FINAL

IMPLEMENTATION PLAN

MAKUA MILITARY RESERVATION
ISLAND OF OAHU

SECTION 1: BACKGROUND AND METHODOLOGY

May 2003

Prepared for:
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Executive Summary

This document was prepared to guide conservation efforts that will result in the stabilization of 27 endangered plant taxa and an endangered species of Hawaiian tree snail that could be affected by military training activities at Makua Military Reservation (MMR) in Hawaii. In 1998, the U.S. Army (Army) initiated formal consultation under section 7 of the Endangered Species Act (16 U.S.C. 1531 et seq.) with the U.S. Fish and Wildlife Service (USFWS) to determine if routine military training at MMR would jeopardize the continued existence of 41 endangered species. The Army is responsible for maintaining stability of each of these taxa, applying additional management specified in this plan, to those taxa below stability. The consultation used an action area (AA) (area potentially affected by military training) that extended beyond the boundaries of MMR and was based on vegetation types, fire history, natural and human-made barriers, and a consensus of where fire could be stopped by State, Federal, and Army fire-fighting resources. Taxa for which either a significant portion of the populations occur within the AA or for which no populations are stable, hereafter referred to as target taxa, were addressed in the Army's proposed action of military training and conservation measures in such a way as to avoid jeopardy.

In 1999, the USFWS issued a biological opinion (BO) concluding that the routine military training and the conservation measures identified by the Army in its Biological Assessment (BA) would not jeopardize the endangered species found within the AA. The conclusion of no jeopardy was based on certain restrictions to military training, preparation and implementation of a wildland fire management plan, implementation of management actions identified in the BA for the 13 endangered species at stability and minimally impacted by Army training, and preparation and implementation of a plan (Implementation Plan) for the additional 27 plant target taxa and one snail target taxon. The Implementation Plan (IP) would identify additional management actions beyond those the Army was already implementing or agreed to implement in the BA to stabilize the 28 target taxa. During the preparation of the IP, the Army decided on additional restrictions to routine military training, four additional taxa were found within the AA, additional populations outside the AA were found for one taxon, and the Federal status of another taxon changed. The Army reinitiated consultation and the USFWS provided a supplement to the BO which determined that the additional four taxa will not be jeopardized by Army training, resulting in a final number of 28 target taxa. When stabilization of all of the target taxa is achieved, restrictions to routine military training may possibly be eliminated, following reinitiation of consultation with the USFWS. In addition, there are other conditions such as fires outside of the firebreak road, discovery of additional taxa, change in status of taxa, *etc.*, which would trigger reinitiating consultation under section 7 of the Endangered Species Act.

To stabilize the target taxa, each taxon must be maintained with sufficient numbers of populations to ensure their long-term viability. Additionally, threats to the managed and reproducing individuals in each population must be controlled, and each taxon must be adequately represented in an *ex situ* (out of the wild) collection. Stabilization is only the first step toward eventual recovery of these endangered species. Recovery of these taxa is beyond the Army's responsibilities under the section 7 consultation process. Because the implementation of this kind of taxon stabilization effort has never before been attempted in Hawaii, the Army created an Implementation Team (IT) to assist the Army and its contractors in preparing the IP. The IT is comprised of biologists representing the Army, USFWS, State of Hawaii, Honolulu Board of Water Supply, The Nature Conservancy of Hawaii, Campbell Estate and endangered taxon or ecosystem experts (see Chapter 3: Implementation Team).

The Makua IP provides taxon background summaries describing the biology and current status of the target taxa, methodology and a conceptual framework for the required stabilization, the specific actions required to stabilize each taxon and the habitat they depend upon, and monitoring protocols to evaluate success of the management actions. The stabilization plan for each target taxon outlines specific actions, including threat abatement and reintroductions into appropriate, protected habitat. Threat abatement actions include control of feral ungulates, selected weeds, predators such as small mammals, insect pests, and diseases. In addition to taxon level management of target taxa *in situ* (in the wild), habitat level management, requiring a broader geographic scope and control of threats affecting ecosystem processes, is also included to support the development of stable populations of target taxa. Because of the widespread distribution of the target taxa and the need for maintaining ecosystem processes, 31 management units (MUs) are proposed in the Waianae and Koolau Mountains of Oahu and at sites on the island of Kauai, where the most important wild populations of the target taxa occur. These areas encompass the important habitat for *in situ* management and reintroduction efforts that will lead to the stabilization of the target taxa. The proposed MUs occur on Army, Navy, State of Hawaii, Honolulu Board of Water Supply, and private lands, and will require cooperation and memoranda of agreement with the landowners prior to initiation of management actions at these sites. This IP includes taxon actions and MU actions, as well as a timetable and budget for implementation.

The anticipated outcome of the IP is the implementation of management actions in populations and MUs to achieve stabilization of populations for each target taxon across its range. To assess the success of the stabilization actions, the monitoring program in this IP will allow for an assessment of both taxon and habitat status over time relative to achieving the IP goals. 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 stabilization of the target taxa within a reasonable time frame. The assessment will also allow for modification of the IP strategies as needed using an adaptive management approach.

The timeline for this IP is projected over 33 years, during which time all of the management actions identified in the IP will be initiated, and in the process of implementation. There are three phases of implementation, each approximately 10 years in duration, which result in increasing levels of taxon and MU management over time. These phases are sequenced based on specific criteria of rarity and risk described in this document. All populations and MUs will be at full stabilization management by the third phase. The implementation of the IP is expected to cost an average of approximately $8,066,000 per year, for an estimated total of $269,551,000 over 33 years. This figure is subject to change depending on timing of implementation of actions. The complete implementation of the IP is estimated to require similar amounts of funding over at least the next 33 years, and then lower funding for maintaining stable populations of the target taxa for the duration of Army training in MMR.

The IP 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. The IP requires the Army to continue as an active member of regional conservation efforts in support of stabilization of the target taxa and the habitats they depend on. 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 Hawaii. Successful implementation of the IP assures that the Army will be in compliance with Endangered Species Act and still accomplish its training mission.

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1.0 Plan Overview

Organization of this plan
This Implementation Plan (IP) is arranged in four sections that reflect different aspects of the IP process:

Section 1: Background and Methodology
The first section provides a general overview and introduction to the target taxa and the proposed actions that are considered necessary to meet the objectives of the IP. It includes an executive summary, a discussion of the methods and approaches used by the Implementation Team (IT) to develop the recommended actions at taxon and habitat levels, and a summary of the background biological information for all of the target taxa. This document is meant to provide a compact summary of the approach and conclusions of the IT, and the goals and strategies of the IP.

Major highlights:

Executive Summary	Threats Assessment
Project History and Scope	Strategy for Stabilization
The Target Taxa	Management Units
The Implementation Team	Adaptive Management
The Action Area	Measures of Success
The Credit System	Conclusions
Population Units	Taxon Summaries

Section 2: Actions Section
This section is the most detailed section, and provides the major protocols for management of the target taxa, including the stabilization plans for each of the target taxa, a discussion of the management actions needed within management units (MUs); MU summary tables and monitoring protocols. It is designed to provide the implementers of the IP with the actions and timeframe for efforts over the short, intermediate, and long-term.

Major highlights:
Approach to *Achatinella mustelina* Stabilization
Achatinella mustelina Stabilization Plan
Approach to Plant Stabilization
Plant Stabilization Plans
Management Unit Summaries
Monitoring Protocols

Section 3: Appendices
The third section of the IP contains numerous supporting documents in a series of appendices that are referred to specifically in the first and second sections of the IP. This includes biological database reports, literature reviews, and guidelines for management actions such as propagule storage and collection.

Major highlights:

Hawaiian Spelling of Place Names
Lyon Arboretum Seed Storage Summary
Phytosanitation Standards and Protocols
HRPRG Propagule Collection Guidelines
Captive Propagation Protocols for *Achatinella mustelina*
Priority Weeds for Selected Makua Management Units

Section 4: Cost and Staffing Estimates

The fourth section of the IP has been prepared primarily for the Army, and includes an overview of estimated costs, a timeline for implementation of actions, and staffing requirements for the implementation of the IP over the 33-year period.

Major highlights:

Cost Estimates Assumptions
Implementation Timeline and Sequencing
Implementation Actions – Detailed Cost Estimates and Time Schedule
Summary of Costs and Army Environmental Staff

Note on the use of Hawaiian diacritical marks in this plan

The Hawaiian language is heavily used in place names and common names of target taxa. Hawaiian spelling makes use of special diacritical marks, including the glottal stop (‘) and macron (a line over a vowel, signifying a long vowel) that are considered important in correct spelling of Hawaiian words. While the importance of correct use of Hawaiian diacritical marks is recognized, the complex interface between databases, spreadsheets and word processing platforms within this document forced the simplification of spelling of Hawaiian words, dropping the use of glottal stops and macrons. A list of the proper spelling of the major Hawaiian place names used in this plan is provided in Section 3, Appendix 1.1: Spelling of Hawaiian Place Names.

2.0 Introduction

Pertinent background and project scope

This document was prepared to guide conservation efforts that will result in the stabilization of 28 endangered plant taxa and an endangered species of Hawaiian tree snail that could be affected by military training activities at Makua Military Reservation (MMR) in Hawaii. In 1998, the U.S. Army (Army) initiated formal consultation under section 7 of the Endangered Species Act (16 U.S.C. 1531 et seq.) with the U.S. Fish and Wildlife Service (USFWS) to determine if routine military training at MMR would jeopardize the continued existence of 41 endangered species. The Army is responsible for maintaining stability of each of these taxa, and applying additional management specified in this plan to those taxa below stability. The consultation used an action area (AA) (area potentially affected by military training), that extended beyond the boundaries of MMR and was based on vegetation types, fire history, natural and human-made barriers, and a consensus of where fire could be stopped by State, Federal, and Army fire-fighting resources. Taxa for which either a significant portion of the populations occur within the AA or for which no populations are stable, hereafter referred to as target taxa, were addressed in the Army's proposed action of military training and conservation measures in such a way as to avoid jeopardy.

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To stabilize the target taxa each taxon must be maintained with sufficient numbers of populations to ensure their long-term viability. Additionally, threats to the managed and reproducing individuals in each population must be controlled, and each taxon must be adequately represented in *ex situ* (out of the wild) collections. Stabilization is only the first step toward eventual recovery of these endangered species. Recovery of these taxa is beyond the Army's responsibilities under the section 7 consultation. Because the implementation of this kind of taxon stabilization effort had never before been attempted in Hawaii, the Army created an Implementation Team (IT) to assist the Army and its contractors in preparing the IP. The IT is comprised of biologists representing the Army, USFWS, State of Hawaii, Honolulu Board of

Water Supply, The Nature Conservancy of Hawaii, Campbell Estate, and endangered taxon or ecosystem experts (see Chapter 3: Implementation Team).

The Makua IP provides the basis for meeting the taxon stabilization requirements of the section 7 consultation. Successful implementation of the IP assures that the Army will be in compliance with the Endangered Species Act and will still be able to accomplish its training mission. These requirements are as follows:

- Identify priority taxa and areas within MMR and in off-site stabilization areas.
- Determine an estimate of the minimum viable population for each taxon considered likely to be jeopardized by Army activities.
- Determine intermediate and final definitions of success for stabilization of each taxon.
- Develop protocols to achieve the highest possible genetic representation that can be collected for each of the target taxa.
- Develop reintroduction and augmentation protocols which include the determination of adequate number of individuals to reintroduce or augment to reach success, number of populations, size or life stage distribution of the population, how to achieve the highest number of individuals possible within a population, contamination issues, timing of reintroduction and augmentation, and site selection.
- Determine habitat management requirements (quality and quantity) for each taxon.
- Identify priority incipient weeds and the areas to be surveyed within MMR and on off-site stabilization areas.
- Develop a method to monitor, integrate and evaluate data, and report results.
- Develop a schedule for completion of implementation actions and a cost estimate for implementation of each identified action.
- Develop a scope of work for each of the implementation actions.

Triggers for reinitiation of consultation

The Army is required to reinitiate formal consultation with the USFWS if:

- The amount of incidental take is exceeded.
    - For the Makua consultation, take was set as loss of up to one tree or bush that is known to harbor, or have harbored in the last 15 years, Oahu tree snails (*Achatinella mustelina*), no more than one active Oahu elepaio (*Chasiempsis sandwichensis ibidis*) nest, or the abandonment of one active elepaio nest (USFWS 1999);
- New information reveals effects of the agency action that may affect listed taxa or critical habitat in a manner or to an extent not considered in any previous biological opinions.
    - Previous biological opinions include the 1999 biological opinion and the supplemental biological opinion in 2001. USFWS and the Army agree that if a taxon within the AA currently not included in this plan decreases to such a level that the Army's actions may potentially jeopardize the taxon (*i.e.*, the entire taxon falls below stability levels throughout its range), the Army is required to reinitiate consultation to include that taxon. Each year, the USFWS and the Army should review the current status of non-target AA taxa throughout their range as part of the IT review process. If either agency becomes aware of a change in the status

    - of the taxon (in or out of the AA), the agency will inform the IT and the other agency.
    - If a non-target AA taxon changes in status to below stability, the Army may become responsible for its stabilization. The USFWS is responsible for tracking the status of such taxon outside of the AA. If taxon already included in the IP reach stability either through management actions or the location of additional populations, the Army would not need to reinitiate consultation, since this is the goal of the IP and measures are included in the IP to potentially reduce management actions and monitor such a taxon to ensure it maintains stability.
- The agency action is subsequently modified in a manner that causes an effect to the listed taxon or critical habitat not considered in the biological opinion.
    - Such modifications may include the use of new types of ammunition or new training maneuvers that may have a high risk for causing fire, or
- A new taxon is listed or critical habitat is designated that may be affected by the action.
    - For example, critical habitat will be proposed soon for several taxa within the Makua AA. The Army is required to reinitiate consultation once the critical habitat is proposed to ensure that its actions do not adversely modify critical habitat for those endangered taxa within the AA which are proposed for designation. The funding and implementation of this IP may preclude the need to designate critical habitat within any of the MUs.

Other particular instances that would require the Army to reinitiate consultation are referred to throughout the IP. In addition, the BO and supplement (USFWS 1999 and 2001) require that the Army reinitiate consultation if a fire occurs outside the fire break road as a result of military activities.

Biological approach

This IP has been developed strictly from a biological perspective. Although primarily taxon-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 a taxon 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 target taxa, and are not compromised by other factors such as land ownership, political jurisdiction, or public opinion. By using such an approach, the action priorities in the IP are fully justified on biological grounds.

Related to this biological approach is the recognition that intensive management efforts at taxon and habitat levels can have negative effects on the target taxa, other sensitive taxa, and native ecosystems if not properly implemented. In addition to proposing actions beneficial to the target taxa, the avoidance of negative affects of proposed actions ("do no harm") is an important guiding principle. Following this principle, the IP 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 target taxa, but also other sensitive rare and endangered taxon known to occupy the proposed management areas. Careful testing of techniques before large-scale implementation and monitoring for the consequences of management actions also reflect this principle.

The IP identifies two types of actions: required and recommended. **Required actions** must be conducted as described in the IP in order to meet stabilization requirements, unless modified through the adaptive management process and approved by the IT and the USFWS. Some of the required actions have several options from which the Army can choose in completing the actions. Required guidelines or protocols are found in ***bold italics*** throughout Section 1. Conversely, the Army will not be required to conduct **recommended actions**. However, the IT has recommended these actions because they will most likely provide information that will give the Army less costly and more efficient methods to achieve taxon stabilization. For example, the IT may recommend researching plant reintroduction methods. This will add an extra step at the onset of implementation, but may result in refined methods that require collection of fewer seeds, propagation of fewer plants, or result in less impact to the reintroduction site due to outplanting and therefore will cost less to implement.

The target taxa

All of the target taxa are federally endangered species endemic to the Hawaiian Islands (see Table 2.1). The majority of the target taxa are endemic to Oahu, with the heart of their distribution in the Waianae Mountains. All but eight are currently restricted to the Waianae Mountains, and one taxon, *Alsinidendron obovatum*, is now only found in the AA. Only taxa currently known from the Makua AA have been included as target taxa. Taxa that have been recorded historically in the AA, but are currently not known to persist there have not been considered for inclusion among the target taxa. For endangered plant taxa with two or more varieties or subspecies, only those found in the Makua AA have been designated target taxa. For instance, varieties of *Plantago princeps* other than var. *princeps* (the variety found in the Makua AA) are not being dealt with, even though the whole species was listed as an endangered species.

Table 2.1 Target taxa of the Makua Implementation Plan

Scientific name	Hawaiian name	Current Range*
Alectryon macrococcus var. *macrococcus*	*mahoe, alaalahua*	W, KA, MO, WMA
Alsinidendron obovatum	-	W
Cenchrus agrimonioides var. *agrimonioides*	-	W, WMA, EMA
Chamaesyce herbstii [3]	*akoko*	W
Chamaesyce celastroides var. *kaenana* [1]	*akoko*	W
Cyanea grimesiana subsp. *obatae* [2, 3]	*haha*	W
Cyanea longiflora [3]	*haha*	W
Cyanea superba subsp. *superba*	*haha*	W
Cyrtandra dentata	*haiwale, kanawao keokeo*	W, K
Delissea subcordata	*haha*	W
Dubautia herbstobatae	*kupaoa*	W
Flueggea neowawraea	*mehamehame*	W, KA, EMA, HA
Hedyotis degeneri var. *degeneri*	*manono*	W
Hedyotis parvula	*manono*	W
Hesperomannia arbuscula [3]	-	W, WMA
Hibiscus brackenridgei subsp. *mokuleianus* [1]	*mao hau hele*	W
Lipochaeta tenuifolia	*nehe*	W
Neraudia angulata	*maaloa, maoloa*	W
Nototrichium humile	*kului*	W
Phyllostegia kaalaensis [3]	*kapana*	W
Plantago princeps var. *princeps*	*ale*	W, K
Pritchardia kaalae	*loulu*	W
Sanicula mariversa	-	W
Schiedea kaalae [3]	-	W, K
Schiedea nuttallii	-	W, MO
Tetramolopium filiforme	-	W
Viola chamissoniana subsp. *chamissoniana*	*pamakani*	W
Achatinella mustelina	*pupu kanioe, kahuli*	W

*Current Range abbreviations: W = Waianae, K=Koolau, KA = Kauai, MO = Molokai, WMA = West Maui, EMA = East Maui, HA = Hawaii

1 Addition to the list of target taxa as a result of IT surveys in the AA during the preparation of this plan.

2 Biological opinion identified this taxon as *Cyanea grimesiana* subsp. *grimesiana*, but further investigation determined it was *Cyanea grimesiana* subsp. *obatae.*

3 Indicates that the species is found within the AA but outside of MMR.

3.0 Implementation Team

Because the implementation of this kind of taxon stabilization effort had never before been attempted in Hawaii, the U.S. Army (Army) created an Implementation Team (IT) to assist the Army and its contractors in preparing this Implementation Plan (IP). The IT is comprised of biologists representing the Army, U.S. Fish and Wildlife Service (USFWS), State of Hawaii, Honolulu Board of Water Supply, The Nature Conservancy of Hawaii (TNCH), The Estate of James Campbell, and endangered taxon and ecosystem experts. The IT convened a series of meetings in which information gathered in the process of developing the IP and was presented, reviewed, and incorporated into the requirements of the IP as described in Chapter 2.0: Introduction.

Table 3.1 Members of the Makua Implementation Team

Name **Affiliation** **IT Subcommittees**	**Organization**
Joel Lau IT Botanical Expert Botanist Reintroduction Subcommittee Database Subcommittee	Hawaii Natural Heritage Program Center for Conservation Research and Training University of Hawaii at Manoa 3050 Maile Way, Gilmore 409 Honolulu, HI 96822
Trae Menard IT TNCH Representative and Campbell Estate liaison Natural Resources Manager Snail Subcommittee Sanitation Subcommittee Monitoring Subcommittee Joan Yoshioka* Pauline Sato IT Alternates *Former TNCH Representative	The Nature Conservancy of Hawaii Oahu Program P.O. Box 971665 Waipahu, HI 96797
James D. Jacobi, Ph.D. IT Ecological Expert Botanist Monitoring Subcommittee Reintroduction Subcommittee Database Subcommittee	U.S. Geological Survey Pacific Islands Ecosystems Research Center Kilauea Field Station P.O. Box 44 Hawaii National Park, HI 96718
Michael G. Hadfield, Ph.D. IT Malacological Expert Professor, Zoology Department Snail Subcommittee	University of Hawaii Kewalo Marine Laboratory Pacific Biomedical Research Center 41 Ahui Street Honolulu, HI 96813

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Name **Affiliation** **IT Subcommittees**	**Organization**
Edward Guerrant, Ph.D. IT Reintroduction Expert Conservation Director Reintroduction Subcommittee Sanitation Subcommittee	The Berry Botanic Garden 11505 SW Summerville Avenue Portland, Oregon 97219-8309
H. Kapua Kawelo IT Army Representative Biologist Reintroduction Subcommittee Monitoring Subcommittee Snail subcommittee Joby Rohrer IT Alternate	Directorate of Public Works, Environmental Division Bldg 104, Wheeler Army Airfield U.S. Army Garrison, Hawaii (APVG-GWV) Schofield Barracks, HI 96857-5013
Christina Crooker IT USFWS Representative Biologist Reintroduction Subcommittee Timeline Subcommittee Marie M. Bruegmann Monitoring subcommittee James Kwon Stephen Miller IT Alternates	U.S. Fish and Wildlife Service Pacific Islands Fish and Wildlife Office 300 Ala Moana Blvd, Rm. 3108 PO Box 50088 Honolulu, HI 96850
Brent Liesemeyer IT State Representative Biologist Talbert Takahama IT Alternate Snail subcommittee	Oahu Division of Forestry and Wildlife State Department of Land and Natural Resources 2135 Makiki Heights Drive Honolulu, HI 96822 Mailing Address: 1151 Punchbowl Street, Room 325 Honolulu, HI 96813
Amy Tsuneyoshi IT BWS Representative Sanitation Subcommittee	Board of Water Supply 630 South Beretania Street Honolulu, HI 96843

4.0 Geographic Scope of the Implementation Plan

Introduction

The Makua action area (AA) includes all of Makua Military Reservation (MMR) (*e.g.*, Makua Valley, Koiahi Gulch, Kahanahaiki Valley, *etc*.), as well as adjacent lands, including portions of Kuaokala Forest Reserve, Pahole Natural Area Reserve, Keaau Valley, and Kaluakauila Valley, that are considered at risk of damage or destruction from military activities originating from within the MMR (see Map 4.1).

