collection

The ultimate goal of collecting seed or other samples for off site (*ex situ*) conservation purposes is to maximize the long-term survival prospects of these populations (or at least their genetic descendants) and species in their native habitats. *Ex situ* samples are thus a means to an end: continued survival of these rare and threatened species in the wild. They are also only one part of the total effort necessary to conserve these plant populations and species.

To the degree that samples can be maintained off site in good condition, they:

1. Reduce the chance that sampled individuals, populations and species will become irrecoverably lost, and
2. Provide material for use in reintroduction, research or other management options.

If done appropriately, off site samples can serve to reduce extinction risk. Collection does have a cost, however small or large, in terms of short-term survival prospects of sampled populations, and also in lost opportunities with management activities. These and other considerations must be weighed when sampling rare and endangered species for *ex situ* conservation attention.

Background _ Center for Plant Conservation (CPC) genetic sampling guidelines for conservation collections of endangered plants and later developments:

The Center for Plant Conservation's *Genetic Sampling for Conservation Collections of Endangered Plants* (CPC 1991) represents the first comprehensive attempt to create general guidelines for conservation collections. The Australian Network for Plant Conservation (ANPC) used the CPC guidelines as a basis for their own guidelines (Touchell *et al.*1997). The CPC collection guidelines are summarized below and are more thoroughly discussed in Guerrant and Pavlik (1998).

In short, the CPC guidelines provide a hierarchical series of questions to consider, and decisions to be made (Table 1). They are:

1. Which species should be collected?
2. How many populations should be sampled per species?
3. How many individuals should be sampled per population?
4. How many propagules should be collected from each individual?

When these four questions have been answered, there is another decision required: Is the desired collection level so great that it is harmful to the population, so that sampling should be distributed over two or more years?

Table 1. Summary of CPC (1991) Genetic Sampling Guidelines**

Questions/Decisions	CPC Recommended Range	Brown and Marshall 1995	Factors to Consider	Target level of biological organization	Key Considerations
Which species should be collected?	--	--	Degree of endangerment	Species	• Potential loss of unique gene pool
How many populations should be sampled per species?	1-5	50	Degree of gene flow among populations	Ecotype and population	• Degree of genetic difference among populations • Population history
How many individuals should be sampled per population?	1-50	50	Diversity among individuals within each population	Individual	• 'Law of diminishing returns' on additional samples • Genetic communication within population
How many propagules should be collected from each individual?	1-20	50	Survivability of propagules	Allele	• Survivability of propagules • Long term use of collection

** One additional question/decision has been added (which community/habitat), along with alternative benchmark values recommended by Brown and Marshall (1995).

A growing consensus appears to be forming among those in the *ex situ* conservation community that, while the general framework is very useful, the recommended ranges for collection may seriously underestimate what is needed. There are two main reasons why this might be. One is that recent estimates of what constitutes a MinASRm Viable Population are dramatically greater than earlier estimates, perhaps by an order of magnitude (Lande 1995, Lynch *et al.* 1995). The other stems from a combination of a greater appreciation of how difficult our basic tasks are, and how much uncertainty is involved in all steps of the process. From collecting a genetically representative sample, through maintaining it for long periods of time, and, finally, using those samples to establish new populations genetically comparable to those from which the propagules were collected are all more challenging than originally thought.

Brown and Marshall (1995) suggested that the objective should be to include in the sample at least one copy of 95% of the alleles that occurred in the large population at frequencies greater than 0.05 (5%). They note that either increasing certainty level over 95%, or dropping the critical allele frequency below 0.05 drastically increases sample size with only marginal gains. They provide what they call benchmark guidelines, which call for sampling 50 seeds each from 50 individuals per population, in 50 populations per eco-geographic portion of each species sampled. Clearly, this is far greater collection pressure than most if not all rare species can support, but it does provide a 'default' target to be adjusted for each species of interest, and the purposes for which collections are being made.

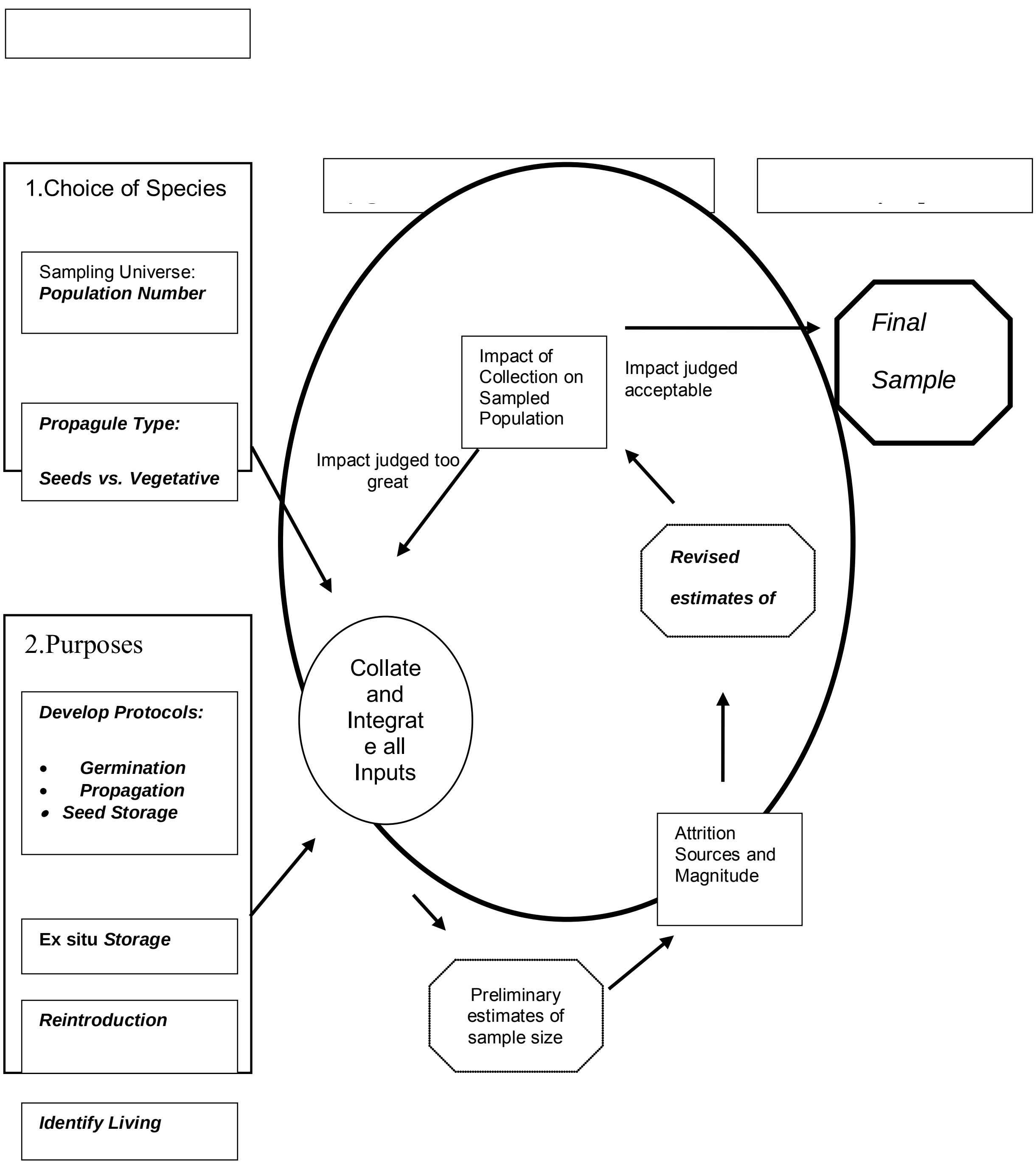
The original CPC recommended ranges were designed to describe how many propagules would be required to capture a genetic representative sample. It did not sufficiently reflect what additional material might be needed to learn how to germinate/propagate a species to compensate for possible attrition during storage, or losses during reintroduction itself (which are turning out generally to be considerable!). Thus, these are MINASRM estimates of what should survive after all these other factors are taken into consideration. Beyond that, the purpose for which a collection is being made will affect the appropriate sample size.

Overview: A process for arriving at an appropriate sample size:

A complex and bewildering network of interconnected factors must be considered in the process of arriving at an appropriate sample size for a conservation collection of an endangered plant species. One way to organize the network is to view it as basically a two step process, which is driven by two independent classes of factors both of which feed into an evaluation cycle (Figure 1).

The major classes of input factors are, 1) the species being considered, and 2) the purposes for which samples are to be used. The choice of a species determines both the sampling universe (*i.e.* how many populations are known and how large are they?), and also strongly influences the type of propagules that can be used. The other major driver concerns the various purposes that an *ex situ* collection is intended to serve. With the species and purposes in place, initial sample size estimates can then be made. However, not all propagules collected can reasonably be expected to survive in good condition during the period of time between collection and successful use. Therefore, sufficient additional propagules will be needed to mitigate expected attrition and revised estimates made. Taking attrition into consideration, the revised sample size estimates are then evaluated for their potential impact on the sampled population. If the estimated impact is judged too great, then this additional factor is added to the sum of inputs, opportunities and constraints, and the process of evaluating needs and impact is repeated. Only when the perceived benefit of collection is judged to be sufficiently high, and the impact on the sampled population sufficiently low, is a final sample size determined.

Figure 1. Conceptual flow chart illustrating how collection size decisions might be made. Illustrated are two major input factors, the choice of species with which to work, and the purposes that collections are intended to serve. The information about species and purposes together are fed into an evaluation cycle that considers attrition to collections while off site, and the potential impact on sampled populations. If the impact is judged to be too great, then the evaluation cycle is repeated until the impact is judged acceptable.



Inputs

There are two main groups of factors that drive the process: The choice of species with which to work, and the purposes for which collections are intended to serve (Figure 1). Each of these two primary drivers has associated opportunities and constraints that flow from them.

Choice of species: The CPC guidelines focus attention on degree of endangerment, and the potential for loss of unique gene pools as primary determinates of which species are chosen for ex situ treatment. The species for which ex situ treatment in the PIP is considered necessary have already been chosen, so these guidelines will not address the choice of species as such.
The choice of a species establishes two sets of opportunities and constraints. One is the sampling universe: how many populations of that species are known, and how large are they? The other concerns our ability to work with the species both horticulturally and for storage purposes: are seeds an option, and if so, how well and economically can they be stored for long periods of time, or must vegetative material be used?

Sampling universe: How many populations are known; how large they are, and in what condition and management context are they found. It is one thing to have an ideal target range for propagules to collect, but the actual optimal number to be taken is subject to many influences, such as population number, size and trend.
Clearly, the suite of species with which the PIP is concerned are extremely rare, often comprised of very few occurrences of very few individuals. The modal category for number of populations per species is 2-5, and the modal category for population size is from 2-10 individuals.

For as grim as these population size figures are, they may seriously over state the number of individuals from which seeds can be gathered. Seeds can only be gathered from successfully reproducing plants, and not all plants in a population are reproductive.

Recommendations: For species with 50 or fewer populations, collect from all known sites, or at least as many as is possible. For species with greater than 50 populations, collect from as many as possible, up to a total of 50. For populations with 50 or fewer individuals, collect from all known individuals; for populations with greater than 50 individuals, collect from 50.

The ultimate number of populations sampled per species is constrained by many factors: our ability to store them in good condition until they might be needed, the available resources, and the large number of other species that must be taken into consideration. Rather than get a 'complete' sample of any one species before moving on to the next, it is necessary to work with many species simultaneously. As a consequence, collection resources will probably spread strategically over many species simultaneously. The challenge becomes less of getting a fully adequate sample of one species before moving on, but getting as many samples as possible of the most critically endangered species first, and then gradually filling out the collections over time. Such a strategy of working with many species concurrently will spread collection pressure on any particular species over more time, which will help spread collection pressure on any one entity over more time.

Propagule types: Seeds and/or vegetative material?

Not only does the choice of species establish the sampling universe of populations and numbers of individuals with which there are to work, but also strongly influences the applicable range of horticultural and other options with which there are to work; with respect to long-term storage, those species with orthodox seeds offer the easiest, and most effective and economic options. For those species with recalcitrant seeds, off site samples may have to be maintained as growing collections. The relative impact on sampled populations is another factor to consider, and again, seeds are preferable to removing vegetative material.

Removal of seeds is considered less damaging demographically than removing vegetative plant parts. This conclusion is based on demographic modeling by Dr. Eric Menges (1992), in which he wrote, "The threat posed to population survival by environmental variation appeared almost entirely due to variation in mortality, growth and reproduction status and not to variation in reproductive output." While seed collection increases environmental variation in reproductive output, taking cuttings increases the variation in growth rate and possibly mortality.

Thus, if there is a choice of propagule type (seeds vs. cuttings) – and seeds can be stored alive for long periods of time - it is generally better on the sampled plants and populations to take seeds. But, this is not always possible.

The seeds of the vast majority of species fall into one of two relatively discrete categories of seed storage behavior: orthodox or recalcitrant. Orthodox seeds can survive drying to such low moisture contents that there is no liquid water left to form ice crystals, and therefore, can be stored at temperatures below freezing without damage. Recalcitrant seeds cannot survive at such low moisture contents, and cannot, therefore, readily be stored at subfreezing temperatures.

Orthodox seeds can generally be stored alive for 'long' periods of time (decades or longer?) without suffering 'significant' ill effects. Recalcitrant seeds are generally very short lived, and cannot be stored off site without labor and resource intensive 'heroic' effort.

Recent work by Dr. Christina Walters (USDA National Seed Storage Laboratory, Ft. Collins, CO) and Alvin Yoshinaga (University of Hawai'i) has shown that a large fraction of Hawaiian native plants have orthodox seeds.

Recalcitrant seeded species, and those with other problems, pose greater challenges for off site storage. Unlike seed collection, cuttings reduce the photosynthetic capital of the plant to some degree, and subjects a plant to invasion by pathogens. Nevertheless, the material obtained can be maintained and proliferated in tissue culture, and can have significant conservation value.

Purpose of collection

Along with the choice of species, the purposes for which a collection is being made is the second major determinant of sample size and density. At one extreme, some purposes, such as obtaining material to learn how to germinate and propagate plants or to determine their seed storage behavior may require very little material to be gathered without much regard to its genetic make up. At another extreme, some purposes, such as salvaging what can be obtained from a doomed population for use in storage and reintroduction may require that large samples be taken from every individual.

Note that it is not always necessary to collect additional material from the field. Suitable material (seeds, growing plants, or plant parts) may be available from other sources, such as existing samples in seed banks, *in vitro* cultures, or various cultivated sources. Where available and appropriate, material already stored off site should be used before new collections are made from wild populations, as long as the stored material is used for research or propagation/storage testing, or is not more than one generation removed from the wild population.