The geographic scope of the Implementation Plan (IP) includes the entire AA plus the portions of the natural geographic ranges of the target taxa considered necessary to achieve stability of these taxa. While the natural geographic range of these taxa is largely confined to the Waianae Mountains of the island of Oahu for the majority of target taxa, a few taxa are also found in the Koolau Mountains of Oahu and on Kauai. Management actions are therefore not limited to the Waianae Mountains or Oahu but include the island of Kauai as necessary for achieving stability for the taxa. All sites for the IP actions are specifically described and mapped in the IP.

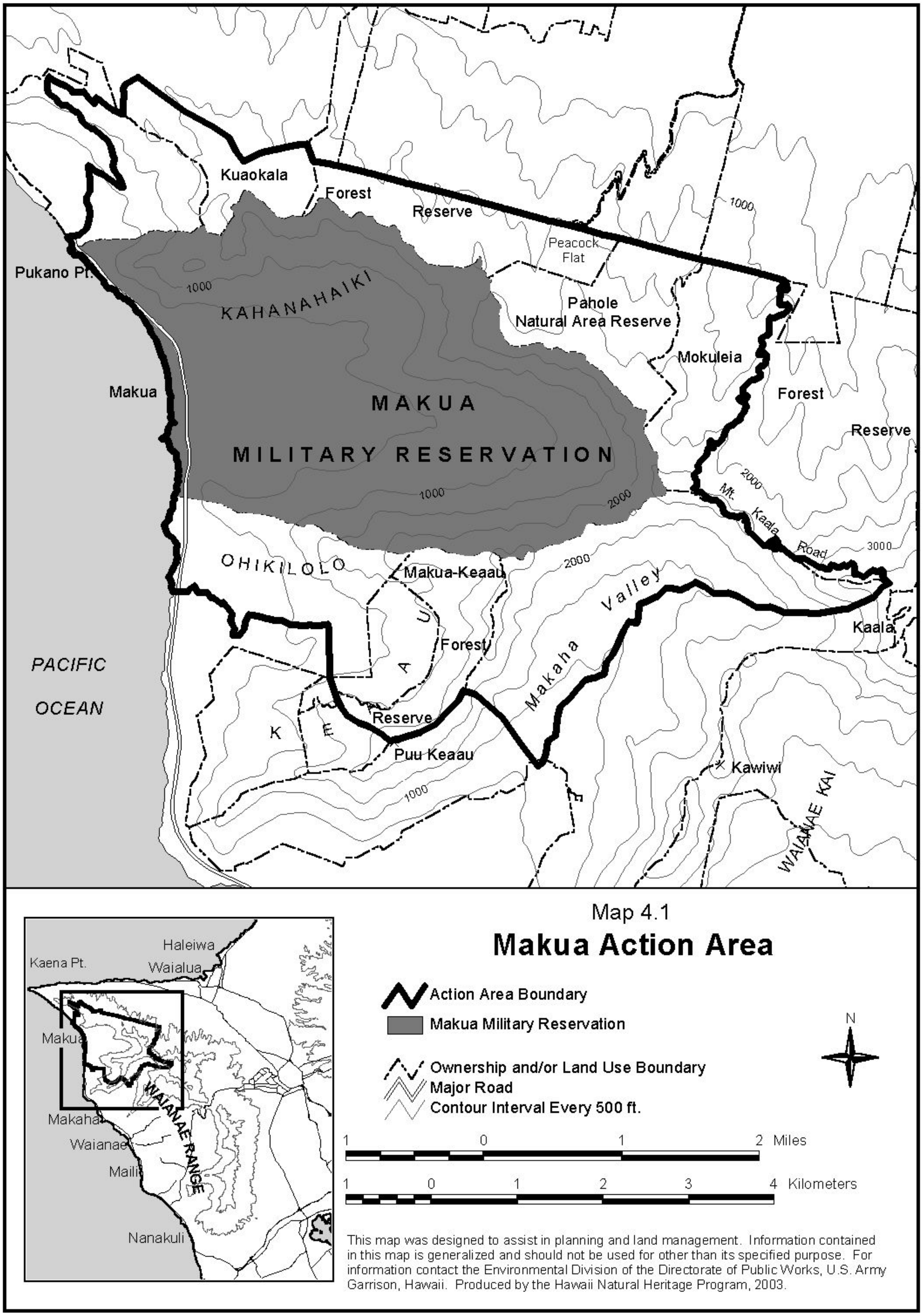
The Waianae region

The Waianae Mountains comprise one of the richest botanical regions in the Hawaiian Islands, including about 10% of the state's rarest plant taxa (HINHP 1996). The arrival of humans, and the resulting introduction of alien species, wildfire, agricultural development, and settlement, has resulted in a loss of native vegetation in the majority of the region, especially below 2,000 feet in elevation. Although there are significant exceptions, the majority of rare and endangered taxa lie within or just outside of the zone of native-dominated vegetation (see Maps 4.2, 4.3, and 4.4). These remaining areas of the most intact native habitat form the majority of the arena for actions proposed in this plan. The map clearly demonstrates the strong correlation between remaining native-dominated vegetation and the remaining current occurrences of the target taxa. These current occurrences provide the potential sites for proposed *in situ* management and reintroductions for achieving stability.

Ownership and management patterns in the Waianae Mountains

There are many landowners in the Waianae Mountains. These include the U.S. Government (primarily U.S. Army (Army) and U.S. Navy (Navy) lands), the State of Hawaii (including Hawaiian Homes Lands, State Forest Reserves and State Natural Area Reserves), Honolulu City and County (Board of Water Supply), and private landowners including The Estate of James Campbell, Dole Food Co., Inc., and a number of other trusts, companies, and individuals. The major patterns of ownership and management are depicted in Map 4.5. The map includes the names of the owners as well as those of the lessees (if any), and also indicates the specific jurisdiction of the parcels (*e.g.*, state, federal, private, city and county, *etc*.). The State's game management area and public hunting areas are also depicted.

A variety of native taxa and habitats exist in the Waianae region and management efforts are underway on many of these lands. For example, portions of the Waianae Mountains are designated as reserves of the State Natural Area Reserves System (NARS), where the land is managed primarily to protect and preserve native ecosystems and taxa. Pahole NAR, Mt. Kaala NAR, and Kaena Point NAR all have active programs of ungulate and weed management, native vegetation restoration, native taxon reintroduction, and other protective management. State Forest Reserves in the Waianae Mountains provide protective conservation zoning and programs for public hunting. The Board of Water Supply lands in upper Makaha Valley are designated as protected watershed with limited public access. A portion of the land holdings of the Estate of James Campbell in the southern Waianae Mountains is managed by The Nature Conservancy of Hawaii as the Honouliuli Preserve, and is dedicated to native taxon and ecosystem protection. Active programs for rare plant and snail protection (including fencing, ungulate control, weed control, and predator control) are underway, as well as some native vegetation restoration projects. Portions of the Navy's holdings in Lualualei are managed by their environmental program, which has mandates to protect endangered species on Naval facilities. The Army's environmental program is engaged in a variety of active management programs in MMR and Schofield Barracks Military Reservation, as well as in other selected areas of the Waianae Mountains. These management programs include fencing for ungulate control, weed control, snail predator control, rare plant reintroduction, and limited vegetation restoration. Through the activities of these various landowners, significant taxon and habitat level management is already underway, contributing to the protection of the Makua target taxa as well as other native taxa.


Kuaokala
Forest
Reserve
Peacock Flat
Pukano Pt.
KAHANAHAIKI
Pahole
Natural Area Reserve
Mokuleia
Forest
Reserve
Makua
MAKUA
MILITARY RESERVATION
Mt. Kaala Road
OHIKILOLO
Makua-Keaau
Makaha Valley
Kaala
PACIFIC OCEAN
Forest
Reserve
KEAAU
Puu Keaau
Kawiwi
WAIANAE KAI
Map 4.1
Makua Action Area
Action Area Boundary
Makua Military Reservation
Ownership and/or Land Use Boundary
Major Road
Contour Interval Every 500 ft.
Miles
Kilometers
Haleiwa
Kaena Pt.
Waialua
Makua
Makaha
Waianae
Maili
WAIANAE RANGE
Nanakuli
This map was designed to assist in planning and land management. Information contained in this map is generalized and should not be used for other than its specified purpose. For information contact the Environmental Division of the Directorate of Public Works, U.S. Army Garrison, Hawaii. Produced by the Hawaii Natural Heritage Program, 2003.

5.0 Identification of Units for Stabilization of Plant and Snail Populations

Ideally, the Implementation Plan (IP) would determine if populations of the target taxa have reached stability based on an assessment of the minimum viable population size (MVP) required for a population to persist over time. The Implementation Team (IT) reviewed the scientific literature and discussed the possibility of establishing MVP targets for any of the target taxa. A review of this literature can be found in the Makua Endangered Species Stabilization Plan (U.S. Army 1999). While determining the MVP for a given taxon is useful for measuring the likelihood of success of different management actions in reaching stability, it was agreed that the biological information needed to conduct such analyses is not available for the target taxa. This is especially true for those taxa with extremely small populations in highly degraded and fragmented habitats. In many cases, it is not clear how to define separate populations, since this requires knowledge of mechanisms for gene flow within and between populations, which can only be generally characterized at this point. Throughout the MVP literature, it is stressed that demographic and environmental considerations are of greater immediate concern than any population size criteria, and that management rather than population size is more likely to increase the likelihood of population stability in the short term.

Snail evolutionarily significant units (ESUs)

Achatinella mustelina is widely and patchily distributed throughout the upper elevations of the Waianae Mountain Range of the island of Oahu. Genetic data were used to construct guidelines by which the maximum amount of genetic diversity might be preserved. By designation of genetically similar populations as evolutionarily significant units (ESUs), it is possible to divide extant tree snail populations into genetically similar units, and focus management efforts on sites at which biological entities or groupings are thought to be evolving relatively independently of one another. An assessment of intrapopulational genetic divergence was used to define the ESUs (discussed at length in the snail stabilization plan, Section 2, Chapter 2.1). When this was applied, all populations sampled in this study could be distinguished as eight ESUs. These ESUs are the basic unit for stabilization of snail populations. Two of the units span distinctly different habitat zones and were thus divided to protect “eco-types” as well as genotypes. Therefore the IP includes protection of 10 field populations that are geographically spread throughout the Waianae Mountain Range to protect the maximum genetic diversity of the species.

Plant populations units (PUs)

For plants, the IT maintained the basic population size criteria developed by the Hawaii and Pacific Plants Recovery Coordinating Committee (HPPRCC 1994) and used as stabilization goals in the Makua Endangered Species Stabilization Plan (U.S. Army 1999), with the modifications discussed in Chapter 9.0: Strategy for Stabilization of Target Plant Taxa, and further clarified in Chapter 9.1: Setting Stabilization Targets.

Because biological populations are so difficult to define, the IT defined population units (PUs) as manageable geographic units of a given plant taxon. The term PU does not presume that the group of plants interacts genetically and ecologically, as would a true population, but more accurately describes a grouping of plants that may or may not be a viable population. PUs are defined according to geographic separation, the presence of other probable barriers to gene flow (such as ridges and habitat discontinuities), and limited likelihood of susceptibility to any given threat event. Based on the current literature on gene flow for plants, little gene flow occurs between individuals separated by over 500 meters, particularly for those taxa in which pollen from one individual must be transferred to another individual for fertilization to occur (Ellstrand *et al.* 1989). To err on the side of caution, the IT doubled this distance, since we know so little about the pollination mechanisms and gene flow of the target taxa. As a general guideline, therefore, ***PUs are comprised of one or more individuals separated by 1,000 meters from other individuals of the same taxon, or less if other factors, such as barriers to dispersal or gene flow, are also present***. Justifications describing the appropriate separating factors or potential genetic affects on wild PUs are documented in each target taxon's stabilization plans (see Section 2, Chapter 2: Stabilization Plans) for any PU that violates the 1,000 meter separation guideline.

The IP evaluated nearly 1,000 current and historic occurrences of the target plant taxa documented from the Waianae Mountains and elsewhere in the archipelago, using the Hawaii Natural Heritage Program database, supplemented by information from recent field surveys. Of these, the IP identified 387 PUs known to be extant in 1989 (ten years prior to the issuance of the biological opinion). A 1989 cutoff date was chosen since it was believed that this represented the most accurate assessment of management options for the target taxa. This differs from the 1970 cutoff date that was used to determine taxa to be considered in the U.S. Army's Biological Assessment (U.S. Army 1999).

A PU is the fundamental geographic and demographic unit for the information contained in the sections of the IP, including the plant taxon summaries, stabilization plans, and the management unit summaries. As the U.S. Army implements components of the IP, which include genetic studies and monitoring of management practices, and more is learned about the target taxa, the information gathered may help refine our understanding of PUs for each taxon. Insights may be gained on the effects of natural barriers (*e.g.*, major ridges) or discontinuities in habitat that separate groups of individuals. The definition and application of the PU guidelines will be reviewed as these data become available from the IP monitoring program. The IT recognizes that local extirpations of PUs may occur. Guidelines for the management consequences for such contingencies are discussed in Chapter 9.2: The Credit System for Plants.

6.0 Management Units

Definition

A management unit (MU) is an area designated by the Implementation Team (IT) for active protective management with the express goal of stabilization of population units (PUs) of target taxa within the context of native habitat. The ultimate goal is the persistence of stable PUs of target taxa, maintained through ongoing management of the taxa and habitat within the MUs. Typically, an MU lies within a fenced area where ungulates and other threats are actively removed or controlled to protect the target taxa. Functioning native habitat to support stable target taxa is the goal of active management within the MUs.

The proposed MUs occur on U.S. Army (Army), U.S. Navy, State of Hawaii, Honolulu Board of Water Supply, and private lands, and will require cooperation and memoranda of agreement with the landowners, as spelled out in scopes of work prior to initiation of management actions at these sites.

Each MU is designed to provide sufficient area for the stabilization of all *in situ* PUs designated as manage for stability (see Section 1, Chapter 9.3: Management Designations) and all reintroduced PUs within the MU. This resulted in the delineation of a number of larger area MUs, each containing numerous target taxa, and also in numerous smaller MUs that might contain only one or two target taxa. Because the MUs are sites of intensive management, it is important to repeat concerns about the harmful effects of human activities in natural areas, including inadvertent introductions of pests and pathogens, direct trampling damage to native vegetation, and genetic contamination of sensitive plant taxa. Detailed plans developed for MU management must include strategies to minimize such harm. See Table 9.8 for a list of particularly sensitive rare taxa in the Waianae Region.

MU designation

The IT designated 31 MUs based on locations of the *in situ* PUs of the target taxa and their potential reintroduction areas. One of the MUs is on the island of Kauai, and 30 are on the island of Oahu. Of these, 27 are in the Waianae Mountains, and three are in the Koolau Mountains. The MUs range from five acres to nearly 825 acres in size (see Table 6.1). These MUs include all of the target taxon PUs designated for management for stability, as well as all selected reintroduction sites identified in the individual taxon stabilization plans (SPs) (see also Chapter 9.7: Approach to Plant Stabilization).

MUs generally are either large or small. Larger MUs were designated to include: 1) relatively high densities of *in situ* PUs of target taxa, 2) large areas of relatively intact native-dominated vegetation which would provide habitat for *in situ* PUs as well as for reintroduction sites, and 3) as far as possible, locations in areas accessible for management (*e.g.*, near existing roads, trails, or helicopter landing areas). These conditions are described in Long-term Threat Management Goals in Management Units (Chapter 10), and addressed in Monitoring (Section 2, Chapter 4). Because many of the MUs are at locations below 2,500 feet elevation, where the majority of native ecosystem loss has occurred, the MUs also include some areas of alien-dominated habitat that will require selective habitat restoration. Small-area MUs were delineated for isolated PUs designated for management for stability, or to provide reintroduction sites that would meet the

Table 6.1 Makua Management Unit List

No.	Management Unit	Acres	Island	Region
1	Alaiheihe to Palikea Gulch	619	Oahu	Waianaes
2	Central and East Makaleha	823	Oahu	Waianaes
3	Ekahanui	221	Oahu	Waianaes
4	Haili to Kawaihapai	161	Oahu	Waianaes
5	Huliwai	118	Oahu	Waianaes
6	Kaahole to Paaiki	468	Kauai	Northwest
7	Kaena and Keawaula	103	Oahu	Waianaes
8	Kahanahaiki	97	Oahu	Waianaes
9	Kaluaa and Waieli	342	Oahu	Waianaes
10	Kaluakauila	152	Oahu	Waianaes
11	Kamaileunu	86	Oahu	Waianaes
12	Kauaopuu	19	Oahu	Waianaes
13	Kaumoku Nui	213	Oahu	Waianaes
14	Kawaiiki	44	Oahu	Koolaus
15	Keaau and Makaha	5	Oahu	Waianaes
16	Lower Kahanahaiki	32	Oahu	Waianaes
17	Lower Kapuna	266	Oahu	Waianaes
18	Lower Ohikilolo	70	Oahu	Waianaes
19	Lower Opaeula	65	Oahu	Koolaus
20	Makaha	172	Oahu	Waianaes
21	Mohiakea	19	Oahu	Waianaes
22	Mt. Kaala NAR	620	Oahu	Waianaes
23	Ohikilolo	578	Oahu	Waianaes
24	Pahole	215	Oahu	Waianaes
25	Palikea	127	Oahu	Waianaes
26	Puu Kumakalii	28	Oahu	Waianaes
27	Upper Kapuna	225	Oahu	Waianaes
28	Upper Keaau	10	Oahu	Waianaes
29	Waianae Kai	125	Oahu	Waianaes
30	Waiawa	75	Oahu	Koolaus
31	West Makaleha	255	Oahu	Waianaes
	Total acreage	6,353		

distance and habitat criteria designated in the Implementation Plan (see Chapter 9.6: Reintroduction and Augmentation).

Geographic context of the MUs

Some of the MUs are geographically distinct and separated from other MUs by intervening areas not receiving management. Others, such as Lower Kahanahaiki, Kahanahaiki, Pahole, Lower Kapuna, Upper Kapuna, West Makaleha, Central and East Makaleha, Mt. Kaala NAR and Alaiheihe to Palikea Gulch, are immediately adjacent to each other and separated only by boundary fence lines. Together the MUs define a large, contiguous landscape of habitat for the endangered target taxa. Despite their contiguity and large total geographic coverage, each MU is treated independently for the purposes of management actions and stabilization credits. Therefore, reintroductions proposed for a given taxon in two adjacent MUs are considered separately, despite geographic proximity (although held to the 500-1,000 meter separation criteria described in Chapter 9.6: Reintroduction and Augmentation).

Sequencing of MU actions

Actions at the MU level extend beyond the parameters of PU-level management to address threat control on a broader scale. The larger MUs have been divided into subunits, and management will be implemented for these MUs at the subunit level. Actions at the MU or MU subunit level have been divided into two major categories: 1) ungulate control through fencing and removal, and 2) weed control over a portion of the MU or MU subunit.

Management at the MU level is dictated by the highest designation of PU management within each MU within each phase. The required MU-level management actions are summarized in Table 9.6. In short, fencing of an MU or MU subunit and ungulate removal will occur for all levels of PU management except baseline, while the control of weeds over a portion of an MU or MU subunit will occur only when a PU of a full taxon stabilization taxon is contained therein. For example, in the Huliwai MU in Phase A, the *Delissea subcordata* PU is designated for partial PU management while the *Cenchrus agrimonioides* PU is designated for baseline. The higher of the two PU management designations, partial PU management, therefore requires ungulate removal and fencing in phase A but does not require weed control over a portion of the MU. In phase B, the *D. subcordata* PU is now designated for full taxon stabilization while the *C. agrimonioides* PU is designated for partial PU management. The higher of the two management designations, full taxon stabilization, now additionally requires the control of weeds over a portion of the MU in Phase B. See Section 1, Chapter 9.3 and 9.4 for a more detailed explanation of management designations and sequencing.

Using the relationship described above, the initiation of MU actions for all MUs and MU subunits was prescribed for each phase. The culmination of this planning effort is seen in Table 9.7. Maps showing the location and sequencing of actions for each MU can be found in the subsections of Section 2, Chapter 3: Management Units. The overall sequence for management of MUs and MU subunits over the 33-year period of initial implementation is determined by the presence of PUs of varying levels of management. Maps 6.1 through 6.7 show the level of MU management in each phase for all of the MUs.

Management activities in the MUs

Management actions to eliminate threats and encourage regeneration of target taxa are required within each MU. Although each taxon has specific threats and habitat needs, many of the threats apply to all or many of the taxa: feral ungulate browsing, competition with alien weeds, seed predation by rats, and the effects of alien pest insects are prominent among these. The management activities to be developed for each MU to counteract these threats, as needed, are briefly described below. The initial phases of MU management call for a survey and assessment of threats to justify the initiation of the management actions below. Subsequently, separate detailed MU management plans for each type of threat must be developed by the Army using the results of these MU surveys to identify specific management needs for each MU. The IT and the U.S. Fish and Wildlife Service must review and approve each of the MU management plans for the various threats.

Threat management

Fencing and ungulate control

Using fences to create areas targeted for ungulate eradication is a well-established practice in other managed Hawaiian natural areas (Cory 2000). Perimeter fences for the MUs typically either follow the MU boundaries, or fall outside MU boundaries when topography forces the fence line to follow ridge tops or contours to avoid cliffs or other natural obstacles. Perimeter fences are typically not inside of the MU boundaries unless topographic or other features keep ungulates out of unfenced sections of the MU. In addition to perimeter fences, a number of fences are proposed to divide large MUs into more manageable subunits (subunit fences), or provide a strategic protective function, such as preventing movement of feral ungulates along ridges (strategic fences). All fence lines are depicted in the map for each MU, and include existing fences, proposed routes for additional fences, and proposed fences of various managing entities (*e.g.*, The Nature Conservancy of Hawaii (TNCH), Hawaii Division of Forestry and Wildlife (DOFAW)). The fences are designed primarily to prevent further invasion of ungulates such as feral pigs, goats, and deer. In very rare cases, perimeter fences are not recommended, for example, when MUs include areas that are considered self-protected (typically by vertical cliffs). In these situations, short, strategic fences might be the only fences proposed. In cases where a fence crosses a trail on public lands, a crossover will be constructed to maintain easy public access. **Placement and size of all MU fences will be refined based on landowner input.**

All proposed routes for additional MU fence lines are approximations only, and subject to a thorough fence line scoping to determine detailed on-the-ground placement that minimizes damage to habitat and rare taxa, and optimizes protection. In cases where little is known about an area, the need for and estimated placement of fences is uncertain, pending initial MU surveys. For example, a large fence is proposed for Alaiheihe Gulch, but the need for fencing and the course of fencing will be determined following proposed surveys for *Achatinella mustelina* in the area.

Within the MU fences, ungulates such as pigs, goats, and feral cattle must be removed until the MU is ungulate-free. Methods for ungulate control and removal are drawn from best available control techniques from natural resource managers at the U.S. Army Environmental Division, the National Park Service, U.S. Fish and Wildlife Service National Wildlife Refuges, State Natural

Area Reserves, preserves of TNCH, and others. These techniques may include public hunting, staff hunting, trapping and snaring, or other methods (Cory 2000).

Weed assessment and control

Within the MUs, highest priority weeds were preliminarily identified and designated for one of two general levels of control (see Section 3, Appendix 3.1: Priority Weeds for Selected Makua Management Units). Incipient habitat modifying weeds ranked highest for control (priority 1) and are slated for complete removal, while other more established and persistent weeds (priority 2) are controlled in the vicinity of PUs and at the MU level to varying degrees (see Chapter 10: Long-term Threat Management Goals in Management Units). Some alien taxa that are less habitat modifying may be tolerated without much control effort being applied at present but warrant monitoring and periodic assessments to determine the need for control. A small number of known or potentially incipient habitat-modifying weeds will be assessed and mapped throughout the Waianae area and in the vicinity of MUs in other regions. The goal of this assessment is to monitor and identify the need to initiate management actions for taxa that may seriously threaten the MUs in the future. All of this information will be used to develop weed control plans for each MU.

The area for weed control typically lies within 50 meters or more of the polygon defined by the existing individuals of the PU for intensive management, with a lower level of control throughout the MU (see Chapter 10: Long-term Threat Management Goals in Management Units). Surveys of the MUs to confirm and augment the weed lists and update their status will be necessary to specify targets for weed control and to specify areas requiring control. Methods for weed control are continually being improved, so are not specified here, but the Army is expected to use the best available control techniques of natural area managers, as noted above for ungulates. Some examples of current methods are included in Section 3, Appendix 3.2: Weed Control Options. In areas dominated by alien taxa, gradual, incremental weed control will be used to avoid rapid or major microhabitat changes.

Small mammal control

Where small mammals have been identified as a threat, small mammal control, in the form of trapping and the use of toxicants, will be implemented within MUs. Mammal control will be focused in the vicinity of PUs and proposed reintroductions/augmentations of target taxa shown to be sensitive to small mammal predation (*e.g*., *Achatinella mustelina* and plants eaten by rats). Small mammal assessments must be conducted within each MU to specify areas requiring control. Current small mammal control techniques include kill-trapping and use of toxicant bait stations. Management should compensate for an edge effect in baiting (Nelson *et al*. in press). The research and protocols for aerial application of rodenticides are currently being explored (Campbell pers. comm. 2000) and may be applicable to MU management in the future. The Army will also assist in funding some of the research needed to register for aerial application.

Euglandina rosea *and other snail predator control*

Because the predatory alien snail *Euglandina rosea* is the primary threat to *A. mustelina*, monitoring and control measures for *E. rosea* are proposed in the *Achatinella* MUs wherever populations of *A. mustelina* are present. Similar monitoring and control protocols are identified for slugs and *Platydemis manokwari*, an alien predatory flatworm. Methods have been developed for the control and exclusion of *E. rosea*, and are described in the *A. mustelina* SP (see Section 2, Chapter 2.1: Stabilization Plan for *Achatinella mustelina*).

Other invertebrate control

Specific management tools are currently not available for insect pests such as two-spotted leafhopper (*Sophonia rufofascia*), black twig borer (*Xylosandrus compactus*), and Chinese rose beetle (*Adoretus sinicus*). Under certain conditions, it may be necessary to apply systemic insecticides to individual plants, which might control alien insect pests, but might also suppress important native insect associates. Research on specific control techniques for slugs, *X. compactus* and other insect pests, and the potential impacts of these control methodologies on native invertebrate taxa is urgently needed, since these threats are considered major factors in the decline of certain native plant taxa (particularly *Alectryon macrococcus* var. *macrococcus* and *Flueggea neowawraea*).

Human impacts

The MUs will have to accommodate at least some level of human presence, including resource managers, volunteers, hikers, and hunters. Signage and some restrictions of human presence in the vicinity of *in situ* populations and reintroduction sites will be necessary.

Fire control

The goal of fire control in MUs is to bring fire threat to zero, or to minimize the threat in those areas where the threat cannot be removed entirely (*e.g.*, some of the driest MUs adjacent to areas bearing significant fire histories). For all MUs with assessed high fire risk (see Section 2, Chapter 3: Management Unit Summaries), fire planning and management programs are considered critical to ensure success of stabilization efforts. Fire is certainly the most devastating of the threats facing MUs and target taxa. Both taxa and habitat can be completely destroyed in a single, brief fire event. Fire pre-suppression and suppression plans should follow those established by other natural area managers. Perhaps the most experienced of these include the National Park Service, the Department of Land and Natural Resources, and TNCH. A single fire management plan will be written to cover issues common to all MU areas, to which separate annexes will be appended to address issues that are specific to each of 11 Fire Management Units (FMUs) (Section 4). An FMU contains a grouping of MUs for which a similar fire management approach may be taken based on geographic proximity, fuel types, fire history and access routes (roads/trails). Fire management plans should assess and address fire threat attributed to both military and non-military ignition sources.

Erosion control

It is important to manage erosion only when *in situ* target taxa are imminently threatened. There are limited erosion management options, but substrate stabilization in localized areas may help lower the risk of harm to target taxa. Additionally, it is expected that control of feral ungulates throughout all of the MUs will significantly reduce erosion in these areas.

Reintroductions and augmentations

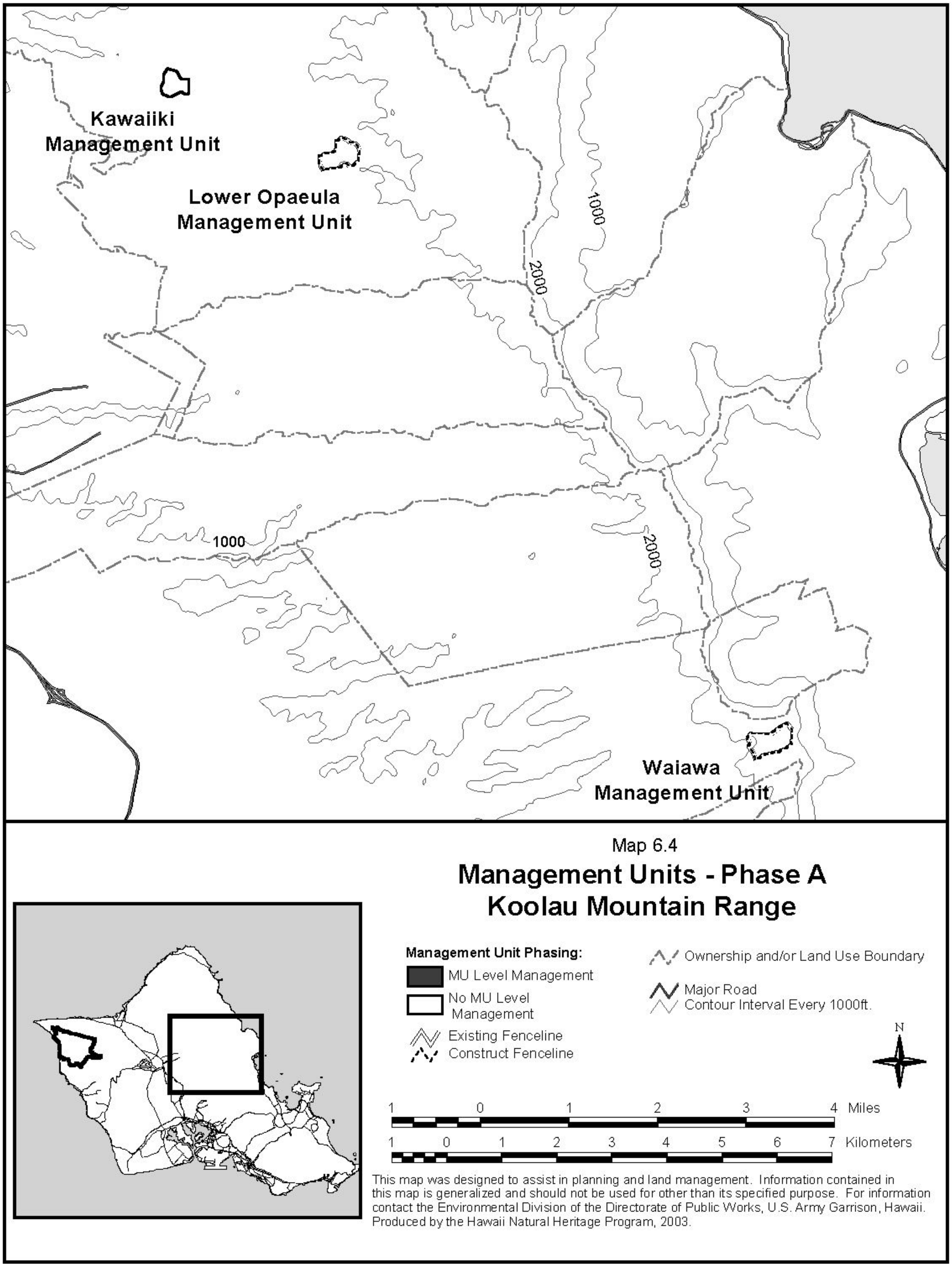
The MUs are the focal sites for all of the reintroductions and augmentations. The details of these reintroductions are specified by the individual SPs for each target taxon (see Section 2, Chapter

2), and in Chapter 9.4: Sequencing of Actions. The lists of target taxa that are slated for reintroductions in each MU are presented in the MU summaries (see Section 2, Chapter 3).

Some lower ranked, and therefore backup, reintroduction sites were remotely located from designated MUs and were not encompassed by MU boundaries. These were typically individual locations proposed for only a single taxon and, if eventually utilized, will be dealt with via small exclosures or strategic fences. Rarely, there are self-protected sites, such as vertical, sparsely vegetated cliffs that require no fencing, no weed control, and only regional ungulate control. While it is anticipated that augmentations will take place in many of the MUs, PU response to threat control cannot be predicted. Results of monitoring will be used to determine which PUs will receive augmentation according to the triggers discussed in Chapter 9.4: Sequencing of Actions. Therefore, augmentations are not indicated in any of the MU summary tables at this time.

MU summary tables

MU maps and summary tables describing the MUs and phasing of management in the MUs are found in Section 2, Chapter 3. All selected reintroduction sites and all *in situ* populations designated as manage for stability are included on the MU maps. *In situ* populations with management designations other than manage for stability and backup reintroduction sites can be found on the SP maps (Section 2, Chapter 2).


Kawaiiki
Management Unit
Lower Opaeula
Management Unit
1000
2000
1000
2000
Waiawa
Management Unit
Map 6.4
Management Units - Phase A
Koolau Mountain Range
Management Unit Phasing:
MU Level Management
No MU Level Management
Existing Fenceline
Construct Fenceline
Ownership and/or Land Use Boundary
Major Road
Contour Interval Every 1000ft.
N
1 0 1 2 3 4 Miles
1 0 1 2 3 4 5 6 7 Kilometers
This map was designed to assist in planning and land management. Information contained in this map is generalized and should not be used for other than its specified purpose. For information contact the Environmental Division of the Directorate of Public Works, U.S. Army Garrison, Hawaii. Produced by the Hawaii Natural Heritage Program, 2003.

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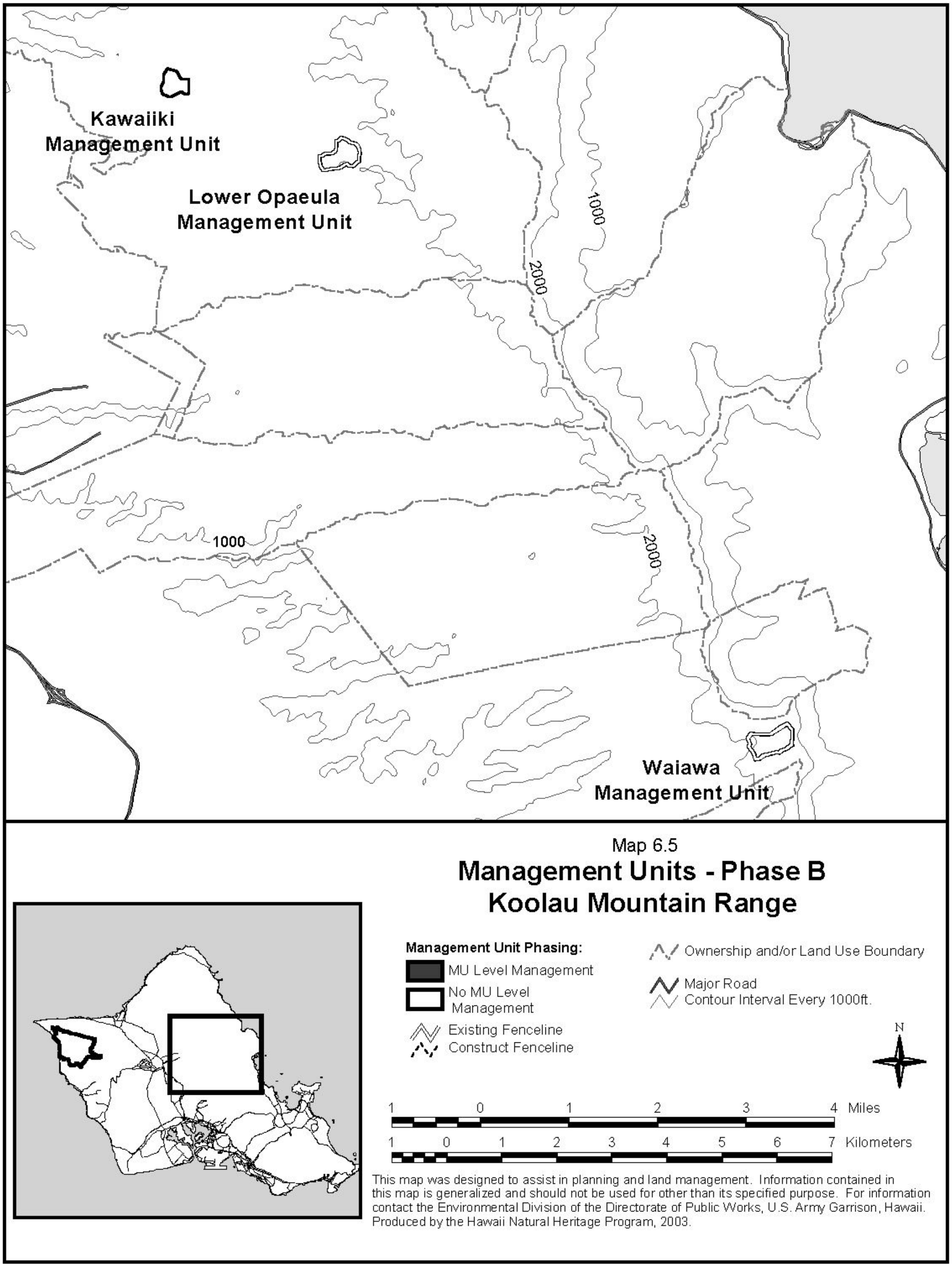
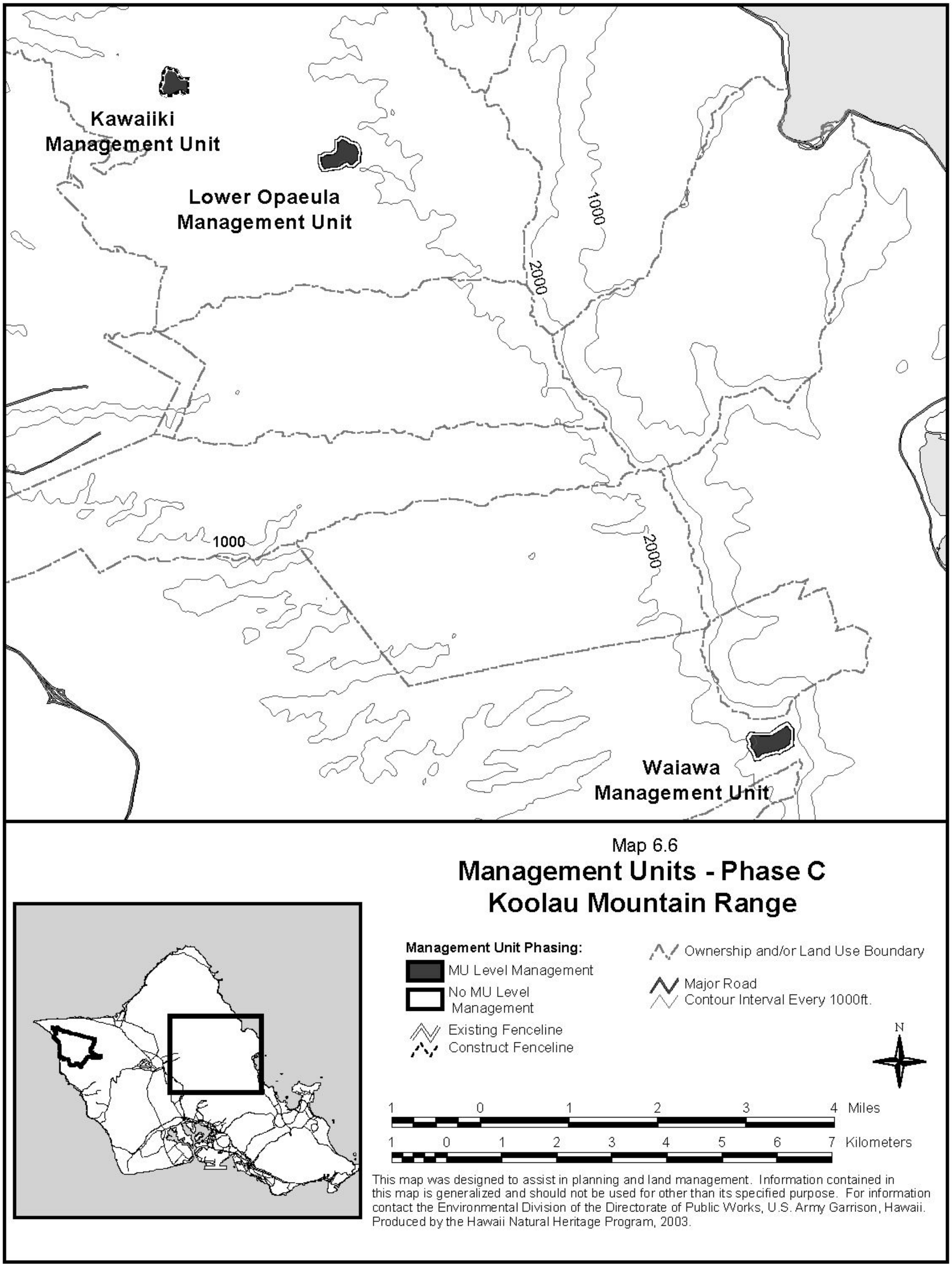

Kawaiiki
Management Unit
Lower Opaeula
Management Unit
Waiawa
Management Unit
1000
2000
Map 6.5
Management Units - Phase B
Koolau Mountain Range
Management Unit Phasing:
MU Level Management
No MU Level Management
Existing Fenceline
Construct Fenceline
Ownership and/or Land Use Boundary
Major Road
Contour Interval Every 1000ft.
N
1 0 1 2 3 4 Miles
1 0 1 2 3 4 5 6 7 Kilometers
This map was designed to assist in planning and land management. Information contained in this map is generalized and should not be used for other than its specified purpose. For information contact the Environmental Division of the Directorate of Public Works, U.S. Army Garrison, Hawaii. Produced by the Hawaii Natural Heritage Program, 2003.