Develop protocols: Germination, propagation, seed-storage behavior, and/or reintroduction

Given the potential negative impact of collection on sampled populations, it is risky to collect material in volume before methods are available to use it well. In practice, there are species and situations, however, where the threat of extirpation in the wild is so high that more extreme measures might be justified. There appears to have been relatively little discussion in the conservation community of how to proceed in such extreme circumstances.

In general, there is rarely reason to think that different populations of a species would have significantly different germination, propagation requirements, and/or seed storage behavior. Therefore, there is no need for a statistically representative sample, as there is, for example, for storage or reintroduction. Thus, samples for these purposes should be taken from sources that will be least likely to harm survival prospects in the wild. In other words, obtain seeds (and/or cuttings) from the largest and/or most secure (or at least most dispensable) sources known. Seeds from properly identified and documented cultivated specimens are generally acceptable for these purposes. It may also be possible to minimize collection pressure by doing pilot work on closely related but more common congeners. Absolute amounts will depend on whether standard horticultural or *in vitro* (tissue culture) techniques are used, or both.

Recommendation: For developing germination and propagation protocols, and determining seed storage behavior, begin with seeds derived from ex situ plants (whenever possible) or minimal collections from the most secure populations. Determine actual sample sizes in consultation with those who will be working with the material. Where possible and prudent, begin with very small samples, especially if the probability of early success is low.

Reintroduction, including augmentation, is not a simple one-size-fits-all procedure. Insofar as appropriate material is already being stored off site, it should where appropriate be used before new collections are made. Actual sample sizes will depend heavily on the questions being asked of the experiment(s), and other aspects of the reintroduction plan being considered.

Recommendation: For developing reintroduction protocols, begin with the smallest collections necessary to address the questions being posed in the experimental reintroductions. Our ability to work with the species successfully will also influence sample size. Are seeds an option for storage, or must growing plants be used?

Ex situ conservation purposes

Seed storage (in seed bank): As a hedge against catastrophic loss in wild populations, and to provide material for reintroduction and other uses, collect and maintain off site as large and genetically representative and diverse an array of genotypes as possible without unduly compromising sampled populations. This is clearly easiest and most economical to do for species with long-lived orthodox seeds, which can be stored for long periods of time in standard (i.e., –20ºC) seed bank facilities. The numbers and genetic diversity of these collections will, of course, be strongly influenced by the number and size of extant populations from which to collect.
The numbers required for storage depend greatly on what purposes the stored seeds are intended to serve. Should an off site collection be expected to support a single reintroduction attempt, two, or ten? Are there other purposes, such as unanticipated scientific research efforts, that an off site collection might be expected to support?

For those species with recalcitrant seeds, a few may be able to be stored under cryogenic conditions (*e.g.*, liquid nitrogen temperatures, approaching –200ºC). The expertise and facilities necessary to store recalcitrant seeds are much more limited than for orthodox seeds. As a practical matter, off site collections of many recalcitrant seeded species will need to be maintained as growing plants.

Recommendation: Begin calculations with generic Benchmark Guidelines for storage offsite of wild collected material (50 populations, 50 individuals/population, and 50 propagules/individual), and from that subtract or add depending on a variety of factors: purpose, sampling universe, our ability to germinate, grow and store seed, and to support and sustain any intended reintroduction back into natural areas and sustain in the face of expected attrition.

Ex situ storage using cultivation of growing plants

In certain cases where there is an immediate and severe risk of extirpation of a population (from fire, ungulate threat, *etc*.) and it isn't possible to collect enough seeds, living tissue may be collected to increase genetic diversity of *ex situ* stock. For small populations, there should be enough off-site plants in living collections or *inter-situ* populations to represent the genetic diversity of the wild populations, which may be used to provide adequate additional seed stock for reintroduction, augmentation, or storage.

A wide range of activities is encompassed by this category. At one extreme are small specimen collections maintained in botanic gardens, the conservation value of which, other than for education, is extremely limited. At the other extreme are medium to large-scale plantings maintained in semi-cultivated to semi-wild conditions. These have variously been called *inter situ* collections or field gene banks.

Relative to stored seed, the cost to maintain growing plants is much greater, and the probability of successfully perpetuating the genetic integrity of stored material is much less. Once the infrastructure is in place, large numbers of seed can be stored in a seed bank at relatively low actual cost, and very low marginal cost. The genetic integrity of stored samples is probably generally much greater than for population samples maintained as growing plants.

This is thought to be true for several reasons. The expected longevity of stored seed is generally much greater than for growing plants. Assuming proper seed storage facilities and techniques are available, both the absolute and relative cost of maintaining the original genetic array of a collection is much less for seeds than for growing plants. It is extremely difficult, if not impossible, to provide habitats off site that are sufficiently similar to those experienced in the wild, so as to avoid artificial selection. In addition to the deleterious genetic effects resulting from random genetic drift due to small population sizes, the genetic addictiveness of growing samples is expected to deteriorate much faster than in dormant seed collections. Finally, there are phytosanitary and related considerations that need to be considered for growing plants, which do not affect stored seed.

Recommendation: For collections that must be maintained as growing plants, the limit is set more by the practical ability to handle a species, so numbers will generally be lower than for seed storage.

Reintroduction, augmentation

Sample sizes necessary to support actual reintroductions and/or augmentations can vary widely. In general, the larger the founding population, the greater will be the chance of it surviving to become an established, self-sustaining population (Guerrant 1996). Not all reintroduction attempts will succeed, even for those species for which protocols have been established empirically. The number of reintroduction attempts and their geographic limitations that a collection is intended to support will also greatly affect the sample size required.

Recommendation: Collect from as large and diverse an array of suitable founders as seems prudent, given the sampling universe with which there is to work, and the ability to maintain the material off site between the time of collection and use.

Recommendation: Collection for these purposes should be evaluated in light of the estimated conservation or other value to the species, and the cumulative impact of all collection activities anticipated for those species and populations.

Evaluation cycle

Sample sizes indicated by the above factors need to be evaluated in light of the following potentially significant factors that may indicate sample sizes larger or smaller than originally indicated.

Recall that the ultimate purpose of *ex situ* collections is to enhance the survival of sampled populations, so a positive balance must be struck between the potential benefits and costs of collection. The next step in the process (Figure 1) is to reconcile the potential benefits and costs, to the benefit of the species.

With the choice of species and collection purposes, initial estimates of sample sizes can be made. Additional material must be added to these preliminary estimates to compensate for expected attrition between collection and use. If the potential impact of the total collection size on sampled populations is judged too great, then this information is added to the mix. The cycle of evaluation is repeated until a reasonable balance is found with what we think can be accomplished without unduly harming the sampled populations.

Sources of attrition in ex situ collections, between collection and successful establishment

It is one thing to collect a genetically representative population sample and quite another to have sufficient and appropriate material available to establish a new, genetically comparable population if and when it becomes necessary. There are many steps along the way in which mortality and other losses can occur, both in terms of sheer numbers and in genetic diversity. In this section, we will consider various sources of attrition, what it takes to monitor them, and how losses can be mitigated.

Survivorship and genetic change in collections

Perhaps the most basic source of loss is due to mortality during off site storage. There may be large differences in mortality rates among different propagule types and different species within a propagule type. Off site collections that must be stored as growing plants present a much more formidable challenge than those that can be stored as dried and frozen seed, and those stored as *in vitro* cultures are presumably somewhere in between.

There are several reasons why growing plants off site for conservation purposes is less desirable than storing them as seeds or as *in vitro* cultures, not the least of which are the resources required to maintain a given number of plants over a long period of time. First, to avoid the genetic losses and other changes that are likely to occur when population sizes are small, a large number of plants must be grown for, perhaps, many generations. The amount of space, man-power and other resources that must be expended to maintain just one population of one species is daunting indeed. If this were not problem enough, growing plants off site will inevitably subject them to a selective environment different than that in which they evolved, thus eroding their ability to survive when their descendants are used for reintroduction back into the wild. The most extreme illustration of this phenomenon is where plants grown off site under conditions sufficiently different than their native habitats cannot survive when returned to their native habitats. While this might seem fanciful to some, it or something close to it happened when the attempt was made to reintroduce to Tenerife, in the Canary Islands, a long established line of *Lotus berthelotii* that had been grown in Europe. The plants all died in the nursery on Gran Canaria, apparently as a result of the higher temperatures there than where they had been grown (Maunder and Bramwell pers. comm.). Another less extreme but still telling example is that of *Amsinckia grandiflora* (Pavlik *et al.* 1993, Pavlik 1995), in which plants were grown at the University of California at Davis in what would seem to be very similar conditions to, and within a few miles of, their native habitat. Electrophoretic analysis of seeds collected twenty years before and held in storage indicated relatively low genetic diversity, but seeds derived from plants grown off site for just a couple of generations showed even less. Although the plants were large and vigorous when grown off site, the pin/thrum ratio of this heterostylous plant was very different in cultivation than it was in the donor population. This suggests that plants derived from seeds grown off site might be less fit when reintroduced than those that had not. Finally, sanitation issues – keeping reintroductions from being a vehicle for introducing pests, pathogens, and weeds into the wild – are most acute when plants are grown off site; the danger of picking up pests and pathogens increases with time in off site cultivation.

Species with orthodox seeds are at the other extreme, where large samples can be in frozen storage for long periods of time with little maintenance and at a relatively low marginal cost. Seeds of some species can presumably be stored for decades, even centuries, with little mortality. We aren't aware of information about the degree to which mortality in seeds banks is selective or random.

Recommendation: Monitor survivorship and health of off site growing collections and respond appropriately. The emphasis should be on improving cultural conditions rather than additional collection.

Monitoring survival rates of stored seed

Although potential mortality rates appear to be quite low in stored seed, survival must nevertheless be monitored. The only sure way to do this is to attempt to germinate samples when they enter the seed bank, and periodically thereafter. This is not as simple as it might seem. First, it is necessary to know how best to germinate the sampled population (Baskin and Baskin in press). While germination requirements are often thought to be species specific, there are examples where germination requirements, at least of widespread species, may differ significantly among populations (*e.g.,* Meyer 1992). Once a suitable protocol is established, it is necessary to subject different seed batches to comparable conditions in order to assess changes in germinability over time. Otherwise, germination rate differences might be due to environmental causes. This will presumably require the use of controlled environment chambers, as ambient outdoor conditions are not sufficiently similar between years.

Interpreting the results of comparisons between different trials is the next hurdle to overcome. While the magnitude of what constitutes a significant decline is a subjective decision, it is possible to analyze sample sizes necessary to detect a given decline. In their Guidelines for the Maintenance of Orthodox Seeds, the CPC (Weiland 1995) suggest a 15% decline as a reasonable threshold to trigger action (either recollection, or a grow-out). (Abella, 2004)

Ideally, the results of statistical tests on seed samples to determine if there has been germinability decline accurately reflect the true condition of the seed lot. However, it is possible, due to chance alone, that our tests will indicate a decline when, in fact, there is none. This is a Type I, or False Change Error, and the probability of making it can be considered the significance of the test. Designated α, this is the p-value commonly cited when a difference is found. Alternatively, and again due to chance alone, a test may fail to indicate a decline when, in fact there has been one. This is known as a Type II, or Missed Change Error, and our ability to avoid it is known as the power of a test. In other words, the power of a test is a measure of how likely our test is to detect a given decline, if there really is one. It is, of course, easier to detect a large decline than a small one, so it is necessary to designate the minimum detectable change when specifying the power of a test. There is no single sample size necessary to detect a given decline. Sample size varies, among other things, according to how tolerant you are of making the two kinds of errors. This is a subjective decision that involves tradeoffs. As the desired significance of a test increases, power declines.

The sample size necessary to detect a given decline also varies with the initial germinability of a seed lot. Figures 3-6 illustrate the differing relationships of statistical power as a function of sample size differences when initial germinability is either 90% or 50%, and the desired significance of the tests are either p=0.1 or p=0.01. There are three patterns to note. First, power increases dramatically as minimum detectable difference increases. Second, to detect a given decline for a given sample size, statistical power is greater if initial germination rate is 90% rather than 50%. Tests are least sensitive when the initial germinability is 50%, and more sensitive toward either extreme. Third, note the increase in statistical power associated with a greater tolerance for making a False Change Error (where α=p=0.1 versus α=p=0.01). Sample sizes refer to the number of seed used in each test, not the sum of two or more tests.

Fig. 3 Chi-square Test of Proportions (Two tailed test)
Higher = 0.9, alpha or p = 0.01

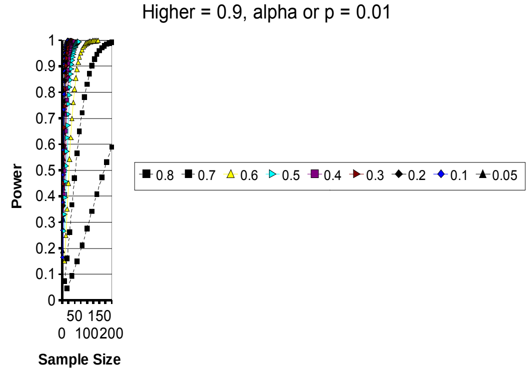
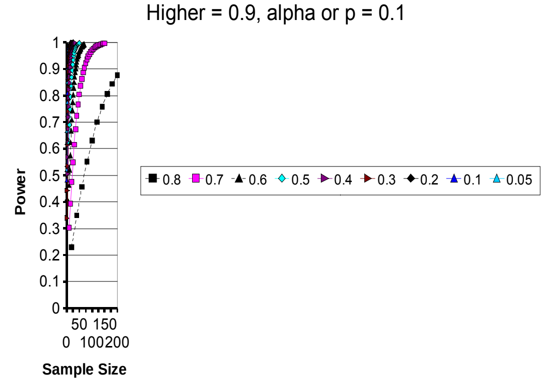
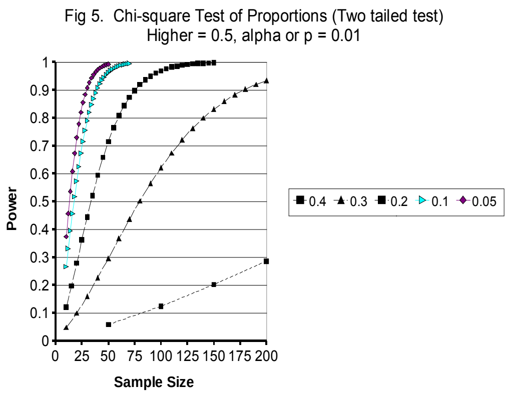
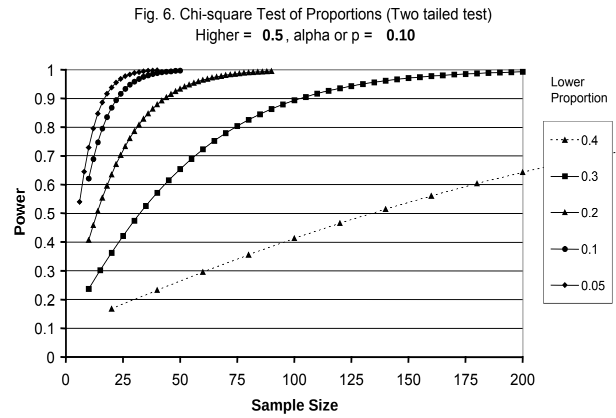


Fig. 4 Chi-square Test of Proportions (Two tailed test)
Higher = 0.9, alpha or p = 0.1







This method of analysis presents several dilemmas. One is that we must choose sample size before we know what the initial germination fraction is. Pilot studies are helpful, but use additional seed. Given the rather large sample sizes often needed to detect changes of a magnitude we might like, we simply will not have (or be willing to use) sufficient seed to be able to monitor a collection as closely as we might like. This sobering fact is especially true when seeds from each maternal parent are maintained separately – which is definitely preferred over bulk collections. This raises a policy choice about how precisely we can know the status of a collection. Resolution of this basic dilemma awaits further discussion in the conservation community. Nevertheless, even small samples can provide meaningful (if not very precise) information about the viability and longevity of a seed stock.