Map 6.6
Management Units - Phase C
Koolau Mountain Range

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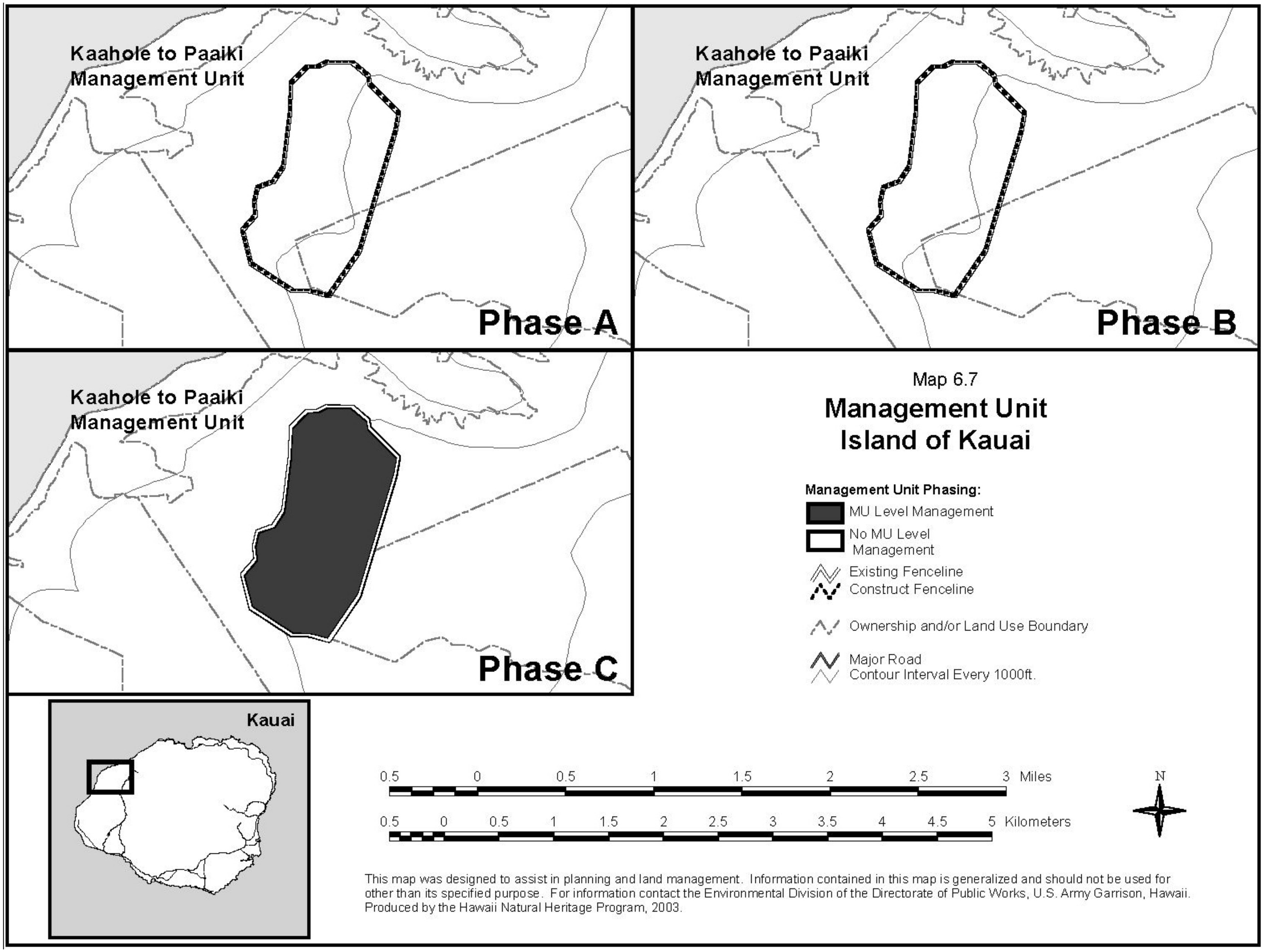

Kaahole to Paaiki Management Unit
Phase A
Kaahole to Paaiki Management Unit
Phase B
Kaahole to Paaiki Management Unit
Phase C
Map 6.7
Management Unit
Island of Kauai
Management Unit Phasing:
MU Level Management
No MU Level Management
Existing Fenceline
Construct Fenceline
Ownership and/or Land Use Boundary
Major Road
Contour Interval Every 1000ft.
Kauai
0.5 0 0.5 1 1.5 2 2.5 3 Miles
0.5 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 Kilometers
N
This map was designed to assist in planning and land management. Information contained in this map is generalized and should not be used for other than its specified purpose. For information contact the Environmental Division of the Directorate of Public Works, U.S. Army Garrison, Hawaii. Produced by the Hawaii Natural Heritage Program, 2003.

7.0 Threat Assessments for the Oahu Action Area

Management unit (MU) and population units (PUs) threats

Part of the necessary background information for the management of the target taxa is a clear assessment of the threats that can hamper the stabilization of each taxon. Fire ignition and introduction of alien taxa, such as weeds and pest animals, are the most important of these threats in the Oahu action area, and have been characterized well in the Oahu Biological Assessment (U.S. Army 2003). In many cases, the threats that are not training-related are held in common among all or most of the target taxa. For example, feral ungulates such as goats and pigs are primary threats to both habitat and individual rare taxa, and the distribution of pigs and goats in the Waianae region (and other target taxon population locations) is generally well known. Other threats are particularly important for certain target taxa (*e.g.*, black twig borer is an important threat to *Alectryon macrococcus* var. *macrococcus* and *Flueggea neowawraea*). For each population unit slated for management for each target taxon, the most important threats were assessed and included in the site characterization fields of the Makua Implementation Plan (IP) database (see Appendix 4.1: Population Units and Individual Data Sheets). A discussion of the threats to each target taxon, a table of the priority PUs for management actions and a table defining *in situ* threats can be found in each one of the individual taxon summaries (see Chapter 16: Taxon Summaries). Specific threat categories assessed include:

- alien plants (weeds)
- erosion
- feral ungulates
- fire
- human activities
- invertebrate pests

In many cases, the specific threats (*e.g.*, the predatory alien snail *Euglandina rosea* as a predator of *Achatinella mustelina*) are well documented. In cases where the impacts of suspected threats upon target taxa are undocumented or poorly understood (*e.g.*, slug impact on *Schiedea kaalae*), research needed to gain insight as to the significance of the threat is identified. Additionally, if the impacts of a threat upon target taxa are well documented but methods to adequately control the threat have not yet been developed (*e.g.*, black twig borer control for *A. macrococcus* var. *macrococcus*), research in this area is required. Current knowledge by members of the Implementation Team (IT), as well as threat characterizations from the biological assessment (U.S. Army 1998b) and the Makua Endangered Species Stabilization Plan (U.S. Army 1999) were reviewed as corroborative information sources in assessing threats to target taxa PUs.

During field surveys conducted by the IT and the U.S. Army (Army), additional notes on specific threats to target taxa and potential management areas were collected and added to the Makua IP database (see Appendix 4.1: Population Units and Individuals Data Sheets). Using the compiled threat information, the IT has incorporated appropriate threat management and monitoring recommendations in each of the individual stabilization plans (see Section 2, Chapter 2.2: Approach to Plant Stabilization) based on currently available information.

Identification of priority weeds

Because there are so many alien plants that negatively impact endangered species and their native habitats, the Scope of Work for the Makua IP charged the IT with identifying and setting priorities for management of weed species pertinent to the stabilization of the target taxa. Based on best current field knowledge, the IT developed a detailed priority weed list characterizing the presence of over 80 alien plant species of concern in the Waianae Mountains. A matrix relating each alien plant species to selected management units in the Waianae Mountains was developed and general management recommendations were made on the need and methods to control these weeds (see Section 3, Appendix 3.1: Priority Weeds for Selected Makua Management Units).

Management recommendations for each weed species in each MU were assigned via management codes, based on the presence of the weed in the MU, and the current state of the threat (*i.e.*, incipient vs. established). If a weed is incipient in a MU, management is targeted at eradication from the MU; if the weed is well established within a MU, only local control is targeted. The life form for each weed species was also indicated, thereby assisting with application of the most effective weed control option available for that life form (see Section 3, Appendix 3.2: Weed Control Options). The list of weeds in Appendix 3.2 is intended to serve as a starting point in developing more detailed alien species control programs for each of the MUs. In addition, priority incipient weeds will be monitored and controlled as needed outside of MUs and PUs, particularly along potential transmission corridors (*e.g.*, roads, trails, fence lines). The methodology for this is described in Section 2, Chapter 4.3: Monitoring Protocols for Areas Outside Management Units.

It is in the best interest of the Army to continue to participate in, and support, multiagency efforts to identify and control incipient alien species on the island of Oahu. This proactive and preventative approach can help minimize future management costs to the Army.

8.0 Strategy for Stabilization of *Achatinella mustelina*

Defining stabilization

The approach to the stabilization of *Achatinella mustelina* taken in the Implementation Plan (IP) is quite different from that of endangered Makua plants. The biology of this tree snail has been studied for several decades in Hawaii. The snail's life history pattern (including low reproductive rate and late age at first reproduction), population dynamics (sometimes including large fluctuations in snail densities when attacked by predators), and vulnerability to predation, coupled with our inability to store propagules, results in a set of targets and timing of stabilization actions appropriate for *A. mustelina*. Actions for snails will all be initiated within the first 10 years of the IP because of the high level of threat from predators that are currently difficult to control. The number of populations needed for snail stabilization is significantly greater than is needed for plants, as is the number of individuals needed to stabilize each population (USFWS 1993a). Similarly, the definition of populations for snails is complicated by the geographic patterns of morphological and genetic variation that have been described for *A. mustelina* in the Waianae Mountains (Welch 1938, Holland and Hadfield 2002).

The U.S. Fish and Wildlife Service's Biological Opinion (BO) (USFWS 1999) concerning stabilization for *A. mustelina* required the management of at least 20 field populations spread throughout the historic range of the taxon in the Waianae Mountains. In an effort to better assess the number of populations needed to stabilize *A. mustelina*, the Implementation Team and USFWS requested that the U.S. Army (Army) support field surveys to determine the locations of remaining populations and molecular-genetic analyses to determine the relationships among the field populations.

Field surveys funded by the Army and conducted from April through June 2000 sampled all areas with distinct, named varieties of *A. mustelina*, as described in Welch (1938). The surveys found 22 populations, some quite close together. Population sizes varied widely. One contained a few hundreds of individuals and may only require management of threats, while other populations had fewer than 100 individuals per population, and several were at risk of imminent extirpation. These populations will require more extensive management.

Tissue samples were taken from 18 locations, and genetic analyses were done on three snails in each population (see Section 2, Chapter 2.1, Attachment 1: Assessment of Genetic Variation). The results indicated the presence of eight genetically distinct groups that are considered to be evolutionarily significant units (ESUs). These ESUs are distributed throughout the length of the Waianae Range, and two of the ESUs spanned distinctly different habitat zones. These latter two ESUs were divided into "eco-types". Based on these data, ***stabilization of* A. mustelina *requires, in part, that the Army must stabilize 10 field populations that are geographically spread throughout the Waianae Range to include the maximum genetic diversity of the taxon.*** This differs from the original 20 populations to be stabilized specified in the initial BO (USFWS 1999).

Stabilization also requires that each population include 300 or more snails, totaled from all age classes. This number was determined largely from empirical observations on the Pahole population of *A. mustelina* (Hadfield and Mountain 1980, Hadfield 1986, Hadfield *et al.* 1993).

Without predators, the size of the Pahole population of *A. mustelina* in a 25 square meters (m^2) quadrate grew from approximately 50 to 300 snails in about 4 years. When predators (rats or the introduced snail *Euglandina rosea*) entered the area, the population diminished rapidly to less than 30 individuals. Recovery from these predation events has been slow, even with active conservation efforts. A third requirement for stabilization of *A. mustelina* is to ***maintain a captive population for each of the 8 recognized ESUs and the two ecotypes for a total of 15 should additional distinct ESUs be located in later surveys.*** A major goal of the captive-rearing program, described in the snail stabilization plan (Section 2, Chapter 2.1), is that it will provide snails that can be used to build up field populations to the required 300 individuals, if deemed necessary.

Management designations

There are a number of challenges in attempting to stabilize populations of *A. mustelina*. These include difficulties in controlling alien predators, documented large fluctuations of snails in populations due to natural disasters or predation events, the slow rate of recovery imposed by their life history traits, and the impacts on wild populations of collection for genetic storage (captive propagation). *In situ* management options range from threat abatement, habitat management, and stimulation of natural regeneration, to salvage of genetic material through collection and captive propagation of the last individuals from declining populations. Where sufficient numbers of individuals exist in a habitat that is either sufficiently intact or restorable, and with a snail population structure that will promote natural recruitment, a population is designated for management for stability. If there are few individuals, and conditions for habitat regeneration or rehabilitation are poor, the population might be identified for collection for captive propagation. Captive propagation serves as a means of preserving genetic resources for future reintroduction attempts that will aid in maintaining the ten field populations required for stabilization. The two alternatives for a given snail population are described more fully below.

Manage for stability

The primary strategy for stabilization of *A. mustelina* is threat management applied to 10 populations, the selection of which is described in the *A. mustelina* stabilization plan (Section 2, Chapter 2.1). The key threat to the snails is predation by the carnivorous snail *E. rosea* and rats; predation by other invertebrates such as the terrestrial flatworm *Platydemis* and indirect threats to habitat, such as those that cause snail host-plant decline and vegetation changes from native forest and shrubland to alien forest, grassland, or shrubland.

Subtasks for management for stability are as follows:

1. Assess snail population sizes
2. Assess threat management needs and choose site(s) for predator and ungulate exclosure(s)
3. Manage threats (as appropriate), including areas adjacent to exclosure(s):
    a) Rat control
    b) *Euglandina* control and exclosure
    c) *Platydemis* and other predator control
    d) Ungulate control and exclosure
    e) Alien plant control
    f) Other host plant/habitat protection needs

    g) Human disturbance
    h) Other threats as assessed
4. Monitoring (see Section 2, Chapter 4: Monitoring), including areas adjacent to exclosures
5. Data management

Collect for captive propagation

In some locations, populations of *A. mustelina* have declined to the point where natural regeneration of the populations is unlikely. For these populations, it is vital to collect a limited number of individuals for rearing in captive propagation to ensure that their genetic material is not altogether lost. Living individuals from severely declining populations can be maintained in a captive- propagation facility until predator control and plant habitat restoration are advanced to a condition that will support reintroduction. The methods of captive propagation of snails have been refined through years of practical experience by Hadfield and others (see Section 3, Appendix 2.5: Captive Propagation Protocols for *Achatinella mustelina*), utilizing environmental chambers maintaining environmental conditions appropriate for *A. mustelina*.

Collect for captive propagation subtasks are as follows:

1. Assess population size (*e.g.*, via direct count)
2. Collect snails [7-10 individuals (but no more than 20%)] from populations designated for captive propagation
3. Maintain and propagate snails in environmental chamber(s)

Reintroduction/augmentation

Augmentation and reintroduction are not currently required for *A. mustelina*, because sufficient numbers of distinct populations representing all ESUs exist to achieve stability via *in situ* management of protected PUs. However, individuals maintained in captive propagation will be available for reintroductions or augmentations in the future, in collaboration with other agencies or organizations.

9.0 Strategy for Stabilization of Target Plant Taxa

The U.S. Fish and Wildlife Service (USFWS) defines plant stabilization according to the recommendations put forth by the Hawaii and Pacific Plants Recovery Coordinating Committee (HPPRCC), a group of botanical experts gathered together by the USFWS to offer guidance on the recovery of listed plants in the Pacific. The HPPRCC decided that a taxon would be considered stable if it met the following three criteria: 1) it has sufficient numbers of regenerating individuals in a minimum number of populations; 2) its threats are controlled at these populations; and 3) these populations are fully represented in an *ex situ* collection (USFWS 1998b). It is important to note that the requirements for stabilization are far below those required for delisting or downlisting, and that stabilization is *not* synonymous with recovery. The Implementation Team (IT) reviewed the guidelines for the number and size of populations required for stability, and refined the target number of reproducing individuals required per population for some taxa. Revisions were based on life history and other factors described in Table 9.1.

Factors that were assessed regarding stabilization included threats that contribute to the decline of the target taxa, and aspects of their biology (especially reproductive biology) that are pertinent to natural regeneration, as well as the state of knowledge regarding propagation, cultivation, and *in situ* care of wild individuals. Additionally, the IT evaluated the potential genetic consequences of manipulations of wild and reintroduced populations of not only the target taxa, but of related taxa and other significant (*e.g.*, rare, threatened, and endangered) taxa that might be affected by proposed stabilization actions.

9.1 Setting Stabilization Targets

It is difficult to determine if a given population structure and distribution will ultimately result in a stable population for a particular taxon. Equally problematic is determining the number and life stage or age class of individuals that need to be introduced or maintained within a population to ensure the long-term stability of a reintroduced population (see Chapter 5: Identification of Units for Stabilization of Plant and Snail Populations).

The Hawaii and Pacific Plants Recovery Coordinating Committee (HPPRCC) (1994) recommended stability goals as three populations of plants with a minimum of either 25 mature and reproducing individuals of long-lived perennials (>10 year life span), 50 mature and reproducing individuals of short-lived perennials (<10 year life span) or 100 mature and reproducing individuals of annual taxa per season (<1 year life span). In addition to numerical criteria, genetic storage must be in effect for the taxon and all major threats must be controlled. These recommendations are consistent with the guidelines of the Center for Plant Conservation (CPC) (Falk and Holsinger 1991). The HPPRCC believes that sustaining a population with this number of reproducing individuals over the short-term ensures that there will be an adequate reservoir of smaller or younger individuals that can develop into mature, reproducing plants with each subsequent generation to prevent extinction, even though it is not adequate long-term to achieve full recovery of the taxon. The number of individuals per population is meant to encompass the effective population size (N_e), which is the number of genetically distinct individuals in a population that are successfully producing viable offspring. The total population size (N) is the N_e plus the remaining individuals in the population. The bulk of research on N_e focuses on animal taxa, however, Mace and Lande (1991) found that for plants, the N_e is typically 20 to 50 percent of N.

The Implementation Team (IT) adopted the HPPRCC population targets as the base population targets for plant taxon stabilization. However, the IT recognized that some factors might modify the base population target upward for some taxa. The IT examined the factors that affect the target plant taxa and compiled a set of modified population targets for stabilization, based on these factors as described below and summarized in Table 9.1.

Factors affecting stabilization targets

The following factors can influence N_e, thereby requiring a larger number of individuals to reach an equivalent N_e to the original stabilization targets. The numbered sections below correspond with the factors for modifying the base population targets in Table 9.1.