Recommendation: Unless very large samples are available, it is unlikely there will be sufficient seed to monitor viability with any high degree of precision.

Demographic costs of reintroduction: Modeling 'expected' attrition using empirical demographic data:

Population size targets, often specifying numbers of mature plants, are indicated in reintroduction plans for each project. While it is not reasonable to expect that all propagules planted will survive to reproduce, what is a reasonable expectation? In order to estimate the range of post-planting decline in population size that might be expected during reintroduction, Guerrant and Fiedler (in press) used empirically derived stage-based transition matrices for a variety of life histories from the literature as a basis for stochastic modeling.

They found, not surprisingly, that the demographic cost during reintroduction can be substantial. In the most extreme case, an outplanting of 1,000 *Panax* seedlings would, on average, drop to just 15 individuals within three years before the simulated populations began to rise. But, of course, many simulated runs ended with extirpation before any increase could begin. If the newly established populations are to have anything like the genetic diversity of the ones from which the founders were collected, expected losses during reintroduction must be accounted for in the original collection. These data are, of course, simulated results based on wild populations with positive growth rates. One assumption of these models is that outplanted individuals will behave demographically identically to naturally occurring plants, which is probably optimistic. Another assumption of the models is that the series of years for which data were gathered in the field accurately reflect what will happen during a reintroduction. Presumably there will be many stochastic environmental effects that cannot be anticipated, but which will affect establishment. Using similar techniques and comparable seed supplies (planted in the field near where they were collected the year they were collected) a series of 27 field germination and seedling establishment trials of *Erythronium elegans* set out yearly with fresh seed each year over a 5-year period spanned the range from 0-94% establishment (Guerrant 1999). Clearly, attrition can be high, and vary greatly among different years.

The implications for collection guidelines to support even one reintroduction attempt are daunting. To compensate for expected losses of these magnitudes suggests that sample sizes might need to be one or two orders of magnitude greater than current suggestions. Unfortunately, such collections either may be too great for sampled populations to bear, or prohibitively expensive in time and other resources needed to collect, store and monitor. In addition to increased sample sizes, other ways to compensate for potential losses associated with reintroduction must be explored.

One such alternative is to use larger founding individuals, which might be expected to have greater survivorship than smaller founders. So, too, any post-planting care that can be provided to increase survivorship of the founding individuals should also reduce the sample size requirements.

Recommendations: Start with an estimate of desired numbers surviving to reproduction, and then account for expected losses during establishment. Maintaining backup clonal material can mitigate some of these losses.

What is the effect of collection on extinction risk of sampled population?

The ultimate purpose of *ex situ* collections is to enhance the long-term survival prospects of sampled populations. Thus, for collection itself to harm the sampled population in the short-term is generally to be avoided. However, even in the absence of collection, at what point does the short-term risk of extinction become so great that sampling at a rate that is harmful becomes justified?

General condition: MinASRm risk to sampled population

The final question posed by the CPC genetic sampling guidelines was the least developed: What level of collection necessitates a multi-year collection strategy? Eric Menges, Samara Hamzé and Ed Guerrant have recently addressed this question with a computer simulation study.

The following paragraphs are the abstract for the manuscript, which is currently in review (and thus subject to change):

> "Seeds are widely considered to be the propagule of choice for *ex situ* conservation collections elative to cuttings or transplants, seeds can easily be collected in large numbers and stored alive for long periods of time; their harvest is thought to be the least damaging to the sampled populations.
>
> "Guidelines for amounts and timing of seed harvests, however, have not been grounded in demographic data or projections. We examined the demographic consequences of 36 patterns of seed harvests: 10, 50, and 100% of fecundity for 10, 50, and 90% of years, on populations of 10, 50, 100, and 500 plants. We compared these results to no-harvest scenarios with the same four initial population sizes. We used published projection matrices from about two dozen plant species encompassing a range of life forms. We modeled using stochastic simulations, alternating projection matrices representing different years and different harvesting intensities. For each species, we examined 40 combinations of conditions in 1,000 replicate simulations for 100 years each and we calculated the proportion of replicates becoming extinct.
>
> "Species differed in sensitivity to seed harvest, with long-lived species, especially woody plants, being least sensitive. Populations of 500 or more were not harmed except by complete harvests for half or more of all years. Small populations of ten were harmed by less complete harvesting, but sensitivity varied widely by species.
>
> "Our modeling suggests three seed harvest rules:

1. Harvesting 10% of seeds in 10% of years (or less) is generally safe.
2. Harvesting 50% of seeds in 50% of years (or more) is generally unsafe.
3. Less intense, frequent harvests are safer than more-intense, infrequent harvests.

Although these analyses encompass many mathematical, biological, and sociological assumptions, they suggest that prudent seed harvesting will not have significant short-term demographic effects."

Recommendation: Less intense, frequent harvests are expected to have less of an impact on sampled populations than more-intense, infrequent harvests. To the degree possible, spread collection out over two or more years, especially for small populations.

Special case: intentionally collect enough to cause short-term risk to sampled population:

As stated in the first section, given the potential negative impact of collection on sampled populations, it is risky to collect material in volume before methods are available to use it well. In practice, there are species and situations, however, where the threat of extirpation in the wild is so high that more extreme measures might be justified; situations in which it might be necessary to act sooner rather than later.

The PIP IT must deal with many species that are so extremely rare and/or endangered that “we may not be able to safely wait until we get the propagation and genetic storage procedures worked out” (Bruegmann and Jacobi, pers. comm.).

Note that the minimum population size Menges *et al.* (in press) modeled was 10 individuals. Part of our reasoning is the belief that populations this small and especially smaller are inherently threatened with extinction, due simply to chance. In the manuscript, Menges *et al.* noted that declining populations represent special cases, where other considerations might become important. If a population is in decline and sliding toward extirpation anyway, collection did not affect the end result – extirpation - just the timing. In such cases, the potential benefits of collection must be weighed against the additional pressure of collection on extinction risk. Another area not covered directly in the models concerns very small and other populations where the probability of extirpation in the foreseeable future due to random factors is so high, that additional risk of ‘rescue’ collections might be of conservation value. The question arises then of what to do with very small or other populations you have reason to think are particularly susceptible to extirpation in the near to medium term (say 5-25 years).

While it is always best to keep in mind the dictum – Do No Harm - it may be necessary in some situations to collect so much material that collection itself becomes a serious threat to the sampled wild population, at least in the short term. The effort to recover the California Condor – which is highly endangered even by Hawai‘i standards - is a case in point. ALL wild birds were captured, thus driving the species to ‘extinction in the wild’ – at least temporarily. These birds were and are being used in a captive-breeding program, and the goal is to release many more individuals into the wild (and in more areas than just the collection sites) than were removed. Thus, we may find ourselves in the uncomfortable position of ‘destroying’ something in order to save it.

Recommendation: For populations of species with low numbers overall, that have 10 or fewer reproductive individuals and a poor history of recruitment, or a population known to be in precipitous decline, collect 20-100% of seed at the discretion of the permitted collector. Such collection levels assume, of course, that adequate facilities and procedures are available to care for the material, and that such collections are part of a more inclusive strategy. For those situations in which germination, propagation, or seed storage methods are not yet available, it may be necessary to collect some material to better ensure the continued existence of the species or populations in question.

Final collection guidelines considering the above factors

To determine the sample sizes that must be collected, use the accompanying worksheets (Tables 2 and 3) to clarify how much is needed for all purposes that are intended to be served, and how much suitable material is in off site collections already.

Genetic Sampling Guidelines Worksheet: Preliminary Estimates Species ______________________________

Page __ of ___	Population For each population indicate name and number of mature and juveniles above preliminary target numbers for collection.														
	Mat	Juv		Mat	Juv		Mat	Juv		Mat	Juv		Mat	Juv	
Purpose of Collection	Indiv	Prop /indiv	Tot Prop	Indiv	Prop /indiv	Tot Prop	Indiv	Prop /indiv	Tot Prop	Indiv	Prop /indiv	Tot Prop	Indiv	Prop /indiv	Tot Prop
To develop protocols															
Germination															
Propagation (standard Hort. proc.)															
Propagation (in vitro)															
Seed Storage Behavior															
Ex situ storage															
Orthodox Seed															
Attrition (rate)															
Recalcitrant Seed															
Attrition (rate)															
In vitro slow growth															
Attrition (rate)															
In Cultivation															
Attrition (rate)															
Reintroduction															
Attrition rate (inc. demog. cost)															
Augmentation															
Attrition rate (inc. demog. cost)															
Other															
Is multi-year collection plan indicated?															

Genetic Sampling Guidelines Worksheet: Page 2 Species ___________________________________

Sampling Universe by population		Existing Collections			Final Targets for Collection			Notes
	Pop size	Seeds	Growing Plants	In vitro	Indiv	Prop/ indiv	Multi-yr col.	

TABLE ABBREVIATIONS:					
col: collection	demog: demographic	Hort: Horticultural	inc: include (ing)	Indiv: Individual(s)	
Juv: Juvenile(s)	Mat: Matured	pop: population	proc: procedures	Prop: propagules	Tot: total

Conclusions:

The basic structure set out in the original Center for Plant Conservation Guidelines for Conservation Collections of Endangered Plants are sound, but the actual numbers need to be revised upward. In the most recent and thorough statistical treatment of sampling strategy, Brown and Marshall (1995) have a benchmark target of 50 individuals per population in each of 50 populations per eco-geographic region per species, which are here suggested as a benchmark against which actual sample sizes are determined.

All numbers are, of course, subject to change, and any collection strategy must be tempered with consideration for the purpose of collection, ability to maintain the samples in good condition off site, and any damage to wild populations done by collecting itself. After all, off site samples are part of a larger integrated conservation program; the ultimate purpose of which is to increase the long-term survival prospects of sampled populations in the wild.

Literature cited

Baskin, C.C., and Baskin J.M. 1998. Seeds: ecology, biogeography, and evolution of dormancy and germination. Academic Press, New York, 666 pp.

Brown, A.D.H., and D.R. Marshall. 1995. A basic sampling strategy: theory and practice: *in* Guarino L., V. Ramanatha Rao, and R. Reid (eds.), Collecting plant genetic diversity: technical guidelines. CAB International for IPGRI, Rome, pp. 75-91.

Center for Plant Conservation. 1991. Genetic sampling guidelines for conservation collections of endangered plants: *in* Falk, D.A., and D.A. Holsinger (eds.), Genetics and conservation of rare plants. Oxford Univ. Press, New York, pp. 225-38.

Guerrant, E.O., Jr. 1996. Designing populations: demographic, genetic, and horticultural dimensions: *in* Falk, D.A., C.I. Millar, M. Olwell (eds.), Restoring diversity: strategies for reintroduction of endangered species. Island Press, Covelo, pp. 171-207.

Guerrant, E.O., Jr. 1999 (July). Comparative demography of *Erythronium elegans* in two populations: one thought to be in decline (Lost Prairie), and one presumably healthy (Mt. Hebo). Final report on five transitions, or six years of data. Unpublished report prepared for the USDI Bureau of Land Management, and USDA Forest Service. 85 pp.

Guerrant, E.O., Jr., and P.L. Fiedler. (*in press*). The sorcerer's apprentice: on the size, composition, and uses of off-site conservation collections: *in* Guerrant, E.O., Jr., K. Havens, and M. Maunder (eds.), Saving the pieces: the value, limits, and practice of off-site plant conservation in support of wild diversity. Island Press, Covelo.

Guerrant, E.O., Jr., and B.M. Pavlik. 1998. Reintroduction of rare plants: genetics, demography and the role of *ex situ* conservation methods: *in* Fiedler, P.L., and P. Kareiva (eds.), Conservation biology for the coming decade. 2nd ed. Chapman and Hall, New York. pp. 80-108.

Lande, R. 1995. Mutation and conservation. Conservation Biology 9: 782-91.

Lynch, M., J . Conery, and R. Bürger. 1995. Mutation accumulation and the extinction of small populations. Amer. Naturalist 146: 489-518.

Menges, E.S. 1992. Stochastic modeling of extinctions in plant populations: *in* Fiedler, P.L., and S.K Jain (eds.), Conservation biology: the theory and practice of nature conservation, preservation and management. Chapman and Hall, New York, pp. 253-75.

Menges, E.S., E.O. Guerrant Jr., and S. Hamzé. (*in press*). What is the effect of seed collection on extinction risk? *in*: Guerrant, E.O. Jr., K. Havens, and M. Maunder (eds.), Saving the pieces: the value, limits, and practice of off-site plant conservation in support of wild diversity. Island Press, Covelo.

Meyer, S.E. 1992. Habitat correlated variation in Firecracker Penstemon (*Penstemon eatonii* Gray: *Scrophulariaceae*) seed germination response. Bulletin of the Torrey Bot. Club 119(3): 268-79.

Pavlik, B.M. 1995. The recovery of an endangered plant. II. A three-phased approach to restoring populations ***in:*** Urbanska, K.M., and K. Grodzinska (eds.), Restoration ecology in Europe. Geobotanical Institute SFIT., Zurich, pp. 49-69.

Pavlik, B.M., D. Nickrent, A. M. Howald. 1993. The recovery of an endangered plant. I. Creating a new population of *Amsinckia grandiflora*. Conservation Biology 7: 510-26.

Touchell, D.H., M. Richardson, and K.W. Dixon (eds.), with consultant ed. A. George. 1997. Germplasm conservation guidelines for Australia: an introduction to the principles and practices for seed and germplasm banking of Australian species. Australian Network for Plant Conservation, Canberra, 40 pp.

Wieland, G.D. 1995. Guidelines for the management of orthodox seeds. Center for Plant Conservation, St. Louis.

8.3 Lyon Arboretum Seed Storage Summary

(The following information was provided by Alvin Yoshinaga, personal communication, 2007)

<u>Of the species on the PTA endangered species list:</u>

Asplenium peruvianum var. insulare

We do not have much experience with ferns. Valerie Pence at the Cincinnati Zoo & Bot. Garden has worked on storage of Hawaiian fern spores off and on. In general, spores that are shed brown can be stored in the same way as seeds. Spores that are shed green are hard to store. There is little data on just how long you can store spores of Hawaiian ferns. A problem with fern spore storage as a conservation technique is that, even if you can successfully germinate the spores after storage, it is often difficult to get sporophytes.

Haplostachys haplostachya

We have very little data for any *Haplostachys*. The great majority of mints store well using conventional techniques.

Hedyotis coriacea

We have no data for *H. coriacea*. *H. terminalis* stores well frozen for at least 5 yrs. Our *H. acuminata* stored well for 1 yr., but not for 2. Refrigeration seemed better than freezing. We did not have much to test, so we need to do more tests with *H. acuminata*.

Isodendrion hosakae

We have very little data for any *Isodendrion*. The great majority of violets (including *V. chamissoniana*) store well using conventional techniques.

Lipochaeta venosa

We have very little data for the *Lipochaeta/Melanthera/Wollastonia* group because we have had difficulty germinating them. Composites store well using conventional techniques.

Neraudia ovata

We have little experience with *N. ovata*. *N. angulata* stores well refrigerated for at least 2 years; seeds also survived frozen storage, but with lower germination.

Portulaca sclerocarpa

We have no data for *P. sclerocarpa*, and only very little for *P. villosa*. *Portulacas* in general store well using conventional techniques.

Schiedea

We have no data for *S.*. *S. nutallii*, *S. ovata*, and *S. trinerve* all store well frozen.

Silene/S. lanceolata

We have no data for *S.*. *S. lanceolata* stores well for at least 5 years refrigerated. Frozen seeds survived with slightly lower germination. GA3 seems to help stimulate germination.

Solanum incompletum

We have had good results with both refrigerated and frozen storage after 5 years; frozen storage would probably be better in the longer run. There are dormancy problems. GA3 seems to help stimulate germination. The Baskins have found that temperature also plays a role in breaking dormancy.

Spermolepis

Spermolepis stores well frozen for at least 1 year.

Stenogyne angustifolia

We have no data for *S. angustifolia*. See note for *Haplostachys*.

Tetramolopium arenarium

T. arenarium stores well frozen for at least 5 years. We have some evidence that at stores better when dried to lower than standard moisture levels. We have no data for *T. diersingii*; our data for other *Tetramolopiums* show that they store well frozen.

Vigna o-wahuensis

V. o-wahuensis seeds store well frozen for at least 2 years. Black seeds store better than brown seeds.

Zanthoxylum Hawaiiense

We have no data for *Z. Hawaiiense*. From circumstantial evidence, it is thought the members of the genus can be stored by conventional techniques.

"Conventional techniques" for storage are refrigeration at around 39 deg. F or freezing at 0 deg. F after drying to proper moisture levels. For refrigeration, the relative humidity of the dryer should be 33% at 77 deg. F or 20% at 39 deg. F. For freezing, it should be around 46% at 77 deg. F or 31% at 39 deg. F. In general, if a seed tolerates both refrigeration and freezing well, it will store longer frozen. There are some that do store better refrigerated, though, so, for seeds for which there is no data, refrigerated storage is the more conservative choice.

8.4 HRPRG Reintroduction Guidelines

Reintroduction Guidelines Hawai'i Rare Plant Restoration Group: August 1999

These guidelines deal with the reintroduction of rare plants. Reintroduction should be a supplement to habitat management not a substitute; the final goal being not the success of an individual plant, but the establishment of a viable population where cross-pollination can occur and in which genetic variation is maintained. An intermediate goal may be to establish a population for field stock or research reasons. It is expected that derivatives of the material in such field stocks will be outplanted more widely once appropriate habitat is secured and stabilized. These plants can be maintained as sources of seeds, cuttings or transplants for reintroduction efforts. Research activities may be intended to identify what factors are causing mortality/decline, to test methods to overcome these factors, or validate planting techniques. Ideally, successful research efforts will be permanent outplantings in their own right. Regardless of the intent of the planting, the process of reintroduction should consider the following guidelines. Many of the guidelines require coordination with other committees within the Hawai'i Rare Plant Restoration Group (HRPRG) as well as with agencies that may be collecting and propagating rare species. Included at the end of these guidelines is a list of contacts who may be contacted to consult on reintroductions. These guidelines have been broken into sections guiding actions before during and following the actual transplanting of a plant.

Prior

1. Prior to the reintroduction of a plant, there are some issues that must be considered to ensure the health of the species, the individual transplanted plant and the surrounding habitat. This must include considerations of the reproductive biology of the species to be outplanted.

    a) Genetic Stock: The agency or individual that is reintroducing a plant must coordinate with the agencies or individuals responsible for the collection, and propagation of the plant. This must be done to ensure a healthy and balanced genetic composition. In addition, a population geneticist may be consulted about strategies and alternatives when dealing with especially rare species or those with specific reproductive qualities. This is, of course, of special concern when dealing with depleted wild populations with remnant genetic stock. It should be the shared responsibility of all agencies and individuals involved to leave an easy-to-follow paper trail back to the source plant (*i.e.*, Rare Plant Monitoring Form (RPMF), greenhouse accession numbers). Reintroduction is the last chance to make sure what we are propagating and planting represents a sufficient amount of the genetic composition of the species. Recalcitrant seed-producing plants may be taken as cuttings and helped into seeding in a greenhouse to increase the overall genetic base of the outplantings. Plants used in reintroduction should be as close to the collected field stock as possible. Plants that have been in the greenhouse for multiple generations may have been selected for different conditions than the reintroduction site and may have high attrition rates when planted. The pollination biology of each species must be researched and considered before reintroduction. Of special concern are pollen dispersal, autogamous (capable of self-pollination on a regular basis) and dioecious species, using propagules or plants from multiple year collections and mixing populations.

- When reintroducing a species that is an outcrosser, one must consider the method of pollen dispersal. For example, wind pollinated species need to be planted close enough to ensure successful cross-pollination and species which require a pollinator must be planted in an area where an appropriate pollinator is known to exist. In a situation where one needs to keep a reintroduced population distinct from a wild population the site must be far enough to not allow cross-pollination. How far is enough depends on the method of pollination (*i.e.*, wind, insects, and birds).
- One needs to determine if the species they intend to reintroduce is obligatively autogamous. Obligatively autogamous species tend to have genetically similar individuals due to their inability to outcross within a population. When collecting propagules for reintroducing an obligatively autogamous species, it is important to collect representatives from as many distinct populations as possible as opposed to getting representation from many individuals in one population as you would for an outcrossing species. If one intends to reintroduce an autogamous species it is important to maintain those distinct populations and not mix them when reintroducing. When reintroducing dioecious species one should plant equal numbers of male and female plants. If the plants are not yet mature and cannot be sexed, one should plant larger numbers of individuals to increase the effective population size.
- When selecting the plants to be used in reintroduction, one must consider the age and year the stock was collected. Using propagules or plants from multiple years ensures better age class representation and possible genetic variety of stock.
- Care should be taken not to mix gene pools that may be distinct and have local or microhabitat adaptations. A site with mixed stock should not be close to a population in which you seek to preserve representatives of geographically isolated subsets.

b) Maps: Prior to the reintroduction of a species, the area should be precisely mapped. Maps should include the historical and present range of the species, locations of known populations and proposed outplanting sites. A GIS database can also be used as a permanent record of the source of a particular population and to track the propagules. This will help ensure a genetic balance throughout the historical range.

c) Threat Abatement: Threats to a population should be noted on the RPMFs used to monitor rare species. An entity involved with reintroduction must obtain copies of the RPMF to track the genetic composition of their plants. As always consulting with anyone associated with the monitoring, collection and propagation of the species is necessary to get any other information. A management strategy addressing the threats compiled from the RPMFs should be in place before plants are reintroduced. Strategies should include measures to control the most likely threats of ungulates and competition with non-native plants. Management activities must be conducted carefully as to not further degrade the habitat for reintroduction. All threat control techniques can be pathways for pathogens and other contaminants and must be executed properly. Weeding around an outplanting site may only proceed after careful considerations of the intent. Changing light regimes and soil composition can negatively impact the habitat for reintroduced plants. In addition, threats to an outplanted population may be different from those affecting the wild populations. For example, a wild population from which propagules are collected may be fenced and weeded but an ideal outplanting site existing off site within historical range may not have any management. Reintroduction should only proceed once a management strategy for the site has been established.

d) Site Selection: Once the historical range of the species is known and a management strategy is established, a suitable site for outplanting within the range must be selected. Again coordination with the collectors and propagators is essential. A site should be chosen according to the biotic and abiotic elements that comprise the habitat for the newly transplanted population. A careful review of the RPMFs may provide all the information available on the source population. However, before outplanting, an agency or individuals should seek any additional information from anyone associated with the monitoring, collection, and propagation of the species. When interpreting historical range, one must consider that recent alterations of the habitats may have left the sites inhospitable for reintroduction. Invasion by alien species and other threats may have left the habitat within historical range unsuitable due to changes in moisture regimes and soil composition. In such cases reintroduction may be most successful in sites outside known historical locations that have maintained the critical biotic and abiotic elements necessary for successful reintroduction.

e) Reintroduction scenario: Sites for reintroduction can be placed in at least three categories each having special considerations.

i) Reintroduction of a species within historical range: Agencies must consider what distinguishes populations from one another for each species that is to be outplanted. The site must be able to support a distinct population or one is only augmenting the adjacent population which may have different ramifications. Specific information about the habitat characteristics of the source population must be matched as close as possible with the outplanting site to provide the best chance for survival. This should be done by consulting anyone associated with the collection and propagation of the species and referring to the RPMFs.

ii) Augmentations: This involves introducing propagules or plants into existing wild populations. This type of reintroduction must be considered on a case-by-case basis for each species. This reintroduction must be done carefully as to not harm the existing population with contaminants or physically altering the soil structure or existing roots. Augmentation may negatively alter the genetic composition of the population with propagules or plants from a single source or ones that have been raised through multiple generations in the greenhouse if not carried out strategically.

Alternative scenarios are preferred due to the difficulty in ensuring a successful reintroduction. The complex problems involved with preventing pathogens from invading the wild population lowers the desirability of this option. It is especially important to contact as many individuals or agencies as possible for comments before augmenting a population.

iii) Introduction of a species to a site outside the known historical range: Agencies or individuals considering this type of introduction need also to consider the possible negative effects on the species. Establishment of a healthy viable population may be hindered by loss of genetic variation being at a site away from other populations. Possible hybridization may occur when bringing a species outside its historical range and into the range of another related species. A site outside the known historical range may lack the habitat characteristics necessary for establishing a healthy population. Contrarily a site outside of the known historical range of the species may be the only place safe from the threats that brought the species to the remnant state we find them in today. In some cases, these sites may also offer the best management option for a particular species. It is also possible that the historical range is incomplete or no longer contain the most appropriate habitat including suitable moisture and soil composition.

f) Site Preparation: Once a proper site has been selected there are steps the agency or individuals can take to prepare it for reintroduction. In accordance with the management strategy for the species and site, it may be initially necessary to construct a small-scale exclosure and/or weed non-native competitors around the site. These actions should be taken in concurrence with protection of the greater habitat, which is critical to the success of an established population. The season in which to plant must be considered. Generally, mesic and dry plant species would face fewer challenges if planted during a wet season. If drought conditions persist for more than a year, it may be beneficial to wait for a better year if storage conditions allow. Techniques for preparing the soil to receive and support a new plant differ depending on the species. One should consider digging holes in advance and composting material on site to provide a favorable substrate. Composting materials should come from on-site and ideally be from native material. Soils may also be tested to guide soil preparation and future fertilization schemes. Coordination with the propagators is essential to ensure the fertilization and pesticide application schemes used in the greenhouse are adopted in the field. A catchment and watering system may also be considered.

During

2. The successful reintroduction from the greenhouse to the ground requires several issues to be taken into account.

a) Sanitation: Coordination with the propagator and collector is necessary to ensure that all aspects of rare plant handling are done with attention to sanitation. Collection should be done with sanitized tools and proper propagation techniques practiced to eliminate possible contaminants. Agencies and individuals involved with reintroduction need to coordinate with the propagator before the date of planting to make sure the propagules are prepared to go out. This may entail use of pesticides to ensure no foreign contaminants are transported to the site. The risk of spreading aliens via reintroduction activities must be adequately addressed and effectively eliminated. Seeds, slugs, disease, parasites, flatworms and other unintended inoculates must be prevented from being transported to the site by any aspect of the operation: protective management activities, materials, personnel and the plants themselves must all be completely free of contaminants. Care should be taken to clean all gear (boots, packs, planting tools, *etc.*) prior to arrival at the site to assure no contaminants are spread unknowingly.

b) Transport: Use caution when transporting fragile plants. Some species may need water or protection from the sun and wind during the transport. The most secure place in a vehicle for transporting plants is directly in back of the driver's seat.

c) Planting: Those involved in the planting of rare plants should be briefed before heading out to the site. Agencies and individuals directing reintroduction need to consider the techniques to be used in getting the plant from the container to the ground. Of special consideration is the decision to use a fertilizer in addition to any on site composting. In areas of low rainfall initial watering may be essential in easing the shock for the new plantings. Building up a pile of mulch around the base of a new plant can help to slow evaporation and keep water near the roots. A layer of cinder an inch thick placed around the base of a new planting can prevent slugs from reaching the plant.