1. Obligate outcrossing

The fertilization of a flower of a genetically distinct individual by the pollen of another genetically distinct individual is known as outcrossing. For taxa incapable of self-fertilization, outcrossing is obligatory. Once a population of an obligately outcrossing taxon becomes too small, or the distance between its individuals increases beyond the range of pollination mechanisms, the population's regeneration rate may decrease, leading to a decline in the number of individuals. Therefore, for taxa that are obligately outcrossing, the base population target

Table 9.1 Target Number of Mature, Reproducing Individuals per Plant Population to Ensure Stability

TAXON	LIFE FORM+	Base Population Target	Modified Population Target	FACTORS*
Alectryon macrococcus var. *macrococcus*	L	25	50	4, 5
Alsinidendron obovatum	S	50	100	7
Cenchrus agrimonioides var. *agrimonioides*	S	50	-	
Chamaesyce celastroides var. *kaenana*	L	25	-	
Chamaesyce herbstii	L	25	-	
Cyanea grimesiana subsp. *obatae*	S	50	100	7
Cyanea longiflora	S	50	75	7, 9
Cyanea superba subsp. *superba*	L	25	50	7
Cyrtandra dentata	S	50	-	
Delissea subcordata	S	50	100	7
Dubautia herbstobatae	S	50	-	
Flueggea neowawraea	L	25	50	2, 4, 5
Hedyotis degeneri var. *degeneri*	S	50	-	
Hedyotis parvula	S	50	-	
Hesperomannia arbuscula	L	25	75	6, 7, 9
Hibiscus brackenridgei subsp. *mokuleianus*	S	50	-	7, 8
Lipochaeta tenuifolia	S	50	50	3
Neraudia angulata	S	50	100	2, 7
Nototrichium humile	L	25	-	
Phyllostegia kaalaensis	S	50	50	3
Plantago princeps var. *princeps*	S	50	-	
Pritchardia kaalae	L	25	-	
Sanicula mariversa	S	50	100	4
Schiedea kaalae	S	50	-	
Schiedea nuttallii	S	50	-	
Tetramolopium filiforme	S	50	-	
Viola chamissoniana subsp. *chamissoniana*	S	50	-	

+LIFEFORMS: L = long-lived, S = short-lived

***FACTORS:**
1 obligate outcrossing
2 dioecy
3 vegetative reproduction
4 infrequent or inconsistent flowering
5 large percentage of non-flowering or non-fruiting plants
6 low seed set or poor seed viability
7 tendency for large declines or fluctuations in population size
8 persistence of the seed bank
9 taxon-specific considerations

should be doubled. None of the target taxa are known to be obligate outcrossers, although some may prove to be such through the study of their breeding systems.

2. Dioecy

Dioecy is the condition in which an individual plant produces only functionally staminate (male) or pistillate (female) flowers. Dioecious plants require the presence of both male and female individuals within pollination range that are flowering at the same time in order to effect fertilization and successful seed set. It is therefore much more difficult to ensure conditions for regeneration with dioecious taxa, especially when it may not be possible to determine the sex of a plant before it matures. For dioecious taxa the base population target should be doubled, so that the chances of having adequate numbers of both sexes established in a managed population are increased. The dioecious target taxa are *Flueggea neowawraea*, and *Neraudia angulata.*

3. Vegetative reproduction

Plants that reproduce vegetatively produce clones of themselves, so that an area that appears to be composed of unique individuals may actually be composed of many genetically identical individuals. These groups of individuals are often more genetically similar within populations and more distinct between populations than taxa that reproduce sexually. Although it may not be necessary to increase the target population goal of vegetatively reproducing taxa, some way to detect genetically distinct individuals must be developed so that population target goals account for unique individuals, rather than clones of one another. The target taxa that frequently reproduce vegetatively are *Lipochaeta tenuifolia* and *Phyllostegia kaalaensis*. With *P. kaalaensis*, vegetative reproduction may be the taxon's primary means of reproduction.

4. Infrequent or inconsistent flowering

Since flowering is a key component of reproduction, any inconsistency in flowering or reduction in the frequency of flowering reduces N_e and therefore reduces the likelihood of maintaining stability. For example, there are some cases where, although the great majority of individuals in a population flower, flowering occurs infrequently. The likelihood of environmental events reducing mass flowering and successful fruiting is much greater for plants that flower sporadically or infrequently than for plants that flower more regularly or frequently. In those taxa with known infrequent or inconsistent flowering, the population target is doubled. This factor is relevant to *Alectryon macrococcus* var. *macrococcus*, *Flueggea neowawraea*, and *Sanicula mariversa*.

5. Large percentage of non-flowering or fruiting plants

This problem is similar to the infrequent or inconsistent flowering factor described above, but concerns populations in which, even during peak flowering times, the majority of individuals do not flower, or are not able to produce fruit or seed. The N_e is much lower than the N in this case, and the population target is doubled. This problem with flowering or fruiting is observed in *Alectryon macrococcus* var. *macrococcus* and *Flueggea neowawraea*. With *A. macrococcus* var. *macrococcus*, certain plants have not been observed to flower in recent years. Of those that do flower, some are not observed to set fruit. With regards to *F. neowawraea*, many individuals are not known to flower.

6. Low seed set or poor seed viability

Low seed set or poor seed viability, whether due to seed predation, disease, pollination failure, or other factors, can potentially lead to decreases in reproductive potential. For taxa with low seed set or poor viability, the target population goal is doubled. Low seed set is observed in certain colonies of *Hesperomannia arbuscula*, where the mature flower heads contain many empty, abortive seeds.

7. Tendency for large declines or fluctuations in population size

Large declines in population size, even if balanced by large increases at other times, reduce the stability of the population through a reduction in N_e. Any negative events during a major low point in a population fluctuation could extirpate the population. For taxa prone to large declines or fluctuations in population sizes, the population target is doubled. These taxa are *Alsinidendron obovatum*, *Cyanea grimesiana* subsp. *obatae*, *C. longiflora*, *C. superba* subsp. *superba*, *Delissea subcordata*, *Hesperomannia arbuscula*, *Hibiscus brackenridgei* subsp. *mokuleianus*, and *Neraudia angulata*.

8. Persistence of the seed bank

This factor does not warrant increasing the population target, but suggests that surveys of historical occurrences should be conducted to check for regeneration from the seed bank, even years after the last observation of mature individuals at the site. A persistent seed bank in a population of short-lived individuals could buffer fluctuations in population size. *Hibiscus brackenridgei* subsp. *mokuleianus* is the only target taxon known to have seed banks remaining viable for a number of years. Therefore, even though the tendency for large declines or fluctuations in population size would suggest increasing the population target for *H. brackenridgei* subsp. *mokuleianus*, the presence of a persisent seed bank balances the need for a larger population size to achieve the same $N_{e.}$ For most of the other target taxa, the persistence of seed banks remains to be studied.

9. Taxon-specific considerations

The population target for *Cyanea longiflora* remains unchanged since the declines in its populations are largely attributable to controllable threats, even though the tendency for large declines or fluctuations in population size would suggest increasing the population target.

The population target for *Hesperomannia arbuscula* is increased more than for the other target taxa because of the precipitous declines of its populations and its extremely low seed set.

9.2 The Credit System for Plants

Origin of the credit system

In the 1999 Biological Opinion for Routine Military Training at Makua Military Reservation (BO), the U.S. Fish and Wildlife Service (USFWS) determined that in order to avoid jeopardizing federally listed plant taxa, the U.S. Army (Army) must ensure that each endangered plant taxon occurring in the Makua action area (AA) remain above, or attain, three populations of an appropriate size for the taxon to be considered stable. According to the recommendations of the Hawaii and Pacific Plants Recovery Coordinating Committee (HPPRCC), a short-lived perennial may be considered stable if it has at least three populations of over 50 reproducing plants each. Similarly, a long-lived perennial may be considered stable if it has at least three populations of 25 individuals each. Of the 41 federally listed plants currently in the AA, 13 taxa already exceed the numerical criteria for stability and have less than 50% of their individuals within the AA, and therefore do not require management actions above and beyond those proposed in the project description in the Biological Assessment (U.S. Army 1998b).

However, 27 plant taxa currently have less than the required number of populations and/or individuals required to qualify as stable, or have greater than 50% of their individuals within the AA. These taxa are referred to as target taxa. For these taxa, the Army must conduct additional management so that each target taxon will attain three population units (PUs) having at least the target numbers of reproducing individuals to qualify for stability, two of which must be outside the higher fire risk area. For these taxa, the HPPRCC recommendations for population size were modified according to circumstances specific to each taxon. The revised target population sizes for stability are outlined in Table 9.1. In addition to achieving the numeric criteria, threats for each of the three PUs must be controlled and the taxon must be fully represented in an *ex situ* collection.

> ***In order for the Army to meet the criteria of stability, it must ensure that at least three PUs of each target taxon reach and maintain stable numbers of reproducing individuals as defined in Table 9.1. The Army must also ensure that the threats at each of these PUs are controlled and that the taxon is fully represented in an*** **ex situ** ***collection.***

Use of the credit system

To assist the Army in calculating the amount of effort needed to achieve three stable populations, a numerical score reflecting the likelihood of reaching stability was assigned to each combination of management action and fire risk area (Table 9.2). The three types of management actions are: 1) management of a PU which has numbers of reproducing individuals at or above the target size for stability, 2) management of a PU currently below the target size for stability, and 3) reintroduction. Similarly, lands to be managed are divided into three categories of fire risk due to military training: 1) the no fire risk area, which is outside of the AA, 2) the lower fire risk area inside of the AA, and 3) the higher fire risk area inside the AA (Map 9.1). It is very important to note that although many areas may be prone to fire, only the risk of fire resulting from military training contributes to the credit designation.

Table 9.2. Summary of the Credit System. Credit values are assigned by area (based upon fire risk due to military training) and by the type of management action (relating to the likelihood of reaching target size for stability).

Management Action	Credit
No fire risk (high credit) area: Outside the AA	
Management of a population at or above target size for stability	1.000
Management of a population below target size for stability	0.500
Reintroduction	0.333
Lower fire risk (medium credit) area: In the AA	
Management of a population at or above target size for stability	0.750
Management of a population below target size for stability	0.375
Reintroduction	0.250
Higher fire risk (low credit) area: In the AA	
Management of a stable population	0.500
Management of a population not considered stable	0.250
Reintroduction	0.167

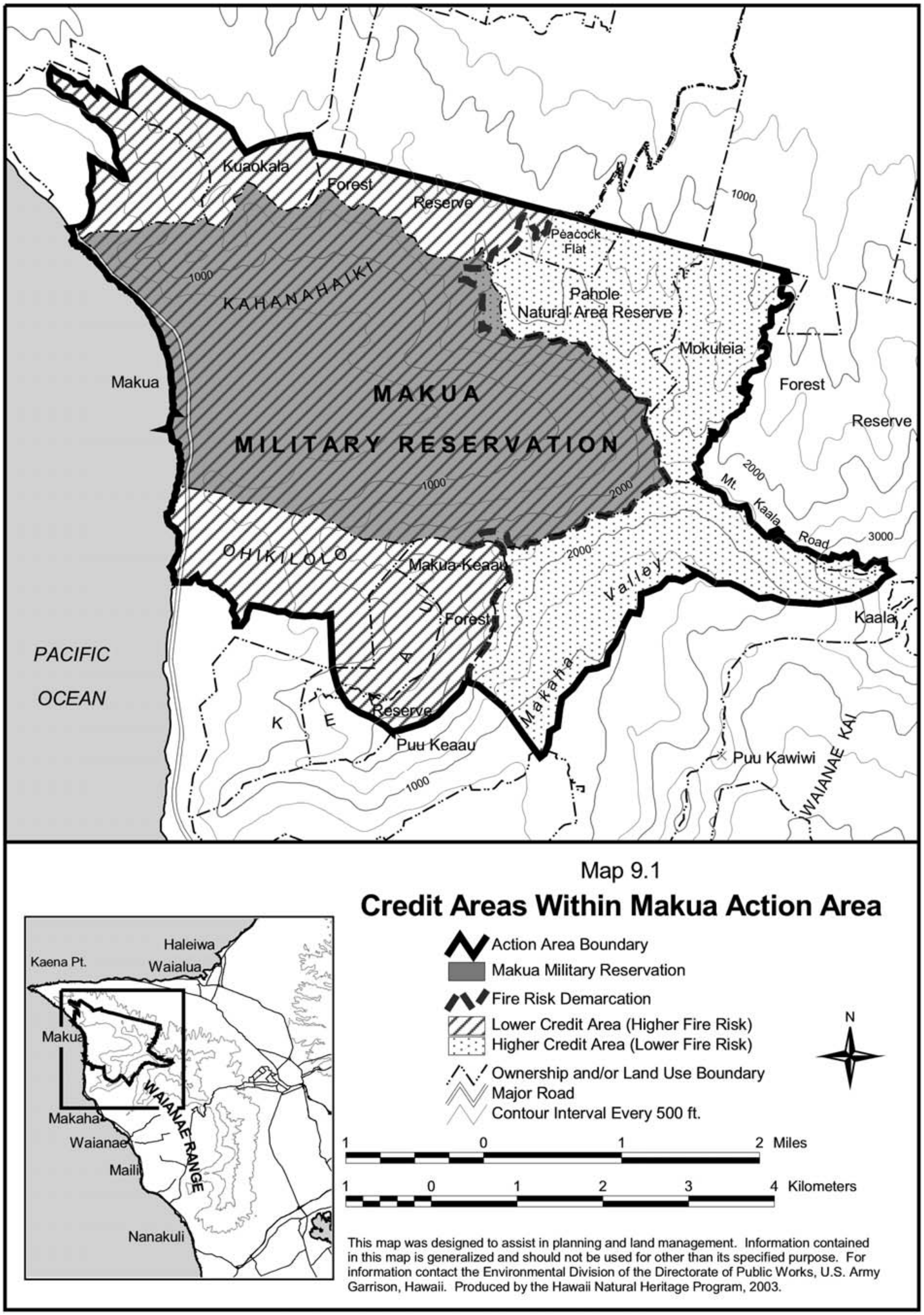
The result is a credit value for each management type in each area of fire risk that represents the combined probability of achieving stable PU numbers. The Army has the best chance of successfully stabilizing three populations by committing to three credits worth of management.

Management of an extant PU that already has the target number of individuals receives one full credit (1.000) because its size is already sufficient for stability. Managing an extant PU that has less than the number of target individuals has a slightly lower probability of success because it will be more difficult to attain the target number of individuals. To reflect this lower chance of success, only half a credit (0.500) is granted. The Makua Endangered Species Stabilization Plan (U.S. Army 1999) suggests that a reintroduced population has an even lower chance of surviving to stability, approximately one in three. The assigned population credit of 0.333 reflects these odds.

The credit for each management action changes based on the risk of fire in the area in which management occurs. It is very important to note that although many areas may be prone to fire, only the risk of fire resulting from military training contributes to the credit designation. A PU located within the no fire risk zone outside of the AA has the highest probability of becoming stable with management because it is most safe from military caused fire. Thus, the credit received for management in such areas is the same as is described in the preceding paragraph.

A PU located within the lower fire risk area within the AA has a slightly lower probability of becoming stable with management because the risk of the PU burning is greater. To reflect this lower chance of success, all management credits are reduced by 25 percent. Therefore, management of a population at or above target size for stability is worth 0.750 credits, management of a population below target size for stability is worth 0.375 credits, and reintroductions are worth 0.250 credits.

Finally, a PU located within the higher fire risk area inside the AA has the lowest probability of becoming stable with management because the risk of burning is greatest. The credit received



Map 9.1
Credit Areas Within Makua Action Area

for management actions in these areas is reduced by 50%. Thus, management of a population at or above target size for stability is worth 0.500 credits, management of a population below target size for stability is worth 0.250 credits, and reintroductions are worth 0.167 credits.

Each stable PU is assigned one credit. ***The final goal of the Army is to achieve at least three stable PUs for each target taxon, thus yielding three credits per taxon.***

Modifications to the credit system

In the BO, a lower-risk fire area was not designated within the AA, and thus, partial credit was not given to such an area. Incorporation of a lower fire risk area was proposed by the Army in consultation with the Implementation Team (IT), Integrated Training Area Management fire experts and other fire experts, and agreed to by the USFWS in the supplemental BO (USFWS 2001). This area was developed in response to measures taken by the Army to further reduce fire risk by eliminating the use of tracer rounds and TOW missiles, as well in response to new information about habitat type and terrain. These additional measures were incorporated into the project design after publication of the original BO in 1999 and were thus not previously considered by the USFWS.

As originally stated in the Makua Endangered Species Stabilization Plan (U.S. Army 1999), no more than one credit per taxon could be received within the AA due to the risks posed by fire from military training. With the separation of the AA into a higher and lower fire risk area, the IT determined that a maximum of 1.50 total credits per taxon are allowed in the AA. However, only 1.00 of the 1.50 credits is allowed within the higher fire risk area within the AA. This requirement concentrates at least half of the Army's efforts in areas outside of the AA, and two-thirds of the effort outside of the highest fire risk area, in order to reduce the possibility of military–caused fire impacting the target taxa.

Despite the risk of military-caused fire within the AA, it is important to manage *in situ* PUs in this area, not only for biological reasons, but because the Army has a responsibility to conserve federally listed taxa occurring on its land under section 7(a)(1) of the Endangered Species Act. In order to underscore the importance of *in situ* management, credits for any individual taxon within the AA cannot equal zero, meaning that some management must occur within the AA. However, the Army is not responsible for stabilizing all target taxa PUs within the AA.

Anticipation of future AA designations

Because credit assessments include PUs of target taxa in the Schofield Barracks Military Reservation (SBMR), the IT anticipated the USFWS consultation with the Army for SBMR and the resultant designation of an SBMR AA. The IT assigned reduced credits to both *in situ* management and reintroductions proposed for SBMR sites accordingly. Because the IT cannot predict the final boundaries of the SBMR AA and any lower fire risk region, actions proposed within SBMR and some adjacent areas were conservatively assigned only half credit (equivalent to that of the higher fire risk region of the Makua AA). The credits for PUs within SBMR AA will need to be reevaluated once the exact boundaries of the AA have been finalized during the SBMR consultation process.

Guidelines for re-evaluating the credit system

The credit system should be strictly adhered to during the initial years of the IP. These guidelines may be modified according to review and discussions between the Army, the IT, and the USFWS. However, as management increases and PUs respond toward stability, there are a number of possible scenarios that may require re-evaluation of the credit system. Some of the anticipated situations are described below.

Stability is achieved by more than one PU within the AA

The IT determined that each target taxon must have PUs of more than 0.00 credits within the AA. Due to the separation of the AA into a higher and lower fire risk area, the IT determined that a maximum of 1.50 total credits per taxon are allowed within the AA, until PUs become stable. Only 1.00 of the 1.50 credits is allowed within the high fire risk area within the AA.

It is possible that stabilization efforts will result in more than one stable PU per taxon within the AA. If a stable PU is within the lower fire risk area, it will be counted toward the goal of taxon stability even if it is the second PU for that taxon within the AA. Thus, for such cases, the original 1.50 credit limit for the total AA may be exceeded. Similarly, if improved fire management leads to a reduced risk to areas within the higher fire threat region of the AA, the IT may consider allowing more than one stable PU to be counted even within this area. This may be particularly pertinent to those taxa with a historical center of distribution in the AA. In such cases it may make biological sense to maintain more than one stable PU of those taxa even in the highest risk portion of the AA. Decisions for these exceptions will be made by the IT during the annual review process and are subject to final approval by the USFWS.

Achievement of stability for PUs within the AA

The IT decided on the following criteria to guide credit changes for PUs within the AA. The IT will make the following changes following approval of the IP.

After IP approval:

1. A PU within the AA's lowest fire risk zone will be assigned one full credit once it meets the criteria for stabilization, rather than the partial credit it received upon initial assessment.
2. A PU within the AA's moderate fire risk zone will be assigned one full credit once it and one other managed PU anywhere meets the criteria for stabilization, rather than the partial credit it received upon initial assessment.
3. A PU within the AA's highest fire risk zone will be assigned one full credit once it and two other managed PUs anywhere meet the criteria for stability, rather than the partial credit it received upon initial assessment.

The option to maintain >3 stable PUs to ensure long-term success

In certain situations, it may be better for the Army to manage more than three stable PUs, although only three are required for legal compliance with the Endangered Species Act. For example, if three stable PUs are established, but one or more of those stable PUs seem marginally secure (*e.g.*, could be quickly destroyed by fire or other chronic threat), the recommended course would be for the Army to invest in management for stability at additional sites. In this manner, the Army can better ensure that it remains in compliance with the requirements of the BO should a PU become unstable.

Achievement of stability and curtailment of mandated management

In a scenario in which PUs are managed successfully, so that more than three PUs achieve stability, the Army would only be required to continue to manage three PUs. The IT, USFWS, and the Army, based upon the results of monitoring, will address the issue of reducing management at required sites. At sites in excess of the required three, it is likely that the IT will recommend stepping down the amount of management effort at those sites, rather than abruptly curtailing management.

Credit differences between wild and reintroduced PUs

Once a PU achieves stability (*i.e.* sufficient numbers of reproducing individuals and strong evidence of recruitment, threats controlled, and representative genetic material in storage), its origin as a preexisting *in situ* PU versus a PU that began as a reintroduction is not critically important. Any PU that achieves stability will be assigned a full credit, regardless of its origins.

Assessment of separate credits following merging of adjacent PUs

For taxa that have the potential to occupy a broad continuous geographic range, the initial designation of separate, adjacent PUs may result, over time, in the merging of the separate PUs into a single, larger PU. In such cases, the IT suggests that credits for the larger PU be counted as if the original PUs were still recognized as discrete units.

9.3 Management Designation

With situations ranging from arguably stable population units (PUs) containing hundreds of vigorous individuals to severely reduced PUs with one or a few individuals at risk of imminent extirpation, the range of possible *in situ* management can vary from maintenance of current conditions and encouragement of natural regeneration on one end to salvage of genetic material from the last declining individual on the other.