Post

3. Following the reintroduction, monitoring is essential to maintain the health of the plant and the surrounding habitat.

a) Monitoring: Coordination with the agency or individual responsible for monitoring the existing populations may be necessary to see that a reintroduced population gets on a regular monitoring schedule. It is recommended that the site be monitored daily for a week after reintroduction. This close monitoring will insure that if there are problems with pests or other unforeseen threats such as drought, they can be addressed before they affect the plants. Use of the RPMF will give important information pertaining to the location, phenology, population structure, habitat characteristics and threats to the new population. Individual plants may be labeled or tagged and tracked using the RPMF. The goal of a successful reintroduction is the establishment of a viable population that maintains the genetic variability of the species and produces successful offspring. Recruitment in the wild is necessary for the reintroduction to be deemed successful. Monitoring a new population is essential to tracking the lineage of the population and to maintain local genotypes. A consistent monitoring schedule will also reduce the chance of a contaminant affecting the population or surrounding habitat. Recording the watering, fertilization and pesticide application schemes will help guide future reintroductions. Center for Plant Conservation (CPC) is currently working on a database to track safety net species including outplantings. Information on reintroduced populations should be transferred into the database.

b) Maintenance: Watering, fertilization and pesticide application may be necessary to ensure success. Supplemental watering especially in dry areas will greatly improve chances for a successful reintroduction.

c) Management: Actions after reintroduction must be taken in concurrence with a habitat management strategy. Reducing competition for resources with non-native plants by weeding may be necessary. A necessary ungulate exclosure may require maintenance.

8.5 Phytosanitation Standards and Guidelines - Pōhakuloa Implementation Team

Introduction

The objective of this document is to state the level of sanitation that will be required during *ex situ* operations and the transition into natural habitats via reintroduction or augmentation projects. Sanitation is a key factor in reintroductions or augmentations by preventing the introduction of foreign organisms into the wild. Plants grown in PTA's Rare Plant Propagation Facility must be visibly weed-free, pest-free, and pathogen-free. All plants to be used for reintroduction or augmentation projects in this plan will be rigorously checked for compliance with the requirements described in the narrative below. If the plants do not meet the standards stated in the guidelines at the time of inspection, they will not be used. The infected plants must be treated so that all alien plant species, pests and pathogens are eliminated before the plants can be reconsidered for Army projects. If any plants become infected with a virus that plant must be immediately removed from the growing area and destroyed. The surrounding plants should be monitored for signs of virus infection as well.

The phytosanitation checklist (see Attachment 1: Phytosanitation Checklist) outlines the range of threats that must be monitored and controlled in both in the nursery setting. The threats that are to be monitored and controlled are arthropods, alien plant species, nematodes, mollusks, pathogens, and small mammals and other pests. The Implementation Team (IT) feels that these threats are major problems that affect the overall health of the plants and can cause possible contamination to the environment if transported into the wild. The table below summarizes the threats and suggested actions to eliminate these problems.

Table 1. Summary of potential pest species or problems with *ex situ* propagation methods and facilities, and prevention and monitoring procedures identified in the Phytosanitation Standards and Guidelines section of the Makua Implementation Plan that have been incorporated into the PIP.

Prevention or Monitoring Procedures	Potential Pest Species or Problem							
	Virus	Bacteria	Fungi	Nematodes	Arthropods	Slugs/Snails	Weeds	Small Vertebrates

1) DOA certification	X	X	X	X	X	X	X	
2) Nursery design					X	X	X	X
3) Media to use				X			X	
4) General sanitation	X	X	X	X			X	X
5) Threat control program	X	X	X	X	X	X	X	X
6) Nursery and plant inspection	X	X	X	X	X	X	X	X
7) Threat monitoring and control	X	X	X	X	X	X	X	X

REQUIREMENTS

1. Nursery Certification by Department of Agriculture (Plant Quarantine Branch)

The Department of Agriculture (DOA) developed this certification process for plant growers in Hawaiʻi that want to export their goods out of state (see Attachment 4: Certification Requirements of Rooted Plants to Meet Burrowing Nematode Quarantine). The nursery certification encompasses various aspects of plant production ranging from general sanitation, to standards of nursery conditions, to pest control. Complying with the certification requirements will require the facilities and equipment to provide clean plants and the absence of nematodes in all plant pots. Examples of the DOA certification requirements as of 1999 are as follows. Plants or plant parts used must be:

1. Propagated from clean (nematode- and virus-free) seeds or cuttings taken at least 12 inches above the ground.
2. Planted in suitable material prepared or treated to assure freedom from burrowing nematodes.
3. Grown in sterilized pots, containers or beds.
4. Placed on sterilized benches or sterilized supports which are at least 18 inches above the ground or floor level.
5. Plants and growing media sampled using methods approved by the Department of Agriculture and found free of the burrowing nematode.
6. Protected from contamination until delivery.

For growers that are not yet certified contact DOA for more information regarding the certification requirements. (Department of Agriculture, Plant Quarantine Station, 701 Ilalo Street, Honolulu, HI 96813. Phone number 586-0844).

2. Nursery/ Growing area

- The nursery ground must be free from alien plant species, live roots and other plant material. The floor shall be paved, or covered with coarse gravel to insure that no dirt areas are exposed. The walkways must be paved with concrete, black top or gravel.
- A six feet buffer zone around the growing area must be free from any vegetation.
- The plants must be grown in an enclosed area to prevent weed seeds from blowing into pots.

- Plants and aerial roots shall not be grown lower than 18 inches from the ground level to top of benches.
- Water hoses must be kept off the ground.
- No plants are to be placed over the propagative stock (hanging containers or secondary benches), nor under the benches to prevent contamination to plant material.

3. Media

- See Attachment 3: Approved Growing Media for a list of IT approved growing media.
- Media must be stored on a concrete slab in an enclosed area (*i.e.,* in bins that are covered, or warehouse)

4. General Sanitation

- The grower must sterilize tools at least daily.
- The grower must keep growing area, benches, and work surfaces free from threats (*i.e.,* alien plant species, nematodes, pathogens).
- The workers shall also maintain the same requirements of cleanliness.
- Benches and plant boxes, used pots, flats and implements must be cleaned and washed free from soil prior to each planting. [There are no longer any nematocides that are registered for ornamental use to sterilize soil under benches. Chlorox cannot be used for soil sterilizing, but is okay for bench, pot and tool disinfecting. There is a fumigant (Vapam), which is registered for soil sterilizing, but is deadly to mammals and is impractical to use. (Murakami pers. comm. 1999)].
- All dead, diseased or infected material in or around the pots should be appropriately disposed of on a daily basis.
- Dead, diseased or decaying plant material should be pruned off with sterilized tools (and re-sterilized between cuts) to prevent further contamination. (*i.e.,* flaming tools)
- Adequate spacing between plants is necessary in order to have good air circulation between and around the plants to prevent pest problems.
- Propagules must be free from threats (*i.e.,* pathogen, nematode, *etc.*). Use appropriate methods to clean plants (*i.e.,* bleach solution). Do not use any propagules that were infested with a virus or nematodes.

5. Threat Control program

*NOTE: The use of pesticides is governed by state and federal regulations. Ensure pesticide use is in compliance with the law, and follow all label directions. If there are any questions, please contact the State of Hawai‘i , Department of Agriculture Pesticide Division for further information.

- It should be noted that if restricted pesticides are used, the applicator must be a certified pesticide applicator.
- The grower must have a monitoring and spraying program for each threat category.
- A copy of all the monitoring and spraying schedules, plant species treated, threat/pest treated, last time sprayed, and chemicals used will be submitted to the Army for review.
- See Attachment 2: Threat Monitoring and Control, for more information on specific threats.

  a) Look for signs and symptoms.
  b) Identify the target pests.

c) Monitor for pests presence and their levels of abundance.
d) Know their life cycle.
e) Monitor on a weekly basis.
f) Contact your local agriculture extension agent or DOA agent for proper identification, up-to-date chemicals and current control practices.

6. Nursery and Plant Inspections

- The nursery will be inspected by the DOA as part of the nursery certification process. All of the plants in the certified area are inspected. If the grower has areas that are not going to be covered under the certification, DOA agents will still factor in those areas as possible sources of inoculum and inspect a percentage of the total area.
- The plants are to be inspected at least three times in the greenhouse setting.
  a) The nursery will be inspected every six months by a DOA agent to see if they are in compliance with the DOA nursery certification requirements.
  b) The grower will monitor the plants on a regular basis in the nursery. The inspection can be done by doing a random spot check of 2-3% of the total growing area weekly or every two weeks (Murakami pers. comm. 1999).
  c) The plants will be inspected the day (or as close to the day) the plants are to be taken to the reintroduction site. The inspections will be performed by the DOA or the Army will contract an inspector.
- The plants should be periodically monitored post-planting to detect any weed seedlings (or other pests) emerging from the root ball area of the plants.
- Inspectors will inspect the nursery, outplanting sites, and/or quarantine house for arthropods, mollusks, nematodes, pathogens, and alien plant species.
- Use traps and baits (*i.e.,* sticky traps, ant traps, and slug bait) to monitor the presence of threats. Check on a weekly basis.

7. If plants fail inspection

- Remove the infected plant from the growing or quarantine area.
- Plants should be treated with the appropriate control method immediately to prevent further infestation.
- Check the surrounding plants to see if they are also infected.
- If the plant is infected with a virus, remove it from the nursery or quarantine area and destroy the plant. Make sure that no part of the plant (*i.e.,* leaves) is remaining. Infected plant material is a source for potential contamination to the surrounding plants. Be sure to wash your hands after handling the plant with the virus and disinfect any tools that were used.
- Once the plant is treated and no threats are detected, it can be used for reintroduction or augmentation projects.

QUARANTINE FACILITY

In order for a facility to be used as a quarantine facility, it must meet the requirements stated in the sanitation guidelines above as well as the following requirements:

- The quarantine facility must have insect screening on all walls and roof of the greenhouse. The recommended height for the roof is 12-20 feet. This is to prevent heat build up close to the plants.

- A daily walk-through of the facility is required to inspect the quarantined plants for possible threat problems.
- Inspection of plant material will be done prior to outplanting by a qualified inspector (*i.e.,* DOA, University of Hawaiʻi Agriculture extension agent).
- Length of time in quarantine: At least two weeks, three weeks if the plants show susceptibility particularly to disease (note: at least 10 days is required to detect insects, 3 weeks to detect fungal diseases).

OPERATING PROCEDURES

Transportation

The Army is responsible for the transportation of plants from nursery to quarantine site or outplanting site. This is to reduce the amount of handling of the plants, and to prevent "sitting" time for the plants in a less desirable holding area which would increase the chances of contamination. This is especially the case for plants obtained from contracted nurseries.

The Army is required to do the following:

- Use a vehicle free from threats (*i.e.*, arthropods, mollusks, pathogens) to transport plants. The storage area of the vehicle shall be enclosed to protect the plants from wind damage and potential threat problems. Follow the Army Environmental vehicle sanitation protocol.

OUTPLANTING

- Clothes, gear, tools, *etc.*, should be free from foreign substances.
- Use on site mulch if needed instead of bringing in to site.

Attachment 1: Phytosanitation Checklist

This checklist must be followed by all growers and will be used by the Army to ensure compliance prior to the acceptance of any plant material.

- ☐ **Nursery Facility** Certified by the State DOA (see “Certification Requirements of Rooted Plants to Meet Burrowing Nematode Quarantine”)
- ☐ Growing area, walls and roof, must be enclosed
- ☐ Walkways covered with coarse gravel or paved with good drainage
- ☐ No vegetation within six feet of growing area
- ☐ No plants over or under growing area
- ☐ Plastic/metal benches at least 18” above ground
- ☐ Water hoses kept off ground
- ☐ Adequate storage for media (concrete/paved floor and enclosed on all sides)
- ☐ Adequate mixing and pouring and storage areas for pesticides
- ☐ Adequate facility for washing and disinfecting pots
- ☐ At least weekly inspections by greenhouse staff
- ☐ Six (6) month inspections by DOA to ensure compliance

Quarantine Facility

- ☐ Certified by the State DOA (see “Certification Requirements of Rooted Plants to Meet Burrowing Nematode Quarantine”)
- ☐ Facility must be enclosed with insect screening, and vents (if applicable) must be covered with insect screening. Have roof 12-20 feet high
- ☐ No vegetation within six feet of growing area
- ☐ No plants over or under growing area
- ☐ Plastic/metal benches at least 18” above ground
- ☐ Water hoses kept off ground
- ☐ Adequate mixing and pouring and storage areas for pesticides
- ☐ Use of yellow and blue sticky traps to detect infestations early
- ☐ Daily inspections by greenhouse staff

- ☐ Six (6) month inspection by DOA to ensure compliance
- ☐ Workers wearing clean clothing and shoes

Equipment

- ☐ Use of only State DOA approved growing media
- ☐ Use of sterilized tools and benches, disinfected pots and trays (if reused)
- ☐ Use of yellow and blue sticky traps to detect infestations early
- ☐ Clean transportation vehicle to pick up and drop plants at other sites (see "Army Environmental vehicle sanitation protocol")
- ☐ Be prepared to detect and control pests, and have proper equipment and training available to conduct daily inspections (*i.e.*, loop, insect ID)
- ☐ Adequate chemical application equipment and Personal Protective Equipment

Chemical

- ☐ Compliance with State DOA regulation regarding use of all pesticides
- ☐ Completion of State Restricted Use Pesticide Applicator Certification if restricted chemicals are the only means of pest control
- ☐ Prepared to apply broad and narrow spectrum fungicides for prevention and control
- ☐ Prepared to spray broad and narrow spectrum herbicides for prevention and control
- ☐ Prepared to spray broad and narrow spectrum insecticides for prevention and control
- ☐ Prepared to spray greenhouse disinfectant (contact DOA for a list of approved chemicals)
- ☐ Must be prepared to provide a spray schedule and history

Cultural

- ☐ Benches cleaned when rotating crops at least every other month
- ☐ Appropriate watering schedule to prevent pests (*i.e.*, not too wet)
- ☐ Watering/irrigation done to prevent splash-over into adjacent pots
- ☐ Dying/dead material removed daily
- ☐ Plants spaced on benches to allow for adequate air movement and drying
- ☐ Propagules inspected and cleaned before planting

Attachment 2: Threat Monitoring and Control

This reference is provided for the nursery grower to help identify threats, their signs and symptoms and suggested methods for their control. This is just a general summary of threats, for more information contact your local agriculture extension agent, Department of Agriculture personnel, or the University of Hawaiʻi Diagnostic Laboratory or Agricultural extension agent.