In general, where sufficient numbers of individuals exist in a habitat either sufficiently intact or restorable, with a population structure that suggests that natural regeneration might occur with some threat abatement, the PU is designated as management for stability. If there are few individuals and conditions for regeneration or habitat rehabilitation are low, the PU might be slated for genetic storage collection or for management as a propagule source for reintroduction attempts. Because PU numbers are low overall for many of the target taxa, habitat quality, geographic distribution, and conservation of distinctive morphologic/ecotypic variation, rather than mere numbers of individuals, played an important role in designating management of PUs. The three main options for management are described more fully below.

Manage for stability

Management of a PU for stability means achieving the target number of reproducing individuals for the PU, controlling threats to the PU, and ensuring that genetic material of individuals in the PU are adequately represented *ex situ*. Credits are only given for those PUs designated as manage for stability, and full credit is assigned to any PU, whether *in situ* or reintroduced, once stability is achieved through the control of threats to the target levels defined for both PU and management unit (MU) levels (see Table 10.1). Monitoring to gauge the response of target taxa to the management efforts is critical to successfully achieving stability. If the number of individuals in a PU falls, monitoring allows the Implementation Team (IT) to adapt management actions to deal with the likely causes of the decline. This may occur either through additional threat management actions or augmentation to the existing PU (see Chapter 9.6: Reintroduction and Augmentation). The management designation set forth in this Implementation Plan (IP) for each PU will be retained even if the number of individuals falls to zero, pending review by the IT. This counteracts a trend of decline for most of the endangered target taxa. In order to achieve the stability goals, threats must be managed to an existing or reintroduced PU over the long-term at a broader habitat level, typically within a fenced MU. The intent of management is to remove or reduce limiting factors to individuals in the PU so that their numbers remain at, or increase to, stable levels as defined in the IP (see Chapter 9.1: Setting Stabilization Targets). Inherent in management for stability is a program of monitoring to gauge the response of target taxa to management efforts. If the number of individuals in a PU falls, management should adapt to deal with the likely causes of decline through additional threat management and/or augmentation of the existing PU. Augmentation represents a special action to bolster population levels in a declining PU, but must be dealt with carefully (see Chapter 9.6: Reintroduction and Augmentation).

Because management for stability involves a large set of coordinated tasks and subtasks, the IT compiled the major management actions, and the subtasks that they trigger, for application to each PU slated for such management.

Manage for stability subtasks for plants are as follows:

1. Collect propagules for genetic storage
2. Assess threat management needs
3. Manage threats as needed:
    a) Ungulate control (possible short-term, small-scale fence)
    b) Weed control (control aggressive understory weeds within 2 m radius)
    c) Small mammal control
    d) Slug control
    e) Chinese rose beetle control
    f) Black twig borer control
    g) Two-spotted leafhopper control
    h) Other threats as assessed
4. Monitor response to management actions (see Section 2, Chapter 4: Monitoring)
5. Manage data
6. If augmentation is indicated:
    a) Collect propagules (seeds or cuttings) for augmentation from designated source populations (see taxon stabilization plan for details)
    b) Propagate for augmentation
    c) Prepare plants for outplanting following phytosanitation protocols (see Section 3, Appendix 2.2: Phytosanitation Standards and Guidelines)
    d) Survey for appropriate outplanting sites
    e) Prepare site for outplanting (*e.g.*, weed control, hole preparation)
    f) Conduct augmentation
    g) Continue threat management
    h) Monitor augmentation (see Section 2, Chapter 4: Monitoring)
    i) Data management

Manage as a propagule source

Management of a PU as a propagule source means that active management is applied for the persistence of individuals at a site for some length of time, but not necessarily toward stabilization of the PU. In other words, it is not a requirement of the IP that the U.S. Army is responsible for long term stabilization of PUs that are designated to be managed as a propagule source. The intent of this management is to allow persistence of individuals at the site until maturation and the production of sufficient propagules occurs. No credit is assigned for management of these PUs.

Management of a site would be required only until sufficient numbers have been met to satisfy collection and propagation goals as identified in the stabilization plans for each target taxon. Typically, the time frame for management would run between one to five years, but should be extended if propagule collection needs are not yet met. Management strategies will range from managing only currently mature individuals to managing all individuals (including seedlings and juveniles) until they reach maturity and produce propagules. In addition to assessing threat abatement needs, periodic field checks for propagule availability and guidelines for biologically sensitive propagule collection are involved (see Section 3, Appendix 2.1: Plant Propagule Collection Protocols).

Manage as a propagule source subtasks are as follows:

1. Collect propagules for genetic storage and outplanting needs
2. Assess threat management needs
3. Manage threats as needed:
   a) Ungulate control (possible small-scale fence)
   b) Weed control (reduce competition and fire risk)
   c) Small mammal control
   d) Slug control
   e) Chinese rose beetle control
   f) Black twig borer control
   g) Two-spotted leafhopper control
   h) Other threats as assessed
4. Monitor response to management actions
5. Manage data

Manage for genetic storage collection

The intent of genetic storage is to achieve adequate and appropriate *ex situ* storage of a target taxon's genetic material as insurance against loss of a PU or important wild individuals. The main goal of genetic storage is to function as a backup in case all *in situ* and reintroduced individuals are lost. Management of the PU and collection and storage of propagule material should continue until sufficient numbers have been met to satisfy collection goals as identified in the stabilization plans for each target taxon. Collections to refresh storage material will be undertaken at appropriate intervals to maintain a viable bank for implementation actions and for contingencies. However, management of the PU need not continue once initial collection goals are met. Options include seed storage (preferred for taxa whose seeds are not recalcitrant), *in vitro* tissue storage, and living collections (cultivated plants). Periodic germination tests of samples in seed storage will be conducted to ensure viability of stock. If the germination rate drops by 15% from the initial rate, this will trigger a recollection effort and/or growing of the collected seed for outplanting or *inter situ* management. Guidelines on the minimum number of collections among populations and individuals to ensure good genetic representation and variability have been reviewed and summarized by the IT in Section 3, Appendix 2.1: Plant Propagule Collection Protocols. Subtasks related to management of genetic storage collection PUs for plants are as follows:

1. Collect propagules for genetic storage
2. Assess threat management needs
3. Manage threats (as needed):
   a) Ungulate control (possible small-scale fence)
   b) Weed control (reduce competition and fire risk)
   c) Small mammal control
   d) Slug control
   e) Chinese rose beetle control
   f) Black twig borer control
   g) Two-spotted leafhopper control
   h) Other threats as assessed
4. Monitor response to management actions
5. Manage data

9.4 Sequencing of Actions

The need for sequencing of actions

Thousands of actions applied over a set of managed areas are needed to ultimately achieve stabilization of the target plant taxa addressed in the Makua Implementation Plan. Recognizing that development of the full set of management actions across the proposed population units (PUs) and management units (MUs) will require years of work, the Implementation Team (IT) developed a sequenced approach that details particular sets of actions to be implemented over a 33-year period. The sequencing is based primarily on biological need, but organizes the timing of events to reflect logistical considerations stemming from the large spatial and temporal scale of the project. The sequencing of management actions will benefit those taxa and actions that require full attention in the early phases that otherwise would not receive the attention necessary.

The IT defined three time phases that span a period of 33 years, in which sequenced actions will take place:

Phase A: years 1 – 13
Phase B: years 14 – 23
Phase C: years 24 – 33

The phases are each a decade long, with the exception of Phase A which has three additional years, reflecting the need for major preparatory actions including landowner negotiations, environmental compliance actions and the building of infrastructure and staffing.

Risk of sequencing

There is a concern that delay of certain actions will adversely affect some PUs and perhaps significantly reduce the likelihood of successful stabilization. This risk is minimized so that those target taxa at greatest risk from military training activities receive all needed PU and MU level management actions during Phase A and those target taxa at extremely low numbers receive full management at the PU level during Phase A. In addition, all other target taxa receive some level of management and monitoring to deal with immediate threats, and to identify situations that may require more immediate management than initially planned.

Actions that are required to guide future management or actions for which risks could not be minimized were not sequenced over time but would be fully implemented in the early portion of Phase A. These actions include surveys, initiation of recommended research, propagation testing, and genetic storage testing and collection, and are summarized in Table 9.3.

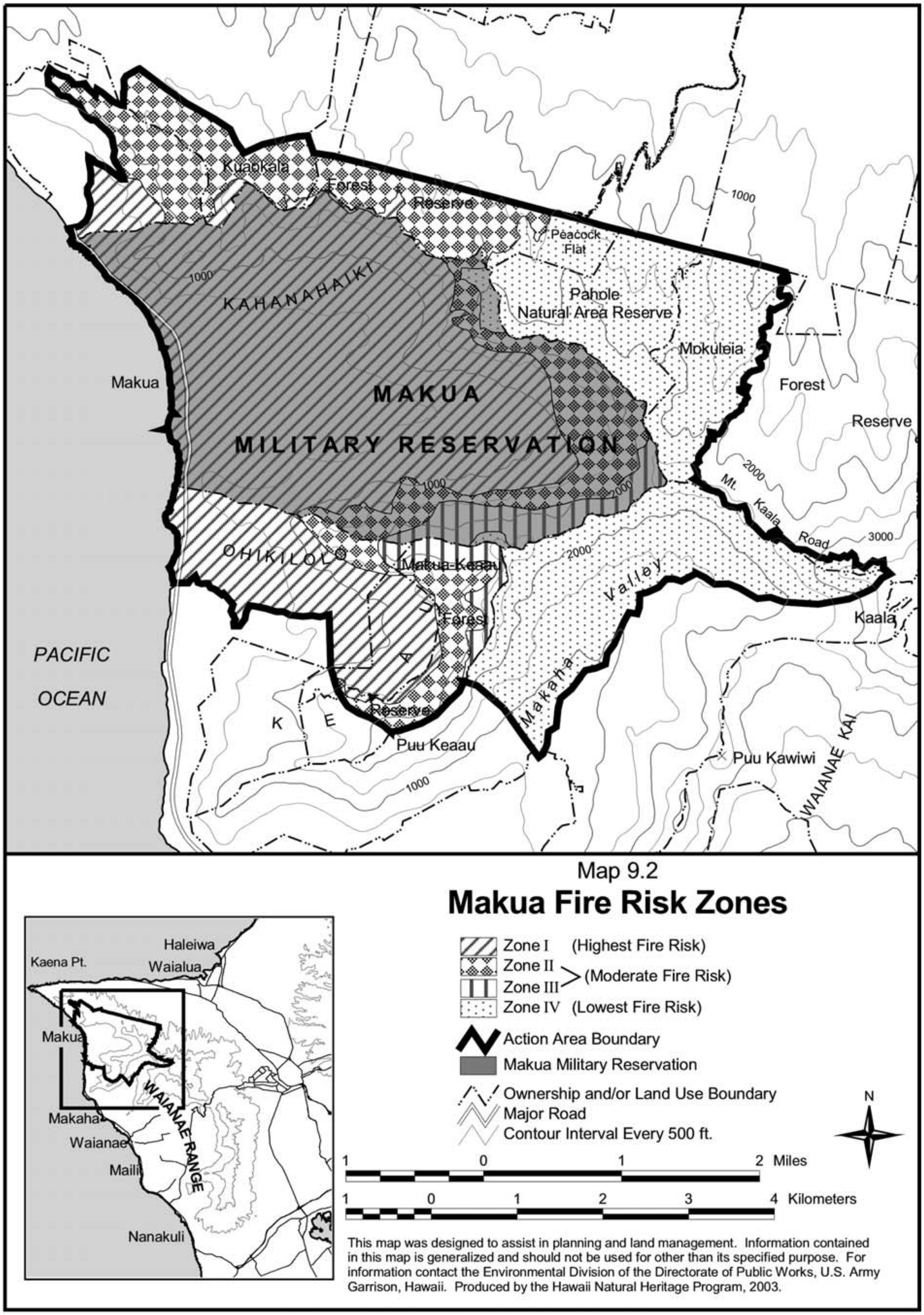
Table 9.3: Non-sequenced Actions (Implemented in Phase A)

Action	Assumption / Justification	Timeline
Research, Surveys	Surveys and research will be initiated in Phase A and need not await NEPA approval. Surveys and research are factors that effect future actions and therefore were not sequenced over time.	Year 1-undefined end date
Propagation Testing	For Full Stabilization taxa lacking propagation technique information	Years 1-2
Propagation Testing	For Partial Stabilization taxa lacking propagation technique information	Years 2-4
Genetic storage-related actions	Collection for genetic storage will be initiated in Phase A and need not await NEPA approval. Collections for genetic storage for plants and captive propagation for snails are important to complete the goal of securing genetic representation of the target taxa and will take place in Phase A.	See below
Genetic Storage Testing	It is of the utmost importance to know the storage potential of all target taxa regardless of their rarity	Years 1-2
Implement Genetic Storage	Collect from all manage for stability, collect for genetic storage, and manage as a propagule source PUs. Start with PUs with fewer numbers of individuals.	Years 1-3
Refresh Genetic Storage	First three years of Phases B and C	Years 14-16 Years 24-26
Manage as a Propagule Source	For any population where threats are not already controlled, manage until propagule goals for reintroduction are achieved.	Year 1-until propagule goals for reintroduction are achieved

Sequencing of taxon- and PU-level actions

The IT used degree of rarity and occurrence in fire risk zones as the primary factors for determining sequencing of actions among taxa and PUs. Fire risk zones were established with guidance from U.S. Army fire experts, yielding four zones within the Makua action area (Map 9.2: Makua Fire Risk Zones).

The target taxa were further categorized according to their rarity (both in terms of total numbers of individuals and number of PUs), and a combination of fire risk and rarity factors yielded a matrix used to determine **at the taxon level** whether efforts would be initiated for full taxon stabilization or partial taxon stabilization during a specific time phase (see Table 9.4). **These**


Kuaokala
Forest
Reserve
Peacock Flat
Pahole Natural Area Reserve
Mokuleia
Forest
Reserve
KAHANAHAIKI
MAKUA MILITARY RESERVATION
Makua
OHIKILOLO
Makua-Keaau
Forest
Reserve
Makaha Valley
Mt. Kaala Road
Kaala
PACIFIC OCEAN
Puu Keaau
Puu Kawiwi
WAIANAE KAI
Haleiwa
Kaena Pt.
Waialua
Makua
Makaha
Waianae
Maili
Nanakuli
WAIANAE RANGE
Map 9.2
Makua Fire Risk Zones
Zone I (Highest Fire Risk)
Zone II
Zone III
(Moderate Fire Risk)
Zone IV (Lowest Fire Risk)
Action Area Boundary
Makua Military Reservation
Ownership and/or Land Use Boundary
Major Road
Contour Interval Every 500 ft.
N
1 0 1 2 Miles
1 0 1 2 3 4 Kilometers
This map was designed to assist in planning and land management. Information contained in this map is generalized and should not be used for other than its specified purpose. For information contact the Environmental Division of the Directorate of Public Works, U.S. Army Garrison, Hawaii. Produced by the Hawaii Natural Heritage Program, 2003.

taxon-level management categories apply only to PUs designated for management and are described as follows:

- **Full taxon stabilization** means that, in a particular phase, all PUs of the taxa that are designated as manage for stability receive the full set of actions required to increase PU levels to achieve stabilization criteria, as defined in the taxon stabilization plans *i.e*., all PUs receive full PU management and all MUs or MU subunits (See Chapter 6: Management Units) containing those taxa receive fences, ungulate removal, and weed control over a portion of their acreage:

  Full PU management: All actions needed to increase population levels to achieve stabilization criteria (see definitions below).

  Associated MU-level management: (see definitions below).

  Reintroductions for a taxon will be initiated in the latter part of the phase in which full taxon stabilization occurs. Reintroductions will receive full PU management and associated MU level management as indicated above.

  In Phase A, only taxa in the highest fire risk zone (zone I) receive full taxon stabilization. However, over the course of the three phases, all target taxa will progress toward full taxon stabilization in Phase C (see Table 9.4).

- **Partial taxon stabilization** means that, in a particular phase, PUs designated as manage for stability receive PU-level management at one of three levels (see definitions below):
  - Full PU management,
  - Partial PU management, or
  - Baseline PU management

  according to PU-level rarity criteria (see Table 9.5). These three levels of PU management are defined below. Fencing and ungulate removal will be completed only for those MUs or MU subunits containing full or partial PU management PUs but no additional MU level threat management is initiated.

  Generally, reintroductions occur when a taxon is at full taxon stabilization. However, if triggered by population declines, augmentations or reintroductions may be undertaken for PUs of taxa with partial taxon stabilization designation. Additionally, for *Cyanea superba* subsp. *superba* which is an extremely rare taxon with partial taxon stabilization designation, and for *Hedyotis parvula*, for which reintroduction techniques are not yet known, reintroductions are proposed in Phase A. These reintroductions receive full reintroduction management, and are indicated in the MU summary tables.

  In Phase A, all taxa occurring in fire risk zones II, III and IV receive partial taxon stabilization but will progress toward full taxon stabilization in Phase C.

Table 9.4: Sequencing of Taxon Stabilization Actions

Fire Risk Zone	Taxa	No.<50 ind.	No.<5 PUs	Phase A	Phase B	Phase C
I	*Hibiscus brackenridgei* ssp. *mokuleianus*	Y	Y	Full	Full	Full
I	*Chamaesyce celastroides* var. *kaenana*	N	N	Full	Full	Full
I	*Lipochaeta tenuifolia*	N	N	Full	Full	Full
I	*Nototrichium humile*	N	N	Full	Full	Full
I	*Tetramolopium filiforme*	N	N	Full	Full	Full
II	*Cyanea superba* ssp. *superba*	Y	Y	Partial	Full	Full
II	*Neraudia angulata*	Y	Y	Partial	Full	Full
II	*Dubautia herbstobatae*	N	Y	Partial	Partial	Full
II	*Pritchardia kaalae*	N	Y	Partial	Partial	Full
II	*Alectryon macrococcus* var. *macrococcus*	N	N	Partial	Partial	Full
II	*Cenchrus agrimonioides* var. *agrimonioides*	N	N	Partial	Partial	Full
II	*Flueggea neowawraea*	N	N	Partial	Partial	Full
II	*Hedyotis degeneri* var. *degeneri*	N	N	Partial	Partial	Full
III	*Hedyotis parvula*	N	Y	Partial	Partial	Full
III	*Sanicula mariversa*	N	Y	Partial	Partial	Full
III	*Plantago princeps* var. *princeps*	N	N	Partial	Partial	Full
III	*Viola chamissoniana* ssp. *chamissoniana*	N	N	Partial	Partial	Full
IV	*Alsinidendron obovatum*	Y	Y	Partial	Full	Full
IV	*Schiedea nuttallii*	Y	Y	Partial	Full	Full
IV	*Cyanea grimesiana* ssp. *obatae*	Y	N	Partial	Full	Full
IV	*Delissea subcordata*	Y	N	Partial	Full	Full
IV	*Hesperomannia arbuscula*	Y	N	Partial	Full	Full
IV	*Phyllostegia kaalaensis*	Y	N	Partial	Full	Full
IV	*Schiedea kaalae*	Y	N	Partial	Full	Full
IV	*Chamaesyce herbstii*	N	Y	Partial	Partial	Full
IV	*Cyanea longiflora*	N	Y	Partial	Partial	Full
IV	*Cyrtandra dentata*	N	N	Partial	Partial	Full

Legend: Full = Full taxon stabilization
Partial = Partial taxon stabilization
(see Table 9.5 for additional information on criteria)
No. <50 ind. = Numbering less than 50 individuals per PU: Y = <50, N = >50
No. <5 PUs = Numbering less than 5 PUs: Y = <5, N = >5

Table 9.5: PU Management Designations for Partial Taxon Stabilization

The shaded portion of this table indicates full taxon-level stabilization.

Taxon-Level Criteria		Population Unit Criteria	Prescribed Action		
<50 ind.	<5 PUs		Phase A year 1 - 13	Phase B year 14 - 23	Phase C year 24 - 33
Y	Y	PU w/ <25 individuals	Full PU management. Minimum of 3 efforts for taxa in this category (with an emphasis on *in situ* populations, then reintroduction)		
Y	N	PU w/ ≤5 individuals	Full PU management		
		PU >5 but ≤25 individuals	Partial PU management		
N	Y	PU w/ ≤5 individuals and a large robust, genetically, diverse population does **not exist** for this taxon	Full PU management	Full PU management	
		PU w/ ≤5 individuals and a large robust, genetically, diverse population **exists** for this taxon	Partial PU management	Full PU management	
		PU w/ >5 but ≤25 individuals	Partial PU management	Full PU management	
		PU w/ >25 individuals to ≤long-term stability goal	Baseline PU management	Partial PU management	
		PU >long term stability goals	Baseline PU management	Baseline PU management	
N	N	PU w/ ≤5 individuals and a large robust, genetically, diverse population does **not exist** for this taxon	Full PU management	Full PU management	
		PU w/ ≤5 individuals and a large robust, genetically, diverse population **exists** for this taxon	Partial PU management	Partial PU management	
		PU w/ >5 but ≤25 individuals	Partial PU management	Partial PU management	
		PU w/ >25 individuals to ≤long-term stability goal	Baseline PU management	Partial PU management	
		PU >long term stability goals	Baseline PU management	Baseline PU management	

Legend: No. <50 ind. = Numbering less than 50 individuals per PU: Y = <50, N = >50
No. <5 PUs = Numbering less than 5 PUs: Y = <5, N = >5

Definitions of PU management levels

Sequencing of actions results in three levels of PU management: full PU management, partial PU management, and baseline PU management. The definitions of these three management levels and their associated MU-level management actions are provided below, and are summarized in Table 9.6.

Full PU management:

All actions needed to increase PU levels to achieve stabilization criteria.

- monitoring of PUs
- control of ungulates over the area needed to stabilize the PU
- management of aggressive weeds to <25% cover throughout PU and to 50-m beyond PU perimeter
- control of other threats (rodents, slugs, human, *etc*.) within the PU as needed for PU stability
- collection of material for genetic storage and propagation
- PU augmentation as needed, based on monitoring results

Associated MU-level management:

- control of ungulates (including fencing) over the entire MU or MU subunit
- control of weeds over a portion of MU or MU subunit

Partial PU management:

Actions needed to increase population levels toward stabilization criteria (varies by taxon, typically toward >25 individuals in PU).

- monitoring of PUs
- control of ungulates over the area needed to stabilize the PU
- management of aggressive weeds to <25% cover throughout PU and to 10-m beyond PU perimeter
- control of other threats (rodents, slugs, human, *etc*.) within the PU as needed to encourage recruitment
- collection of material for genetic storage and propagation
- population augmentation as needed, based on monitoring results

Associated MU-level management:

- control of ungulates (including fencing) over the entire MU or MU subunit

Baseline PU management:

Actions needed to maintain baseline population levels which will result in no net loss of individuals. Baseline actions will be conducted for all PUs designated as manage for genetic storage collection until collection goals are met. Baseline actions will be conducted for all PUs designated as manage as a propagule source until propagule goals for outplanting are met. Baseline actions will be conducted for all PUs designated as manage for stability until superceded by a more intensive management designation (such as partial or full PU management). See Chapter 9.3: Management Designations for a discussion of PU management designations.

- monitoring of PUs
- management of ungulates at small scale around individuals (as needed)
- management of aggressive weeds (as needed)
- control of other immediate threats (rodents, slugs, human, *etc*., as needed)
- collection of material for genetic storage and propagation

Associated MU-level management:
None

Triggers for increasing from baseline to partial PU management
The schedule of assigned PU management in each phase is outlined in Table 9.7. This schedule is subject to monitoring feedback whereby increased management may be triggered at any time if PU trends, as outlined below, are detected. Such decisions to increase management are based on decreases in mature individuals in PUs designated for management. Once a PU has moved up in management status (*e.g.*, from baseline to partial), it will remain at that higher level of management.

Management is triggered to a higher level if any of the following changes are detected:

- If the number of mature individuals falls below 25
- If the numbers of mature individuals show declines of 10% or more (5% for long-lived taxa) between successive years for two subsequent years
- If the numbers of mature individuals decrease by >20% in a single year

A trigger was not developed to increase from partial to full PU management because the main difference between partial and full management is the extent of weed management around PUs. This added buffer is meant to prepare the larger area necessary for increases in PU size toward stability, so there are no recommendations for graduating from partial to full PU management based on declines, only based on the sequencing of phases.

Triggers for augmentation of PUs under partial or full PU management
Augmentation of plant PUs may be initiated if any of the following changes are detected at a PU despite active threat management for at least one year:

- If the number of mature individuals is five or less
- If no evidence of regeneration is detected over two subsequent years in which more common community constituents are showing significant regeneration
- If the numbers of mature individuals show declines of 10% or more (5% for long-lived taxa) between successive years for two subsequent years, and there is no significant regeneration
- If the numbers of mature individuals decline >20% in a single year

Table 9.6: PU-level and MU-level Management Actions Dictated by PU Management Designation

206 PU management designations are listed in order of decreasing management effort.

		PU management designation	PU Management Goal	PU-level management actions: Ungulate management	PU-level management actions: Control of other threats*	PU-level management actions: Weed control around PU	PU-level management actions: Other	MU-level management actions: Ungulate management (including fencing)	MU-level management actions: Weed control
Full Taxon Stabilization	*In situ* PU	**Full PU management**	Increase PU levels to achieve stabilization criteria	Over the area needed to stabilize the PU	As needed to stabilize PU	Manage aggressive weeds to <25% cover throughout PU and to **50-m** beyond PU perimeter	Monitor, Collect propagules, augment PU as needed	Over entire MU or MU subunit that is designed for the PU	Over a portion of MU or MU subunit
Full Taxon Stabilization	Reintroduction	**Full PU management**	Establish populations that achieve PU stabilization criteria	Over the area needed to stabilize the PU	As needed to stabilize PU	Manage aggressive weeds to <25% cover throughout PU and to **50-m** beyond PU perimeter	Monitor	Over entire MU or MU subunit that is designed for the PU	Over a portion of MU or MU subunit
Partial Taxon Stabilization	*In situ* PU	**Full PU management**	Increase PU levels to achieve stabilization criteria	Over the area needed to stabilize the PU	As needed to stabilize PU	Manage aggressive weeds to <25% cover throughout PU and to **50-m** beyond PU perimeter	Monitor, Collect propagules, augment PU as needed	Over entire MU or MU subunit that is designed for the PU	None
Partial Taxon Stabilization	Reintroduction	**Full reintroduction management**	Establish populations that achieve PU stabilization criteria	Over the area needed to stabilize the PU	As needed to stabilize PU	Manage aggressive weeds to <25% cover throughout PU and to **50-m** beyond PU perimeter	Monitor	Over entire MU or MU subunit that is designed for the PU	None
Partial Taxon Stabilization	*In situ* PU	**Partial PU management**	Increase PU levels towards stabilization criteria (typically toward >25 individuals; target varies by taxon)	Over the area needed to stabilize the PU	As needed to encourage recruitment	Manage aggressive weeds to <25% cover throughout PU and to **10-m** beyond PU perimeter	Monitor, Collect propagules, augment PU as needed	Over entire MU or MU subunit that is designed for the PU	None
Partial Taxon Stabilization	*In situ* PU	**Baseline PU management**	Maintain baseline population levels (no net loss of individuals)	At small scale around individuals (as needed)	As needed to control immediate high threats	Manage aggressive weeds (as needed)	Monitor, Collect propagules	None	None

*Rodents, slugs, humans, *etc*.

In special cases, the Army managers may decide on the need for augmentation prior to a year of threat management. Similarly, they may decide that augmentation is unnecessary. Such decisions are subject to review at annual IT meetings.

Sequencing of MU actions

Actions at the MU level extend beyond the parameters of PU-level management to address threat control on a broader scale. The larger MUs have been divided into subunits, and management will be implemented for these MUs at the subunit level. Actions at the MU or MU subunit level have been divided into two major categories: 1) ungulate control through fencing and removal, and 2) weed control over a portion of the MU or MU subunit.

Management at the MU level is dictated by the highest designation of PU management within each MU within each phase. The required MU-level management actions are summarized in Table 9.6. In short, fencing of an MU or MU subunit and ungulate removal will occur for all levels of PU management except baseline, while the control of weeds over a portion of an MU or MU subunit will occur only when a PU of a taxon with a full taxon stabilization designation is contained therein. For example, in the Huliwai MU in Phase A, the *Delissea subcordata* PU is designated for partial PU management while the *Cenchrus agrimonioides* PU is designated for baseline. The higher of the two PU management designations, partial PU management, therefore requires ungulate removal and fencing in Phase A but does not require weed control over a portion of the MU. In Phase B, the *D. subcordata* PU is now designated for full taxon stabilization while the *C. agrimonioides* PU is designated for partial PU management. The higher of the two management designations, full taxon stabilization, now additionally requires the control of weeds over a portion of the MU in Phase B.

Using the relationship described above, the initiation of MU actions for all MUs and MU subunits was prescribed for each phase. The culmination of this planning effort is seen in Table 9.7. Maps showing the location and sequencing of actions for each MU can be found in the subsections of Section 2, Chapter 3: Management Units.

Table 9.7: Sequencing of Management Unit Actions

ISLAND	MU NAME	Subunit	Highest level of taxon/PU management in PHASE A	Highest level of taxon/PU management in PHASE B	Highest level of taxon/PU management in PHASE C	Acres
Oahu	Alaiheihe to Palikea Gulch	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	619
Oahu	Haili to Kawaihapai	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	161
Oahu	Kaena and Keawaula	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	103
Oahu	Kaluakauila	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	152
Oahu	Kamaileunu	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	86
Oahu	Kauaopuu	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	19
Oahu	Kaumoku Nui	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	213
Oahu	Lower Kahanahaiki	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	32
Oahu	Lower Ohikilolo	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	70
Oahu	Makaha	Subunit I	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	95
Oahu	Mt. Kaala NAR	Subunit II	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	114
Oahu	Ohikilolo	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	578
Oahu	Puu Kumakalii	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	28
Oahu	Upper Keaau	-	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	10
Oahu	Waianae Kai	Subunit I	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	93
Oahu	Waianae Kai	Subunit II	Full taxon stabilization	Full taxon stabilization	Full taxon stabilization	9
Oahu	Ekahanui	Subunit I	Full PU Management	Full taxon stabilization	Full taxon stabilization	44
Oahu	Ekahanui	Subunit II	Full PU Management	Full taxon stabilization	Full taxon stabilization	177
Oahu	Kahanahaiki	Subunit II	Full PU Management	Full taxon stabilization	Full taxon stabilization	34
Oahu	Kahanahaiki	Subunit I	Full PU Management	Full taxon stabilization	Full taxon stabilization	63
Oahu	Kaluaa and Waieli	Subunit II	Full PU Management	Full taxon stabilization	Full taxon stabilization	120
Oahu	Kaluaa and Waieli	Subunit III	Full PU Management	Full taxon stabilization	Full taxon stabilization	99
Oahu	Lower Kapuna	-	Full PU Management	Full taxon stabilization	Full taxon stabilization	266
Oahu	Makaha	Subunit II	Full PU Management	Full taxon stabilization	Full taxon stabilization	77
Oahu	Mt. Kaala NAR	Subunit IV	Full PU Management	Full taxon stabilization	Full taxon stabilization	175
Oahu	Pahole	-	Full PU Management	Full taxon stabilization	Full taxon stabilization	215
Oahu	Palikea	Subunit I	Full PU Management	Full taxon stabilization	Full taxon stabilization	14
Oahu	Upper Kapuna	-	Full PU Management	Full taxon stabilization	Full taxon stabilization	225
Oahu	Waianae Kai	Subunit IV	Full PU Management	Full taxon stabilization	Full taxon stabilization	9
Oahu	West Makaleha	-	Full PU Management	Full taxon stabilization	Full taxon stabilization	255
Oahu	Central and East Makaleha	Subunit V	Partial PU Management	Full taxon stabilization	Full taxon stabilization	35
Oahu	Central and East Makaleha	Subunit IV	Partial PU Management	Full taxon stabilization	Full taxon stabilization	197
Oahu	Central and East Makaleha	Subunit I	Partial PU Management	Full taxon stabilization	Full taxon stabilization	209
Oahu	Huliwai	-	Partial PU Management	Full taxon stabilization	Full taxon stabilization	118

ISLAND	MU NAME	Subunit	Highest level of taxon/PU management in PHASE A	Highest level of taxon/PU management in PHASE B	Highest level of taxon/PU management in PHASE C	Acres
Oahu	Waianae Kai	Subunit III	Partial PU Management	Full taxon stabilization	Full taxon stabilization	14
Oahu	Central and East Makaleha	Subunit II	Baseline PU Management	Full taxon stabilization	Full taxon stabilization	144
Oahu	Central and East Makaleha	Subunit III	Baseline PU Management	Full taxon stabilization	Full taxon stabilization	238
Oahu	Kaluaa and Waieli	Subunit IV	Baseline PU Management	Full taxon stabilization	Full taxon stabilization	27
Oahu	Kaluaa and Waieli	Subunit V	Baseline PU Management	Full taxon stabilization	Full taxon stabilization	9
Oahu	Mt. Kaala NAR	Subunit III	Baseline PU Management	Full taxon stabilization	Full taxon stabilization	76
Kauai	Kaahole to Paaiki	-	Full PU Management	Full PU Management	Full taxon stabilization	468
Oahu	Waiawa	-	Full PU Management	Full PU Management	Full taxon stabilization	75
Oahu	Keaau and Makaha	-	Partial PU Management	Full PU Management	Full taxon stabilization	5
Oahu	Kaluaa and Waieli	Subunit I	Partial PU Management	Partial PU Management	Full taxon stabilization	87
Oahu	Lower Opaeula	-	Partial PU Management	Partial PU Management	Full taxon stabilization	65
Oahu	Mohiakea	-	Partial PU Management	Partial PU Management	Full taxon stabilization	19
Oahu	Palikea	Subunit II	Partial PU Management	Partial PU Management	Full taxon stabilization	2
Oahu	Kawaiiki	-	Baseline PU Management	Baseline PU Management	Full taxon stabilization	44
Oahu	Mt. Kaala NAR	Subunit I	Baseline PU Management	Baseline PU Management	Full taxon stabilization	255
Oahu	Palikea	Subunit III	Baseline PU Management	Baseline PU Management	Full taxon stabilization	99
Oahu	Palikea	Subunit IV	Baseline PU Management	Baseline PU Management	Full taxon stabilization	9
Oahu	Palikea	Subunit V	Baseline PU Management	Baseline PU Management	Full taxon stabilization	3

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9.5 Plant Propagule Collection and Storage

Because of a trend of decline in population units (PUs), largely due to unmitigated threats to wild populations, there is an urgent need for collection of propagules for the purpose of safeguarding genetic variability, and for providing stock for outplanting efforts. Significant effort will be required to gather propagules (seeds or cuttings) from all PUs designated for management to stability, and PUs identified for long-term genetic storage or as propagule sources for reintroduction and/or augmentation. The benefits of using seeds versus cuttings or other propagules are discussed in Section 3, Appendix 2.1: Plant Propagule Collection Protocols.

Both genetic storage (to guard against loss of wild populations) and propagule collection (to support reintroduction efforts) plays a vital role in the stabilization of the Makua target taxa. ***A secure seed/propagule storage facility is required to realize the short, medium, and long-term propagule storage needs related to Makua target plant taxa stabilization actions.*** This can be developed either via expansions of existing facilities such as at the Lyon Arboretum in Honolulu and the National Seed Storage Lab (NSSL) in Colorado, or may require the establishment of a new, independent facility. NSSL may work well for long-term storage, but short- and medium-term storage that can be accessed readily requires development of a secure local facility. Facility improvements at Lyon Arboretum, or development of similar facilities elsewhere in the state (*e.g.*, in the University of Hawaii campus network, or other agricultural or horticultural sites) could satisfy those requirements. Facilities must be available for both seed and tissue storage.

While seeds are the preferred propagule for storage, information on the storage ability for the seeds of all target taxa needed to be researched. Lyon Arboretum, and the NSSL in Colorado were able to provide considerable background information on previous attempts to store seeds of target or related taxa. ***If seeds from a particular taxon are known to be recalcitrant (not storable under standard freezing techniques), collection of vegetative material and research on alternative storage methods are required***. If storage potential for a target taxon is not yet known, further collection for the purposes of seed storage testing is required, following guidelines in Section 3, Appendix 2.1: Plant Propagule Collection Protocols. Current knowledge of seed storage potential for target taxa can be found in Section 3, Appendix 1.3: Lyon Arboretum Seed Storage Summary. If propagation techniques for a target taxon are not yet known, further collection for the purpose of propagation testing is required, following guidelines in Section 3, Appendix 2.1: Plant Propagule Collection Protocols.

Protocols were developed by the Implementation Team (IT) for propagule collection, derived from a balance between the need to remove seed or other living material in sufficient quantity to serve the purposes of stabilization with not harming wild plants or unduly reducing potential natural regeneration. The IT, in its consideration of such balances, turned to The Center for Plant Conservation and the Hawaii Rare Plant Restoration Group (HRPRG). Each has worked with rare Hawaiian plant taxa and developed specific, recommended protocols for propagule collection (see Section 3, Appendix 2.4: HRPRG Collecting and Handling Protocols). The IT used these protocols to develop guidelines for propagule collection specifically for the Makua Implementation Plan (see Appendix 2.1: Plant Propagule Collection Protocols). These collection guidelines served as a basis for detailed collection recommendations made in the individual taxon stabilization plans (see Section 2, Chapter 2: Stabilization Plans).

To safeguard against loss of genetic variability, the immediate establishment of cultivated stock from taxa or PUs with the following risks is imperative:

- small PUs (<5 individuals) that are geographically isolated, morphologically distinct, or located in unique habitat,
- from PUs with >5 individuals but showing a history of rapid decline, or considered particularly vulnerable to imminent extirpation, or
- for those taxa whose seed storage ability is unknown or uncertain, until it can be demonstrated that seed storage is effective.

The purpose of this living stock is primarily to generate seeds or other viable propagules for more conventional storage before those populations at risk are extirpated by threats or stochastic events. Sites for living collections are yet to be determined.

9.6 Reintroduction and Augmentation

Given the historical trend of reduction in geographic range, numbers of populations, and numbers of individuals of endangered taxa in Hawaii, one of the strategies in the stabilization of the Makua target taxa is reintroduction of individuals into suitable managed habitat within the known historical range or likely suitable habitat of a taxon. **Reintroduction** is defined in this plan as establishing a number of individuals into a geographic area within a taxon's historic range that is currently not known to contain the taxon, with the express purpose of establishing a sustained or growing population. The plant reintroduction and augmentation strategies presented in the Implementation Plan (IP) are based on other efforts, including the Hawaii Rare Plant Restoration Group (HRPRG) reintroduction guidelines (see Section 3, Appendix 1.2: HRPRG Reintroduction Guidelines) and the Makua Endangered Species Stabilization Plan Appendix: Reintroduction for Mitigation – Justification and Guidelines (U.S. Army 1999).

Most of the target taxa have declined to such levels that threat management alone will not allow return of the taxa to stable levels. Reintroduction supports the primary strategy of active *in situ* management of extant wild populations toward stability. While reintroduction might be necessary to achieve stability, activities involved in reintroduction can be extremely harmful unless care is taken to minimize impacts such as damage to habitat or other native taxa via trampling, introduction of disease and alien taxa, and genetic contamination of target taxa or other native taxa. As part of this preventative approach, a list of particularly sensitive rare taxa in the Waianae Region was developed (see Table 9.8), so that their presence at or near any proposed *in situ* management site will trigger assessments of strategies needed to alleviate potential harm.

Reintroduction must be distinguished from augmentation, which involves the addition of individuals to a geographic area that is currently known to contain the taxon. The express purpose of an augmentation is to increase the number of individuals in a population to enhance the possibility of cross-pollination between the plants. It is also used to increase the genetic variability of the population by introducing individuals that bring new alleles into the population that may have become lost over time as the population declined. A major concern in augmentation lies in the increased potential to negatively impact the genetic makeup of the pre-existing population. This is discussed in more detail below.

Genetic considerations

It is important to carefully consider potential genetic consequences when choosing individuals for use in reintroduction and augmentation. Reintroduction and augmentation can be carried out using plants from a single source or by mixing plants from more than one source. Each strategy may have both positive and negative consequences and the risks of each must be carefully balanced.

When a large and healthy source population is available, it is generally wise to use a variety of individuals from a single source for reintroduction. For such a population, it can be assumed that genetic problems such as inbreeding are not manifested and will likely produce a genetically healthy reintroduction.

Table 9.8 Rare Plant Taxa Found in the Waianae Range. Taxa are listed as endangered (E), considered for listing as threatened or endangered (C) by the U.S. Fish and Wwildlife Service, or identified as species of concern (SOC), and have less than 500 individuals globally; or non-listed species (NS) with less than 5 known population units and less than 1,000 individuals globally.