1. Arthropod Monitoring and Control

- Look for signs and symptoms.
- Identify the target pest.
- Monitor for pests presence and their levels of abundance.
- Know their life cycle.
- Monitor on a weekly basis.
- Contact your local agriculture extension agent or DOA agent for proper identification, current control practices, and up-to-date chemicals to use.

a) **Ants**:

- DESCRIPTION: There are many types of ants that affect plants in the nursery as well as in the wild. They have six legs and have a chewing mouthpart. They can range in color and size. They live in colonies and the queen lays thousands of eggs in individual sacs.
- SIGNS AND SYMPTOMS: Ants are usually found on plants that have scale, mealy bug or any other insect that produces honeydew. The ants farm these insects for the honeydew they produce. They can be seen crawling all over the plant and/or pot. "Tunnels" built by ants that are made out of potting media from the pot can be found on the stems protecting insects that produce honeydew.
- CONTROL: There are two distinct types of ants to control. One type is sugar loving and the other prefers an oil-based food. Bait for ants at first sign of presence. If population increases, find and destroy the nest.

b) **Aphids**:

- DESCRIPTION: There are many types of aphids that attack plants; however, all of them are soft-bodied and have piercing sucking mouthparts. Their bodies are pear-shaped and can range in colors from yellow to green to black. Aphids secrete a sweet, sticky substance, which is called honeydew. Ants farm aphids for a constant source of honeydew, which is the ant's source of food. The females bear live young. Once they reproduce, aphids can have many generations a year.
- SIGNS AND SYMPTOMS: When aphids are present on the plant, pale yellow spots are visible on the foliage. Also, leaves may be curled, puckered or stunted. Presence of sticky honeydew is also a good indicator of aphids. Sooty mold may be visible growing on the honeydew. Check under leaves and at growing points for aphid infestation.

- CONTROL: Be aware that there are several beneficial insects that prey on aphids. If population numbers increase, spray insecticide as directed on the chemical label. Just a note: aphids are usually attracted to plants over-fertilized with nitrogen.

c) **Beetles**:

- DESCRIPTION: Beetles range in size, shape and color; however all have hard bodies and wings (Ball and Ball 1990). They have chewing mouthparts.
- SIGNS AND SYMPTOMS: Check for chewed up plant parts such as leaves and flowers. If left unattended, the beetle can totally denude the plant.
- CONTROL: Manually pick beetles from the plant by hand. Remove leaf litter around the plant to eliminate suitable habitat.

d) **Black Twig Borer**:

- DESCRIPTION: Adult females are twice a big as the males at about 1/16 inch long and are shiny black in color. The males are reddish-brown in color and can't fly. The entire life cycle can take about a month to complete (Tenbrink and Hara 1994). They have chewing mouthparts.
- SIGNS AND SYMPTOMS: Stems become weakened and breakage often occurs. Look for small round holes. The twig borers will create holes in the branches and create a living area. Die back of the plant is not caused by the borers feeding on the plant. Instead, it is caused by the physical infestation and the introduction of pathogens (Tenbrink and Hara 1994).
- CONTROL: Remove and destroy infested parts. There may be some biological control insects, but more information is needed. Not too much is known about control methods.

e) **(True) Bugs**:

- DESCRIPTION: True bugs range in body shape, size and color. Typically, the body is shield shaped and about 1/6-1/2 in long (Ball and Ball 1990). When smashed, they often exude a distinct odor. They have piercing-sucking mouthparts.
- SIGNS AND SYMPTOMS: The infested plant may have disfigured growth such as discolored spots, stunted growth, or wilted shoot tips (Ball and Ball 1990).
- CONTROL: If infestation is low, hand pick the insects. Clean the area surrounding the plant of leaf litter to decrease suitable habitat.

f) **Cutworms**:

- DESCRIPTION: Cutworms are soft-bodied caterpillars that are dull gray or brown in color, and are 1 to 2 inches in length. They are nocturnal feeders that find refuge in the soil or leaf litter during the day. As adults, they change into moths. The females lay the eggs in the soil, and they can produce an average of 5 generations a year. (Ball and Ball 1990).

- SIGNS AND SYPTOMS: If seedlings are mowed down or chomped down near the soil line, that's a good indicator of cutworm damage. Some cutworms also attack the seedlings from below the soil line, damaging the roots and causing the plants to wilt. (Ball and Ball 1990). Damage looks similar to mollusk damage.
- CONTROL: Put up biological, chemical or physical barriers around the seedlings to deter the cutworms. There may be some beneficial biological control.

g) **Leafhoppers**:

- DESCRIPTION: Leafhoppers have wedge-shaped bodies that are 1/8-1/4in long. They have a hunched look to them since their folded wings are slightly protruding from their bodies. (Ball and Ball 1990, Kessing and Mau 1993a). They range in colors from green, brown or yellow. They are not very active, however, when disturbed; they can jump suddenly or move sideways with agility. They have piercing-sucking mouthparts and can spread virus (Ball and Ball 1990).
- SIGNS AND SYMPTOMS: They feed on all part of the plant (except the roots). As they feed, toxins are released into the plant causing yellowing or discoloration. Leaves will turn yellow and fall off. Leafhoppers excrete honeydew, so ants and sooty mold may be present. (Ball and Ball 1990)
- CONTROL: There may be some beneficial biological control (*e.g.* mymarid wasp) (Kessing and Mau 1993b). Keep area around plants clear of leaf litter and alien plant species.

h) Mealy bugs:

- DESCRIPTION: Mealy bugs have piercing-sucking mouthparts, and can attack either the foliage or the root system, depending on the species. They are mobile throughout their lifecycle. Depending of the species, males are relatively short-lived, living an average of 27 days, while the females can live around 115 days (Martin and Mau 1992). Their bodies are covered with a white waxy substance that gives it a "mealy" look (Tenbrink and Hara 1993).
- SIGNS AND SYMPTOMS: Leaves will look droopy and the areas they feed on will be yellow and discolored. They excrete honeydew, which can cover portions of the plant. Look for sooty mold, which grows on honeydew. If ants are present, that's a good indicator that mealy bugs are there. They can be vectors of pathogens.
- CONTROL: There may be some beneficial biological control (*e.g.*, parasitic wasps). Mixing white oil with the chemical will aid in smothering the scale.

i) Scale insects:

- DESCRIPTION: Scales are related to mealy bugs and aphids, and have bodies that range from 1/12 inch to 1/5 inch (Ball and Ball 1990). Most scales are only mobile during the first stage of their lifecycle. Usually, after their first instar, the female scales become immobile attaching themselves to the plant and form a protective coat. This protective coat can vary from cottony white masses to waxy shells. Males, if present, are not able to feed since they don't have mouthparts. The females either lay eggs or bear live young under the protective scale (Mau and Kessing 1992). Several generations can be produced per year. (Ball and Ball 1990)

- SIGNS AND SYMPTOMS: Areas where they are feeding on will turn yellow and may drop. They excrete honeydew can cover portions of the plant. Look for sooty mold, which grows on honeydew. If ants are present, that's a good indicator that scales are there. They can be vectors of pathogens.
- CONTROL: There may be some beneficial biological control (*e.g.*, parasitic wasps). Spraying the scale during their mobile stage is the most effective chemical practice. The dead scales are persistent on the plant, so check the scale population prior to spraying (it may just be dead scale shells). Just a note: Over use of nitrogen fertilizer can encourage growth of scale attracted to succulent new growth.

j) Spider mites:

- DESCRIPTION: Spider mites are extremely tiny. Adult females, which are larger than the males, are not any bigger than 1/20 inch (UCDANR 1995). They have piercing-sucking mouthparts that they use to feed on the underside of leaves and flowers. As they feed, toxins are injected into the plant that result in distorted growth and discoloration of the plant. New generations can be produced as quickly as 2 weeks if the conditions are right (Ball and Ball 1990).
- SIGNS AND SYMPTOMS: Check the underside of leaves and on flowers for webbing and tiny excrement pellets as this will indicate the presence of spider mites. Also, if the foliage begins to turn yellow and develop a dry, sandpapery texture, or become distorted in growth that is a good indicator of spider mites. To check whether the spider mites are still on the plant, use a hand lens and examine the underside of leaves. Tap the branch tip or leaves while holding a white paper underneath to catch the spider mites. (Ball and Ball 1990, UCDANR 1995)
- CONTROL: There may be some beneficial biological control (*e.g.*, parasitic mites and ladybird beetles). Spider mites thrive in hot, dry, dusty conditions. The warmer the conditions, the faster they reproduce. Make sure the plants have adequate water because when plants are water-stressed, they are more susceptible to spider mite damage. Be aware that some chemicals such as carbaryl and pyrethroids can actually increase spider mite production (UCDANR 1995).

k) Thrips:

- DESCRIPTION: The adult thrips are winged and are less than 1/25 inch long. They are shiny and usually black or yellow in color and have a rasping mouthpart. Thrips can produce approximately 8 generations per year. They thrive in dry environments so make sure the plants are adequately misted and watered (Ball and Ball 1990).
- SIGNS AND SYMPTOMS: Check the new growing tips or buds for thrips. If the leaves are curled, or if tiny, black excrement on the leaves is visible, that's good indicator that thrips are present. Also, if there is dried tissue on the leaves, or discoloration or disfiguration of the leaves or flowers, that can be another indication of thrips (Ball and Ball 1990 UCDANR 1996).

- CONTROL: There may be some beneficial biological control (*e.g.,* predatory mites). Prune affected flowers and foliage, and dispose of properly. Use sticky traps to monitor. Keep plants adequately watered, and do not let it become water-stressed (Ball and Ball 1990, UCDANR 1996).

l) **Whitefly**:

- DESCRIPTION: Whiteflies are white, tiny moth-like four-winged insects with piercing-sucking mouthparts. The immature whiteflies resemble aphids, however they are legless and not very mobile once they start feeding (Ball and Ball 1990, Flint and Parrella 1995). They produce many generations per year, sometimes one generation in less than three weeks depending on the temperature. They thrive in warmer climates (Flint and Parrella 1995).
- SIGNS AND SYMPTOMS: Check the underside of the leaves for whiteflies. If present, the leaves will prematurely turn yellow and then fall off. The plant growth will also be stunted. Whiteflies produce honeydew, so check for presence of sooty mold or ants.
- CONTROL: There may be some beneficial biological control (*e.g.*, parasitic wasp). Use sticky traps to monitor the whitefly population on a weekly basis in conjunction with a weekly foliage inspection (Flint 1995). Horticultural soaps and other insecticides can be effective in controlling the population. "Try to time treatments when your monitoring results indicate that most of the population is in the first, second, or third instar stage" (Flint 1995). When spraying, make sure there is good coverage of insecticides to the underside of the leaves.

2. Weed Monitoring and Control

- Any plant (alien or native) in the pot other than the designated plant is considered a weed.
- Monitor on a weekly basis.
- Install weed mat in and around the growing area.
- Have a buffer area around the growing area/nursery of at least 6 feet
- Enclose growing area to prevent weed seeds from blowing in to pots.
- Pull alien plant species from pots and growing area as they come up. Do not let them go to seed.
- If weed problem gets out of hand, apply herbicide.
- Contact your local agriculture extension agent or DOA agent for proper identification, up-to-date chemicals and current control practices.

3. Nematode Monitoring and Control

- Look for signs and symptoms.
- Identify the target pests (make sure it is a nematode).
- Know their life cycle.
- Monitor on a weekly basis.
- Due to the fact that there are many different nematodes, contact your local agriculture extension agent or DOA agent for proper identification, up-to-date chemicals and current control practices.

- DESCRIPTION: Nematodes are tiny, microscopic, worm-like organisms that are usually translucent with a white hue, and have bodies that are covered by a tough cuticle (Ball and Ball 1990).
- SIGNS AND SYMPTOMS: In general, plants affected by nematodes look unhealthy or stunted. It is difficult to identify nematode damage, but damage from a root-knot nematodes can be seen as galls on the roots. Look for plants that look sickly for no apparent reason. Chlorotic leaves or yellow patches on the plant, wilting, and stunting are the main symptoms to look out for. For a positive identification, a dissection of the root is necessary. If nematodes are present, roots will be reduced and have galls (Holtsmann and McSorley 1993, Ferreira and Boley 1991).
- CONTROL: There are a few cultural control steps that can be implemented to prevent the spread of nematodes. Have good sanitation practices like removing and destroying infected parts or plants from the growing area and disposing of them properly. Do not dispose of in the compost piles. There are some nematocides that are no longer recommended for control. It would be best to contact DOA, or a UH Agriculture specialist to check on the species of nematodes, and chemicals to use for controlling nematodes.

4. Mollusk Monitoring and Control

- Look for signs and symptoms.
- Identify the target pests (make sure it is a pest and not a beneficial insect).
- Monitor for pests presence and their levels of abundance.
- Know their life cycle
- Monitor on a daily basis, usually early morning is best.
- Contact your local agriculture extension agent or DOA agent for proper identification, up-to-date chemicals and current control practices.

a) Slug

- DESCRIPTION: Slugs are terrestrial mollusks that do not have shells. They have slimy bodies, are usually 1 to 2 inches (some can even reach 8 inches) long and travel on a foot that leaves a trail of slime behind. The colors range from white, yellow to black. They have a rasping mouthpiece. The eggs are in translucent-white, individual sacs, which form a cluster, and are usually found in dark, cool, moist areas or underground. Slugs can produce about 6 generations per year and take about a year to mature. (Deputy and Murakami 2000).
- SIGNS AND SYMPTOMS: Look for the slime trail, which is usually silver in color. Damage to the plant, such as large ragged holes in leaves, flowers, and stems, is done by the slug. They can quickly defoliate the plant if not controlled. Check the undersides of pots and in drainage hole of the pot to see if they are present. Slugs begin feeding at the bottom of plants and work their way up (Ball and Ball 1990).
- CONTROL: Keep area around plant and in pot clear of leaf litter. Manually dispose of any slugs in growing area. Set up traps to lure slugs and then dispose of them. Set up a physical or chemical barrier to deter slugs. Use baits to kill slugs (Deputy and Murakami 2000).

b) Snails

- DESCRIPTION: Snails are soft-bodied mollusks that are protected in a shell. They can range in color from cream, pink to gray. The markings on the shell vary from species to species. They can be found in moist, dark areas, usually coming out at night to feed with their rasping mouthpiece (Ball and Ball 1990). They produce about 80 eggs at a time, and can lay eggs up to 6 times a year. The eggs are rounded and white in color, and can be found in the upper layer of the soil. The snails mature in two years (Deputy and Murakami 2000).
- SIGNS AND SYMPTOMS: Look for the slime trail, which is usually silver in color. Damage to the plant, such as large ragged holes in leaves, flowers, and stems, is done by the snail. They can quickly defoliate the plant if not controlled. Check the undersides of pots to see if they are present (Ball and Ball 1990).
- CONTROL: Keep area around plant and in pot clear of leaf litter. Manually dispose of any snails in growing area. Set up traps to lure snails and then dispose of them. Set up a physical or chemical barrier to deter snails. Use baits to kill snails (Deputy and Murakami 2000).

5. Pathogen Monitoring and Control

- Look for signs and symptoms.
- Identify the pathogen.
- Know their life cycle.
- Monitor on a daily basis.
- Contact your local agriculture extension agent or DOA agent for proper identification, up-to-date chemicals and current control practices.

a) Bacterial disease

- SIGNS AND SYMPTOMS: Infected plants often have rotted leaves, stems, branches, or tubers, which have a foul odor. When cutting into an infected area, a small amount of whitish or yellowish ooze will seep out. Other symptoms include wilted leaves or stems, or odd shaped galls on the stem or on the roots near the soil line. Symptoms can spread quite quickly by splashing water (such as irrigation or rain) or by infected soil. They can enter a plant either through wounds or through the stomata (Ball and Ball 1990).
- CONTROL: Besides chemical control methods, also remove all infected plants, and wash hands and sterilize tools after handling infected plants. Provide ample spacing between plants to encourage good air circulation. Clean up and remove diseased plant parts and dispose of them by placing in plastic bag or sealed container right away.

b) Fungal diseases

- SIGNS AND SYMPTOMS: Look for rust-colored or powdery-white looking spots on either side of leaves. These spots will eventually make the leaf chlorotic and will eventually kill the leaf tissue. Also, look out for water soaked spots, greasy looking areas, or black streaks or blotches on the leaves or stems (Ball and Ball 1990).

- CONTROL: Besides using fungicide control methods, remove affected areas and dispose of in a plastic bag or a sealed container. Be sure to wash hands and sterilize tools after handling infected plants. Provide ample spacing between plants to encourage good air circulation (Ball and Ball 1990).

c) Viral Diseases

- DESCRIPTION: "Viruses are basically parasites, multiplying inside their hosts or if no host is available, lying inactive but viable in dead plant material for up to 50 years while waiting for a new victim" (Ball and Ball 1990).
- SIGNS AND SYMPTOMS: Be aware of plants that have poor overall growth (like stunted leaves, and flowers). There may be yellowish mottling patterns on the leaves, stems or blossoms that make the plant look sickly (Ball and Ball 1990).
- CONTROL: Viruses are spread by insects with piercing-sucking mouthparts such as aphids and leafhoppers. Garden tools and humans are other vectors of viruses. Do not take cuttings from infected plants as the cuttings will also have the virus. Remove and destroy (not in the compost pile) the infected plants, and wash hands and sterilize tools after use (Ball and Ball 1990).

6. Small Mammals and other pest monitoring and control

- Look for signs and symptoms.
- Identify the target pests.
- Monitor for pests presence and their levels of abundance.
- Know their life cycle
- Monitor on a daily basis.
- Contact your local agriculture extension agent or DOA agent for up-to-date chemicals and current control practices.

a) Rats/Mice

- SIGNS AND SYMPTOMS: Look for seedlings and/or seeds dug up, uprooted and eaten. Droppings and tracks.
- CONTROL: Traditional mousetrap and bait. Use good sanitation practices by cleaning up all possible food sources, using rodent-proof containers of metal or glass, and removing tall grass, alien plant species and shrubby growth.

b) Birds

- SIGNS AND SYMPTOMS: Young seedlings and/or buds may be nipped off. Look for droppings and feathers.
- CONTROL: Barriers and deterrents like metallic ribbon and owl figures.

c) Toads and Frogs

- SIGNS AND SYMPTOMS: Look for evidence of nestling in pots such as vegetation in pots that are smashed or pushed to the side of the pot. Toads and frogs are potential carrier of nematodes.

- CONTROL: Do not have standing water anywhere that would make it favorable to toads or frogs. Capture manually and dispose/release in favorable habitat far away from the growing area.

Attachment 3: Approved Growing Media

This list of approved growing media was modified from the Department of Agriculture's Approved Growing Media for Japan-Hawai'i Burrowing Nematode Certification Program.

1) Peat
2) Bark
3) Bark charcoal
4) Perlite
5) Vermicultie
6) Rock wool
7) Pumice
8) Volcanic cinder*
9) Coir

*If volcanic cinder is used, it must be from a cinder pit where the cinder source is certified. This is a voluntary compliance with the Department of Agriculture.

Note: Compost is NOT allowed in the growing media at any time. It can carry pathogens, weed seeds/spores, and other pests.

Attachment 4: Certification Requirements of Rooted Plants to Meet Burrowing Nematode Quarantine

REVISED 8/82

State of Hawai‘i

DEPARTMENT OF AGRICULTURE

Plant Quarantine Branch

Honolulu, Hawai‘i

CERTIFICATION REQUIREMENTS OF ROOTED PLANTS

TO MEET BURROWING NEMATODE QUARANTINE

I. QUARANTINE

The states of California, Louisiana, and Texas have established a quarantine against the nematode, *Radopholus similis*. The commodities covered by this quarantine are:

A. All earths including sand and soil, **except** industrial sand and clay.

B. All plants and plant parts with roots, including aerial roots, **except**:

1. Air plants, including certain orchids and other plants produced epiphytically, if growing exclusively in or on soil-free material such as osmunda fiber, tree trunk, or bark.
2. Aquatic plants if free from soil.
3. Plants secured by air layering if roots are established and enclosed in the original soil-free moss wrappings.
4. Root and soil-free cuttings of Ti *(cordyline* subsp.*)*.

C. All parts of plants produced below the ground or soil level **except:**

1. Dormant bulbs and corms for propagation, if free from roots and soil, **but not including taro** corms for propagative purposes.
2. All fleshy roots, corms, tubers and rhizomes for edible or medicinal purposes if washed or otherwise free of soil.

D. All plant cuttings for propagation.

II. CERTIFICATION REQUIREMENTS

(Based on California's Quarantine 25, the most restrictive of the three states involved.)

All commodities covered by this quarantine are prohibitive entry into these states unless each shipment or lot is accompanied by a certificate issued by a State Plant Quarantine Inspector, establishing that all material contained in the shipment meets **one** of the following conditions:

A. It has been determined through survey by methods approved by the California, Louisiana and Texas Departments of Agriculture, at six month intervals that the burrowing nematode does not exist on the property or premise or facility used to grow the nursery stock, and that the seed or plant parts used for production of the plants were determined by the certifying officer to be free from burrowing nematodes, or

B. The plants or plant parts being shipped to these states were protected from burrowing nematode infestation by all the following sanitation methods:

1. Propagated from clean seed or from cuttings taken at least 12 inches above the ground.
2. Planted in suitable material prepared or treated to assure freedom from burrowing nematodes.
3. Retained in sterilized pots, containers or beds.
4. Placed on sterilized benches or sterilized supports at least 18 inches or above from the ground or floor level.
5. Area beneath the benches or supports holding plants treated at six month intervals with a registered nematocide or other material having nematocidal value and approved by Department of Agriculture officials, **except** when smooth, clean flooring of concrete is present.
6. Plants and growing media sampled using methods approved by these states and found free of the burrowing nematode.
7. Protected from contamination until shipped.

C. The shipment consists of only unrooted plant cuttings of plants, which are not prime hosts, and the cuttings were taken at least 12 inches above ground level and were protected from contamination until shipped.

*Root-free and soil-free cuttings

III. PRODUCTION OF NEMATODE-FREE PLANTS OFF THE GROUND UNDER CONDITION 1

(Including terrestrial or ground orchids such as *Arundina, Bletia, Cymbidium Phaius, Spathoglottis, etc.*, grown in soil)

A. Growing Ground or Nursery Area.

1. The nursery growing ground must be free from alien plant species, live roots and other plant growth (cleaned by bulldozing, hoeing or weed killers).
2. The soil floor shall be paved, covered with plastic covering, gravel, black sand, cinders or similar materials. (Saw dust is not recommended because of its tendency to retain moisture which is favorable for the development and increase of burrowing nematodes.)
3. Walkways must be paved with concrete, black top or gravel.
4. The grounds shall be fumigated or treated with nematocides at dosages specified under III-C-1a-f.

B. Benches, Watering System, *etc.*

1. The benches shall not be closer than 3 feet from the nearest shrubbery or plants or overhanging tree branches.
2. Plants and aerial roots shall not be grown lower than 18 inches from the ground level to top of benches.
3. Overhead sprinklers are recommended for watering but hoses may be used if they are kept off the ground.
4. Benches and plant boxes, containers, flats and implements must be washed free from soil and treated with 5% formaldehyde, Vapam or similar nematocides prior to each planting.

C. Preparation of Planting Media and Treatment of Infested Grounds

1. Sand, cinders or used peat fern fiber or moss, *etc.*, must be sterilized or treated with nematocide.

   (Clean new peat, *etc.*, need not be treated.)

   a. Steam sterilization 1600 ºF. - 2000 ºF. at center of media for 30 minutes.
   b. Methyl bromide (98%) 1-4 lbs. per 1,000 cu. ft. or 100 sq. ft. for 24 hours at 70 ºF. or above. (Under gas-tight cover-aerate 2-3 days.)
   c. DD Mixture 20-40 gals. per acre or 5 ml (1 tsp. per cu. ft. (No cover or water seal-aerate 1 week for every 10 gals./acre.)
   d. EDB (40% by wt.) 20-40 gals. per acre or 1.7 ml (1/3 tsp.) to 5 ml (1 tsp./cu.ft.) (No cover or water seal-aerate 10-14 days.)
   e. Vapam: 1 qt. Vapam in water per 100 sq. ft. for 5 days (water seal-aerate 14 days or more).
   f. V-C 13 nemacide 1 pt.: 50 gals. water per 100 sq. ft. - 1/2 pt.: 9 gals. per 1 1/3 cu. yd. (1 tsp.: qt. water/per cu. ft.) (Drench-aerate 14 days.)

NOTE: Contact Hawaiʻi Department of Agriculture, Pesticide Section for Pesticide Use Requirements.

D. Planting Materials, Seeds.

1. Clean seeds, rootless cuttings, aerial cuttings, crowns, or suckers taken well off the ground may be planted in clean or treated media under supervision.
   (The above materials must not contact the ground or soil at any time.)
2. Rooted plants, off-shoots, suckers, corms and rhizomes (except bench-grown epiphytic orchids in moss) - each plant or propagative part must be determined as free from burrowing nematode before planting under supervision.
   (Laboratory inspection fee - charged at the rate of $2.00 for 1-6 "plants.")
3. No plants are to be placed over the propagative stock (hanging containers or secondary benches).

E. Cost of Inspection for Commercial Nurseries Upon Request.

1. Nurseries carrying less than 10,000 plants of varieties covered by burrowing-nematode quarantines…
   $20.00 - each field inspection
2. Nurseries carrying more than 10,000 plants of varieties covered by burrowing-nematode quarantines...
   $40.00 - each field inspection
3. Mileage charge: For travel to and from the Department's offices, additional charges of 20 cents per mile.

IV. PRODUCTION OF EPIPHYTIC ORCHID PLANTS GROWN OFF THE GROUND.

In the quarantines, air plants include "certain orchids produced epiphytically if growing exclusively in or on soil-free material such as osmunda fern and bark." The phrase "if growing exclusively" apparently is the criterion to reject or release the orchid plant upon arrival. The theory is that if an orchid plant arrives on the mainland with the roots imbedded in the soil-free media, the inspector can be reasonably sure the plant was grown epiphytically off the ground and free from *Randopholus similis.* If not, the plant may be rejected. Certification in Hawaiʻi is guided by the above and discretion of the inspector at the time of examination.

Exceptions to the above interpretation can be expected from some counties. San Luis Obispo County, California, has refused all rooted orchid plants regardless of the potting material unless certified with a special burrowing-nematode certificate. To eliminate the uncertainty of rejections, commercial orchid growers should have their nurseries approved. The following requirements must be met to qualify for special burrowing-nematode certificates.

A. All epiphytic orchid plants must have originated in soil-free media, kept off the ground and the premises inspected at six month intervals.

1. Recommended height of benches, *etc.*, at least 18 inches or higher from ground.
2. Aerial roots must not touch the ground.
3. Premises or greenhouses must be relatively free from alien plant species, live roots and other plant growths.
4. Orchid plants growing on approved premises should be kept free from injurious insects, pests and diseases at all times.

5. Overhanging tree branches.

B. Owners of approved nurseries must agree to ship clean plants, bench-grown in soil-free media only.

C. Cost of Inspection for Approval of Orchid Nurseries.

1. Nurseries carrying less than 10,000 plants of varieties covered by burrowing-nematode quarantines…
   $20.00 - each field inspection
2. Nurseries carrying more than 10,000 plants of varieties covered by burrowing-nematode quarantines...
   $40.00 - each field inspection
3. Mileage charge: For travel to and from the Department's offices, additional charges of 20 cents per mile.

V. SHIPPERS OF SMALL LOTS OF ROOTED PLANTS (COMMERCIAL AND NON-COMMERCIAL)

A. Certification of small lots (1-6 plants) to California, Louisiana and Texas.

(Large lots of 100 or more plants - inspection by special arrangements only.)

Small lots of rooted materials or plant cuttings may be tested for the presence of the burrowing-nematode by subjecting the root or cutting samples to the Baermann funnel method of detecting nematodes as outlined in "Standard Procedures for County Plant Nematology Work" (PI. Path. B-61-6).

B. Places of Inspection.

Plant Quarantine Station
701 Ilalo Street
Honolulu, Hawaiʻi 96813
(Phone: 586-0844)

Plant Inspection Office
Lihue, Kauai, 96766
(Phone: 274-3071)

Plant Inspection Office
635 Mua Street
Kahului, Maui 96732
(Phone: 873-3556)

Plant Inspection Office
Kilauea and Lanikaula Streets
Hilo, Hawaiʻi 96720
(Phone: 974-4141)

C. Time Required.

Owners must agree to leave plants at their own risk for about 5 working days pending examination.

D. Sample Preparation.

Sufficient roots or part of the cutting will have to be removed for examination.

E. Conditions, *etc.*, of Materials.

Plants must be washed and may be repacked in spagnum moss, peat moss or vermiculite by the owner before submitting for inspection.

Rhizomes, flowering ginger rhizomes, Heliconia, coconut plants, *etc.*, should be brought in with roots and rootlets attached or be refused for testing.

It is recommended that antheriums, philodendrons, *etc.*, be limited to young suckers, top cuttings or plants originating in moss and grown off the ground.

Plant quarantine supervision of plants cut 12 inches above the ground level or collecting of rooted aerial growths of red ginger, papyrus on private premises for export certification is available on an appointment basis. Charges for this service will be in accordance to Regulation 6.

F. Charges.

$2.00 for 1-6 plants brought to Quarantine Station or Inspection Office. (Charges will not be refunded regardless whether or not plants are found to be infested with burrowing-nematodes.)

NOTE: Requirements and conditions stated are subject to change as the concerned state's quarantine regulations are amended from time to time.

Literature Cited

Ball, J. and L. Ball. 1990. Rodale's flower garden problem solver. Rodale Press, Emmaus, pp. 277 - 349.

Deputy, J. and P. Murakami. 2000. Slugs and Snails. Landscape, Floriculture, and Ornamentals News, no. 8, July 2000: 10-12.

Ferreira, SA., and R.A. Boley. 1991. *Rotylenchulus reniformis*: crop knowledge master. Dept. of Plant Pathology, College of Tropical Agriculture and Human Resources, Univ. of Hawai'i .

Flint, M.L, and M.P. Parrella. 1995. Whiteflies in the greenhouse: an integrated pest management guide. University of California Dept. of Agric. and Natural Resources (UCDANR), Publication 2, Oakland..

Holtsmann, O.V., and McSorley. 1993. *Meloidogyne sp.:* crop knowledge master. Univ. of Hawai'i .

Kessing, J.L.M., and R.F.L. Mau. 1993a. *Abgrallaspis cyanophylli* (Signoret). Univ. of Hawai'i Dept. of Entomology fact sheet, Honolulu.

Kessing, J.L.M., and R.F.L. Mau. 1993b. *Empoasca Solana* (DeLong). Univ. of Hawai'i Dept. of Entomology fact sheet, Honolulu.

Martin, J.L., and R.F.L. Mau. 1992. *Planococcus citri* (Risso). Univ. of Hawai'i Dept. of Entomology fact sheet, Honolulu.

Mau, R.F.L., and J.L.M. Kessing. 1992. *Coccus viridis* (Green). Univ. of Hawai'i Dept. of Entomology fact sheet, Honolulu.

Tenbrink, V.L., and A.H. Hara. 1993. *Pseudococcus longispinus* (Tarigioni-Tozzetti). Beaumont Research Center fact sheet, Hilo, Hawai'i .

Tenbrink, V.L., and A.H. Hara. 1994. *Xylosandrus compactus* (Eichoff). Beaumont Research Center fact sheet, Hilo, Hawai'i .

UCDANR, 1995. Ehler, L.E., L.D. Godfrey, P.B. Goodell, P.A. Phillips, and F.G. Zalom, (eds.), Spider mites: an integrated pest management guide. Publication 6. Univ. of California Dept. of Agric. and Natural Resources, Oakland.

UCDANR, 1996. Olson, B., P.A. Phillips, and F. G. Zalom, (eds.), Thrips: an integrated pest management guide. Publication 30. Univ. of California Dept of Agric. and Natural Resources, Oakland.

8.6 Pōhakuloa Training Area Seed/Plant Distribution List

State Agencies

Lyman Perry
State Botanist
lperry@dofawha.org

Vickie Caraway
State Botanist
Vickie.L.Caraway@Hawai'i.gov

Nick Agorastos
Natural Area Reserves System
nagorastos@dofawha.org

Patty Moriyasu
Volcano Rare Plant Facility
pmoriyas@Hawai'i.edu

Joan Yoshioka
Plant Extinction Prevention Program (PEP)
jyoshioka@dofawha.org

Kealii Bio
Big Island PEP Coordinator
Bigislandpep@gmail.com

Ane Bakutis
Oahu PEP Coordinator
Anebakutis @gmail.com

Hank Oppenheimer
Maui PEP Coordinator
Hmo3500@earthlink.net

Jennifer Higashino
Palila Project
jhigashino@dofawha.org

Paul Higashino
Kaho'olawe Island Reserve Commission
phigashino@kirc.Hawai'i.gov

Federal Agencies

Thomas Belfield
Hawai'i Volcanoes National Park
tbelfield@gmail.com

Bill Garnett
Molokai PEP Coordinator
wili@wave.hicv.net

Marie Bruegmann
US Fish and Wildlife Service
Marie_bruegmann@fws.gov

Tanya Rubenstein
Three Mountain Alliance
Tanya_rubenstein@contractor.nps.gov

Botanical Gardens

Peter Van Dyke
Amy Greenwell Botanical Garden
pvandyke@bishop.bishop.Hawai'i.org

Mike DeMotta
National Tropical Botanical Gardens
mdemotta@ntbg.org

Private Agencies

Art Medeiros
Leeward Halaeakalā Watershed
art@lhwrp.org

Namaka Whitehead
Kamehameha Schools/Bishop Estate
nawhiteh@ksbe.edu

8.7 Nene Survey Protocol for KMA

Ke'āmuku Nēnē Surveys

Historically, Nēnē have been infrequently, incidentally sighted at Pōhakuloa Training Area, and never during Nēnē surveys. At the Beginning of 2008, however, the first breeding pair was recorded in the Ke'āmuku Maneuver Area (KMA). Nēnē breeding season is one of the longest of any wild geese (USFWS 2004). Most Nēnē lay eggs from October to March with a nesting peak in December, and most goslings hatch in December and January (USFWS 2004). Nēnē mate for life and remain close to each other throughout the year. They are known to have high nest site fidelity, meaning that they return to the same area to nest from year to year (Banko1988; Banko *et al.* 1999). Female offspring return to their natal fledging sites to nest, while males disperse (Banko and Manuwal 1982; Woog 2000). Nēnē have adapted to a terrestrial life and as such, do not need wetlands in their habitat. Their preferred habitat includes grasslands, shrub lands and dryland forests. Some community types such as high-elevation sparsely vegetated lava flows and open native alpine shrubland-woodland that Nēnē inhabit are found at PTA (USFWS 2004). Information is limited regarding habitats Nēnē use at PTA and how important those habitats are for Nēnē.

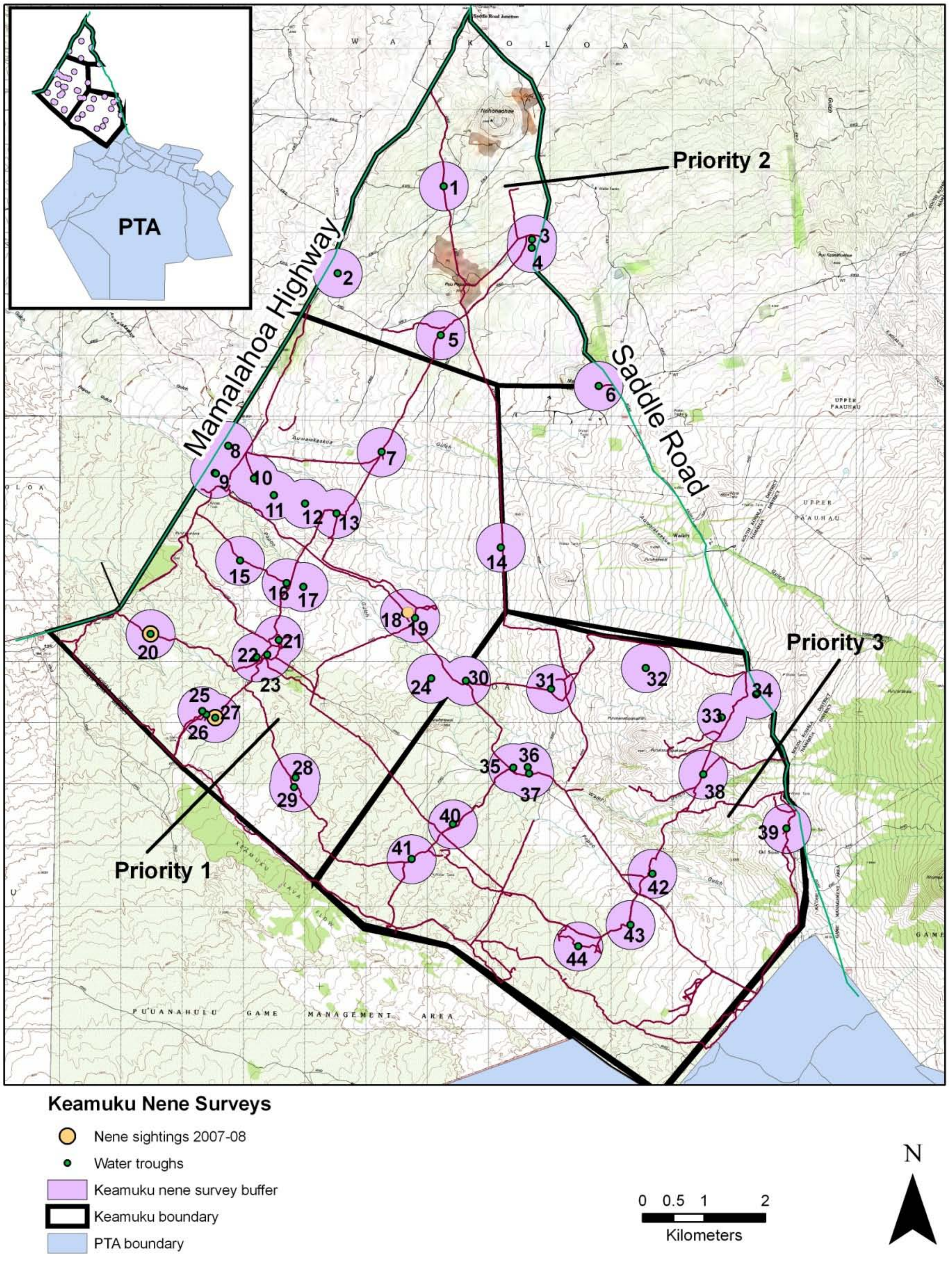
Breeding Season Surveys:

After the first nesting Nēnē pair was observed in the KMA in January of 2008, planning for future breeding season surveys was initiated. It was determined that Nēnē prefer areas with both shorter grass species for food and mobility and taller fountain grass clumps for nest sites. Nēnē were also reported being associated with cattle water trough areas that had hutches similar to structures used during Nēnē captive breeding efforts. Using this information, Pōhakuloa Training Area Natural Resources staff (NRS) developed a survey strategy for the KMA (Figure 1). Each potential Nēnē site is surveyed once a month during the breeding season. Approximately two survey days per week are required to complete the surveys monthly (eight survey days or 16 personnel days). Cattle water troughs that have been identified as survey target areas due to Nēnē preference for the remnant hutch structures in these areas and the mixed grass matrix often associated with these areas. At this time there are no sightings or anecdotal evidence that Nēnē use areas not associated with the cattle troughs. Because KMA is over 23,000 acres, the entire area cannot reasonably be surveyed for breeding birds even once during the breeding season. Therefore we are concentrating on areas with the most potential for breeding birds based on past and anecdotal observations. PTA NRS is exploring the use of aerial photography to identify other areas with short and tall vegetation matrices not within the 400 meter buffers to ensure all potential areas are included in survey efforts.

To identify sites with high potential for Nēnē, 400 meter buffers were created around these areas. Then the KMA was divided into survey priority areas 1 (highest potential), 2 (medium potential) and 3 (lowest potential) based on:

1. Whether or not the section is in a buffer zone
2. If the section had previous Nēnē sightings/nests
3. The military's proposed development of the section; and
4. The suitability of the habitat and vegetation for Nēnē activities.

Figure 1. Ke'āmuku Maneuver Area priority assignment and Nēnē survey buffers.



Sections that are outside of buffers, with previous Nēnē sightings and suitable Nēnē habitat, which the military plans to develop, will be the highest priority. Priority areas 1 and 2 are surveyed on foot by biologists with binoculars through areas of suitable Nēnē habitat within the 400 Meter buffers. Priority area 3 is surveyed from a vehicle using binoculars because this area is a monoculture of short grass or dirt with no suitable nesting locations. Priority 3 areas are so open, that the area can easily be scanned from the vehicle using binoculars or scopes.

Survey Protocol:

Priority 1 and 2 Areas - Foot Surveys

- Surveyors use their GPS units with the 400 meter water trough buffer polygons loaded and their track logs on to completely survey suitable Nēnē habitat within the buffer.
- Surveyors spread out within the suitable habitat (shorter grass areas with taller grass or shrubs within or along edges) and sweep the area on foot with the aid of binoculars to search for Nēnē.
- Pictures will be taken and the location and date will be noted to keep a record of Ke'amuku phenology.
- Each buffer will be recorded on the data sheet after it has been surveyed even if no Nēnē are observed.

Priority 3 Areas - Vehicle Surveys

- Pairs of two drive to 400 meter buffer areas in Priority 3 area.
- The passenger uses binoculars to search the monoculture short grass for Nēnē
- If there are any areas that seem appropriate for Nēnē nesting, the surveyors will investigate on foot.
- Pictures will be taken and the location and date will be noted to keep a record of Ke'amuku phenology.
- Each buffer will be recorded on the data sheet after it has been surveyed even if no Nēnē are observed.

Action Plan for Finding Nēnē

- Any Nēnē observed will be recorded on the data sheet with a waypoint, the number of Nēnē observed, their leg band information if possible, and their activity or behavior (honking, guarding, chasing, sitting on a nest, hiding, feeding, flying etc). Data collected will be consistent with information collected by the National Park Service and incorporated into a compatible database.
- A description of how to approach the territory to minimize Nēnē disturbance will be noted on the data sheet.
- One surveyor will remain at the territory to observe the Nēnē and their activities and to determine their nesting status, while the remaining surveyors continues the survey
- When a nest is found, it is assigned a unique nest number:
  YEAR + 3 digit nest #. Example: 2008001. . . 2008002. . . 2008003.
- When a nest is found, the USFWS will be notified within 48 hours providing all relevant nest information.

Discussion:

The 2008-2009 breeding season is the first time that the KMA will be systematically surveyed for nesting Nēnē. At this time there are no results to indicate whether or not the proposed survey method is a successful one. Based on Nēnē nest site fidelity behavior, NRS anticipates being able to target known nest locations in the future as the primary method for nest searching, a common practice for other Nēnē management areas on the island. If the proposed nest surveying technique proves to be successful, it will continue to be used to locate new Nēnē nesting territories.

PTA NRS will develop, in consultation with USFWS, a detailed plan for nest monitoring and management prior to November 2009. Specifics about nest protection, predator control, and nest monitoring with cameras and personnel will be included. All requirements from the 2008 BO regarding reporting to USFWS and training will be incorporated into the plan.

Recommendations:

Because a more consistent Nēnē presence on PTA and in the KMA is a recent discovery, the Army has initiated a three year period in which to gather as much information regarding Nēnē behavior, habitat use, movement patterns, nesting habits, predatory threats and military conflicts as possible to inform more permanent management in the future. During this time, a variety of management strategies should be piloted to protect the Nēnē and to test different techniques for success.