Taxon Name	Family	Common Name	Federal Status
Abutilon menziesii	Malvaceae	*kooloaula*	E
Abutilon sandwicense	Malvaceae	no common name	E
Achyranthes splendens var. *rotundata*	Amaranthaceae	no common name	E
Alectryon macrococcus var. *macrococcus*	Sapindaceae	*mahoe*	E
Alsinidendron obovatum	Caryophyllaceae	no common name	E
Alsinidendron trinerve	Caryophyllaceae	no common name	E
Bobea timonioides	Rubiaceae	*ahakea*	SOC
Bobea sandwicensis	Rubiaceae	*ahakea*	SOC
Bonamia menziesii	Convolvulaceae	no common name	E
Caesalpinia kavaiensis	Fabaceae	*uhiuhi*	E
Cenchrus agrimonioides var. *agrimonioides*	Poaceae	*kamanomano*, *umealu*	E
Centaurium sebaeoides	Gentianaceae	*awiwi*	E
Chamaesyce celastroides var. *kaenana*	Euphorbiaceae	*akoko*	E
Chamaesyce herbstii	Euphorbiaceae	*akoko*	E
Colubrina oppositifolia	Rhamnaceae	*kauila*	E
Ctenitis squamigera	Dryopteridaceae	*pauoa*	E
Cyanea acuminata	Campanulaceae	*haha*	E
Cyanea calycina	Campanulaceae	*haha*	C
Cyanea grimesiana subsp. *grimesiana*	Campanulaceae	*haha*	E
Cyanea grimesiana subsp. *obatae*	Campanulaceae	*haha*	E
Cyanea longiflora	Campanulaceae	*haha*	E
Cyanea pinnatifida	Campanulaceae	*haha*	E
Cyanea superba subsp. *superba*	Campanulaceae	*haha*	E
Cyperus pennatiformis subsp. *pennatiformis*	Cyperaceae	no common name	E
Cyperus trachysanthos	Cyperaceae	*puukaa*	E
Cyrtandra dentata	Gesneriaceae	*haiwale*	E
Cyrtandra rivularis	Gesneriaceae	*haiwale*	SOC
Delissea subcordata	Campanulaceae	no common name	E
Diellia unisora	Aspleniaceae	no common name	E
Diplazium molokaiense	Athyriaceae	no common name	E
Dubautia sherffiana	Asteraceae	*naenae*	SOC
Eugenia koolauensis	Myrtaceae	*nioi*	E
Exocarpos gaudichaudii	Santalaceae	*heau*	SOC
Flueggea neowawraea	Euphorbiaceae	*mehamehame*	E
Gardenia brighamii	Rubiaceae	*nanu*	E
Gardenia mannii	Rubiaceae	*nanu*	E

Taxon Name	Family	Vernacular Name	Federal Status
Gouania meyenii	Rhamnaceae	no common name	E
Gouania vitifolia	Rhamnaceae	no common name	E
Hedyotis coriacea	Rubiaceae	*kioele*	E
Hedyotis degeneri var*. coprosmifolia*	Rubiaceae	no common name	E
Hedyotis degeneri var*. degeneri*	Rubiaceae	no common name	E
Hedyotis parvula	Rubiaceae	no common name	E
Hesperomannia arborescens	Asteraceae	no common name	E
Hesperomannia arbuscula	Asteraceae	no common name	E
Hibiscus brackenridgei subsp. *mokuleianus*	Malvaceae	*mao hau hele*	E
Isodendrion laurifolium	Violaceae	*aupaka*	E
Isodendrion pyrifolium	Violaceae	*aupaka; wahine noho kula*	E
Joinvillea ascendens subsp. *ascendens*	Joinvilleaceae	*ohe*	C
Labordia cyrtandrae	Loganiaceae	*kamakahala*	E
Lipochaeta lobata var*. leptophylla*	Asteraceae	*nehe*	E
Lobelia oahuensis	Campanulaceae	no common name	E
Lobelia sp. (related to *L. hypoleuca* in West Range of Schofield Barracks)	Campanulaceae	no common name	NS
Melicope christophersenii	Rutaceae	*alani*	C
Melicope makahae	Rutaceae	*alani*	C
Melicope pallida	Rutaceae	*alani*	E
Melicope saint-johnii	Rutaceae	*alani*	E
Myoporum stellatum	Myoporaceae	*naio,* bastard sandalwood	SOC
Neraudia angulata var*. angulata*	Urticaceae	no common name	E
Neraudia angulata var*. dentata*	Urticaceae	no common name	E
Nesoluma polynesicum	Sapotaceae	*keahi*	SOC
Nothocestrum latifolium	Solanaceae	*aiea*	C
Phyllostegia hirsuta	Lamiaceae	no common name	E
Phyllostegia kaalaensis	Lamiaceae	no common name	E
Phyllostegia mollis	Lamiaceae	no common name	E
Phyllostegia parviflora var*. lydgatei*	Lamiaceae	no common name	E
Plantago princeps var*. princeps*	Plantaginaceae	*ale*	E
Platydesma cornuta var*. decurrens*	Rutaceae	no common name	C
Pleomele forbesii	Agavaceae	*halapepe*	C
Pritchardia kaalae	Arecaceae	*loulu*	E
Pritchardia sp. (related to *P. martii* in North Palawai Gulch, Honouliuli Preserve)	Arecaceae	*loulu*	NS
Pteralyxia macrocarpa	Apocynaceae	*kaulu*	C
Ranunculus mauiensis	Ranunculaceae	*makou*	C
Sanicula mariversa	Apiaceae	no common name	E
Scaevola coriacea	Goodeniaceae	dwarf *naupaka*	E

Taxon Name	Family	Vernacular Name	Federal Status
Schiedea hookeri	Caryophyllaceae	no common name	E
Schiedea kaalae	Caryophyllaceae	no common name	E
Schiedea kealiae	Caryophyllaceae	no common name	E
Schiedea nuttallii	Caryophyllaceae	no common name	E
Schiedea pentandra	Caryophyllaceae	no common name	SOC
Sicyos lanceoloidea	Cucurbitaceae	*anunu*	SOC
Sicyos waimanaloensis	Cucurbitaceae	*anunu*	SOC
Solanum nelsonii	Solanaceae	*popolo*	C
Solanum sandwicense	Solanaceae	*popolo aiakeakua*	E
Stenogyne kanehoana	Lamiaceae	No common name	E
Tetramolopium filiforme var. *polyphyllum*	Asteraceae	no common name	E
Tetramolopium lepidotum subsp. *lepidotum*	Asteraceae	no common name	E
Urera kaalae	Urticaceae	*opuhe*	E
Vigna o-wahuensis	Fabaceae	no common name	E
Viola chamissoniana subsp. *chamissoniana*	Violaceae	*pamakani, olopu*	E

Large healthy populations are not always available. In these situations, the risks of mixing versus using a single source must be weighed. For normally outcrossing plants with small populations, random genetic drift may play a larger role in the genetic structure of a population than natural selection. The consequence of this is often a reduction in fitness known as inbreeding depression. Such a reduction in fitness occurs because inbreeding increases homozygosity, which may lead to the expression of recessive deleterious alleles. In addition, an inbred population may lack the allelic diversity required for a population to change gene frequencies in order to adapt to a changing environment over time. Small population size and inbreeding are not necessarily problematic for plants that are normally self-pollinated because such plants may have already purged their deleterious alleles.

To ensure adequate genetic diversity and to avoid inbreeding depression so that a population can evolve over time, multiple sources may be mixed for both reintroduction and augmentation.

Using multiple sources does, however, introduce the risk of reduced fitness due to outbreeding depression. Outbreeding depression is thought to be a consequence of crossing individuals that are locally adapted for different environments. The result is offspring that are poorly adapted to either of the parental environments. Outbreeding depression may also result due to the disruption of coadapted gene complexes when highly unrelated individuals are crossed. This may be less of a concern when working in already degraded sites because plants may be adapted to formerly pristine habitats and are no longer adapted to current conditions.

The risks of inbreeding and outbreeding depression are serious, yet such genetic problems are difficult to detect with certainty. In order to reduce the risks of each, the Implementation Team (IT) chose to approximate naturally occurring genetic interactions. To this end, source stock for augmentation is normally chosen from the same population unit (PU) or a geographically adjacent PU. Similarly, stock for reintroduction is normally chosen from one or more sites that are in close geographic proximity to each other. In certain cases in which populations are known to have recently declined to very low numbers, more aggressive mixes of sources are proposed as experiments.

In addition to avoiding the risks of inbreeding and outbreeding depression in order to create genetically viable *populations*, it is important to maintain the genetic variability of the *taxon* as a whole. To this end, the IT was careful to maintain peripheral PUs, or PUs occurring in unique environments, because they may contain different or rare alleles. In order to avoid swamping the genetically based characteristics of such a PU with more common alleles from other populations, augmentation will normally be conducted using stock from the augmented PU. For the same reasons, reintroductions in such PUs often use plants from a single source, as the need to maintain unique alleles may outweigh the chance that inbreeding depression may occur. For taxa in which such unique populations are managed separately, other management actions, such as reintroduction or augmentation using stock from a larger population or mixed stock, will also be conducted in order to avoid relying solely on populations that carry a higher possibility of being inbred.

Given the genetic concerns of augmentation in particular, to distinguish geographically between a proposed reintroduction and an augmentation (especially given the uncertainty of the presence or absence of wild individuals of the target taxa in a reintroduction/augmentation area) the IT proposes that for plants, reintroduction sites be selected using the distance criterion developed to distinguish between separate *in situ* PUs. That being the case, ***a reintroduction is any outplanting of a taxon that occurs 1,000 meters or more from known wild individuals of that taxon.*** There is one caveat to the 1,000 meter rule, which is applied if there are natural barriers to gene flow between the outplanted and the wild individuals (such as a major ridge or habitat discontinuity). In those cases, ***a proposed reintroduction may occur as little as 500 meters from a wild population, but the barrier to gene flow must be described and the consequences of the reintroduction should be monitored carefully for unwanted genetic effects***. In cases where a reintroduction occurs within 1,000 meters of an *in situ* PU, the justification based on natural barriers is described in the stabilization plans (SPs). ***An augmentation is any addition occurring within a 1,000 meter radius of wild individuals***, if there are no barriers to gene flow.

For plant taxa, concern over genetic interactions between outplanted individuals and closely related taxa via hybridization is another complication that might argue against reintroductions or augmentations where such related taxa are present. ***Outplanting lines were established delineating regions where reintroductions and augmentations can occur without concern for hybridization with related taxas***. Outplanting lines are identified on some of the distribution maps included in the taxon summaries in Chapter 16. Typically, a comparison was made of the known distribution of the target taxon with that of the related taxon of concern, and then a line was drawn prohibiting any outplanting that might result in an unnatural overlap in distribution where genetic exchange through cross-pollination might occur. An outplanting line was not established if the distributions of the target taxon and the related taxon are already known to overlap in the wild, or if hybridization between the two taxa already occurs naturally. For certain taxa whose recorded range is limited, an outplanting line was drawn at the edges of the recorded range, restricting reintroduction of the taxon to within the line. All proposed reintroduction sites for a taxon were selected in observance of the outplanting lines.

By the same token, a conservative approach was taken with regards to the potential negative genetic consequences of initial reintroductions or augmentations involving very different stocks. Therefore, the mixing of individuals from widely separated geographic locations is generally not included in the SPs except as an experiment to test for inbreeding depression. Likewise, the mixing of distinct ecotypes or morphologically distinct forms is generally not recommended. Concerns about genetic variability and distinctiveness led to preliminary genetic testing on key target taxa, for which genetic issues could be addressed.

Genetic analysis

Genetic variability and similarity play large roles in decisions regarding reintroduction and augmentation. Such information was largely lacking for the target taxa at the time of the IT formation. For *Achatinella mustelina* and certain plants, it was determined that some level of research of genetic variability and pattern were needed before key decisions regarding the before key decisions regarding the geographical location and maternal parentage of reintroduced PUs could be made.

An assessment of genetic variability within populations and genetic distinctiveness between populations and forms of several of the target plant taxa was conducted. In particular, genetic testing investigated issues regarding:

- genetic variability and distinctiveness between the various populations and varieties of *Neraudia angulata*
- genetic distinctiveness between *Cyanea grimesiana* subsp. *grimesiana* and *C. grimesiana* subsp. *obatae*
- genetic variability within the very few remaining individuals of *Cyanea superba*
- genetic differences between plants of *Lipochaeta tenuifolia* at a low elevation dry site at the seaward end of Ohikilolo Ridge and plants at higher, wetter locations on the ridge
- genetic differences between Waianae and Koolau populations of *Schiedea kaalae*
- genetic variability relating to geographic distribution in the diffusely distributed *Flueggea neowawraea*
- genetic distinctiveness of northern and southern Waianae populations of *Chamaesyce herbstii*

Random Amplified Polymorphic DNA (RAPD) analyses (Williams *et al*. 1990) were run on selected samples of the above plant taxa from different geographic areas and individuals. Principal Component Analyses (PCA) gave a preliminary indication of patterns of variability for the genetic loci tested. The results of these tests were used in formulating recommendations for those taxa in their specific SPs (see Section 3, Appendix 1.4: Plant Genetics).

Sanitation concerns

The second major concern (common to both reintroduction and augmentation) is contamination of the pre-existing population of the same taxon, as well as any other taxa in the area, with new pathogens (*e.g.*, diseases, parasites, invertebrate pests, or non-native plants) that might be brought to an area with the introduced plant or animal material. Although this risk is also important in reintroductions, the risk is even higher in augmentations because any pathogen that is deleterious to the introduced individuals is more likely to affect the individuals of the same taxon in the augmented population. Great care must be taken to avoid harm to the augmented population, especially in initial augmentations, when the protocols are being validated. The sanitation concern can be addressed by taking several actions:

- thorough surveying of a prospective augmentation or reintroduction site for the presence of rare taxa (*i.e.*, target taxa and rare taxa listed in Table 9.8)
- strict sanitation and pest control measures at facilities preparing propagules or individuals for augmentation
- strict protocols for prevention of contamination during the augmentation process
- careful selection of augmentation sites
- careful management of the augmentation sites
- intensive monitoring of augmentation sites for contamination

Careful monitoring will address the effectiveness of the sanitation protocols and some of the initial restrictions may be relaxed. ***Until the phytosanitation protocols are tested, no outplantings (augmentations or reintroductions) will be conducted within 100 meters of the rare listed in Table 9.8***. This distance restriction may be relaxed or removed altogether if sanitation protocols result in no pathogen problems. The full phytosanitation guidelines developed by the IT are presented in Section 3, Appendix 2.2: Phytosanitation Standards and Guidelines.

Priority setting for reintroduction sites

The IT carefully prioritized proposed reintroduction sites in the SPs for the target taxa, based on biological considerations. The result is a specific listing, in each of the taxa's SPs (found in Section 2, Chapter 2: Stabilization Plans), of the IT's determination of the preferred sites for reintroduction attempts for each target taxon. ***The highest ranked sites should be pursued as sites for the required reintroductions and can be rejected only with strong justification, approval of the IT, and approval from the U.S. Fish and Wildlife Service (USFWS) before lower ranked sites are considered.*** The U.S. Army (Army) has the burden of justifying the selection of a lower-ranked site to the IT and USFWS.

Priority setting for reintroduction sequence

Sequencing of reintroduction actions follows the priorities defined in Chapter 9.4: Sequencing of Actions. Each outplanting effort will take place over a 3- to 5-year period. In order to refine outplanting techniques for taxa for which reintroduction is planned but where outplanting techniques are not yet known, ***at least one outplanting effort, either via reintroduction or augmentation, will be initiated in Phase A.*** For each taxon receiving full taxon stabilization in Phase A, an outplanting effort will be initiated before year 7. Any remaining reintroductions slated for Phase A for these taxa will be undertaken between years 9 – 11. For each taxon receiving full taxon stabilization in Phase B or C, an outplanting effort will be initiated before year 10. Remaining phase B and C reintroductions will be carried out within the first 3 years of the last half of those phases (*e.g.*, years 19-21 for Phase B and years 29-31 for Phase C). For

Cyanea superba, which has only one *in situ* PU, more than one outplanting effort will be conducted in the first half of Phase A.

Reintroduction and augmentation guidelines

The selection of reintroduction sites is based on careful review of biological criteria designed to provide appropriate habitat for the target taxa within management units (MUs). Initially, until effective and safe outplanting techniques are developed, reintroduction locations within a site, while still within appropriate habitat, will avoid the most pristine areas to avoid contamination and minimize harm to *in situ* native taxa and their habitats.

Reintroduction sites were selected over a broad geographic range in order to reduce the risk that catastrophic events (such as storms, disease outbreaks, fire, predators, and herbivores) might adversely impact all the individuals of a taxon. Therefore, ***in general, no more than two reintroductions per target taxon will be placed in a single MU.*** For example, if four reintroductions of a given taxon are recommended, at least two MUs will be selected for reintroduction sites, and preferably four (one in each MU). If limited appropriate sites are available, then the IT will revisit this requirement to determine if exceptions to the rule are warranted.

The initial reliance on *in situ* management and reintroductions, using augmentation only when threat management does not result in adequate natural regeneration, is a fundamental approach for all of the stabilization strategies. The decision to augment an *in situ* population must be approved by the IT and the USFWS. ***In general, no augmentation will be conducted until after at least one year of partial or full PU management, and after sanitation protocols are sufficiently tested and judged appropriate***. Augmentation of plant populations will be initiated if any of the following changes are detected at a PU despite active threat management for at least one year:

- If the number of mature individuals is five or less
- If no evidence of regeneration is detected over two subsequent years in which more common community constituents are showing significant regeneration
- If the numbers of mature individuals show declines of 10% or more (5% for long-lived taxa) between successive years for two subsequent years, and there is no significant regeneration
- If the numbers of mature individuals decline >20% in a single year

In special cases, the Army managers may decide on the need for augmentation prior to a year of threat management. Similarly, they may decide that augmentation is unnecessary. Such decisions are subject to review at annual IT meetings.

Augmentation is justified only if there is no regeneration response as a result of threat management (*e.g.*, ungulate removal, weed control, *etc*.) over time. ***Augmentations will be done conservatively, using source stock only from the same PU initially.*** Mixing will be avoided unless genetic problems, such as inbreeding depression or loss of variability, are suspected. In general, any mixing will use sources from populations as near as possible to the planting site, both geographically and ecologically.

Reintroduction population size

Determining the optimal number of individuals for initial reintroductions is difficult at best (Guerrant 1996). The long-term goal is to attain a genetically diverse and viable PU, but the actual number of individuals needed to reach that goal is not well understood. The IT has developed targets for each taxon it feels are adequate to achieve the long-term goal (see Chapter 9.1: Setting Stabilization Targets), through the maximization and equalization of genetic representation of the initial outplanted individuals (within the constraints identified above in Genetic considerations), and the maximization of survivorship and reproductive output of those individuals.

Survivorship plays a key role in determining how many individuals must be planted to attain the target population size. The Center for Plant Conservation presumes a 10% long-term survivorship of reintroduced plants (CPC 2000). However, the Army has demonstrated an 80% survivorship rate during the initial years of their reintroductions. The Army does not currently have data on the long-term survivorship of their reintroduced individuals, but the preliminary data is hopeful, and some reintroduced plants are already successfully setting seed. Additionally, with significant pre-planting preparation, post-planting care, monitoring, and adaptive management, survivorship can be enhanced. Because all these measures are included in the IP, and because of the preliminary success of Army reintroductions, the IT expects a 75-90% survivorship. Based on the results of monitoring, the Army is prepared to increase their outplanting effort as needed to respond to lower survivorship levels. Once a scheduled reintroduction begins, it will take place in three stages over a three to five year period. Given these considerations, the number of individuals needed for each outplanting effort were determined for plants and for seeds.

Number to plant

Three categories were identified for taxa for which reintroductions are planned. These three categories identify the number of individuals to outplant in the first of the three stages for each PU. Numbers to plant in subsequent years and number of years over which reintroductions will take place will be adjusted based on survivorship measured during the first or second stage of outplanting in the previous years.

1- greater than 90% survivorship observed
2- greater than 80% survivorship observed
3- no outplanting data available

Table 9.9 Number to Plant for Each Survivorship Category

Category	Number to plant
1	111% of target, expecting 90% survival
2	125% of target, expecting 80% survival
3	133% of target, expecting 75% survival

For example, *Delissea subcordata* is in Category 1. Based on the expected survivorship for Category 1 taxa, if the PU target is 100 plants, 37 individuals would be planted in each of three years to reach a total of 111 plants. If less than 90% survivorship was observed after the first outplanting, the number planted in successive years would be increased accordingly. The number could also be adjusted in the opposite direction if a greater survival rate than expected is observed. A minimum of 30 individuals will be planted in initial years to establish a large enough sample size to judge success. The number to plant for each target taxon requiring reintroduction is identified in Table 9.13, and incorporated into each taxon's SP (see Section 2, Chapter 2: Stabilization Plans).

Table 9.10 List of Taxa by Survivorship Category

Category	Taxon	
1	*Cenchrus agrimonioides* var. *agrimonioides* *Delissea subcordata*	*Schiedea nutttallii* *Pritchardia kaalae*
2	*Alsinidendron obovatum*	*Cyanea superba* subsp. *superba*
3	*Chamaesyce herbstii* *Cyanea grimesiana* subsp. *obatae* *Cyanea longiflora* *Dubautia herbstobatae* *Hedyotis parvula* *Hesperomannia arbuscula* *Hibiscus brackenridgei* subsp. *mokuleianus*	*Neraudia angulata* *Phyllostegia kaalaensis* *Sanicula mariversa* *Schiedea kaalae* *Tetramolopium filiforme* *Viola chamissoniana* subsp. *chamissoniana*

For seed sowing

Two categories were identified for taxa for which seed sowing is recommended:

1- No information on seed sowing known, taxa are short lived and have a shorter time to first reproduction
2- No information on seed sowing known, taxa are long lived and have a longer time to first reproduction

Table 9.11 Number of Seeds to Sow for Each Survivorship Category

Category	Number to plant
1	2000% of target (20 times target), expecting 5% survival
2	5000% of target (50 times target), expecting 2% survival

Table 9.12 List of Taxa by Seed Survivorship Category

Category	Taxa
1	*Hedyotis parvula* *Sanicula mariversa* *Tetramolopium filiforme*
2	*Pritchardia kaalae*

328 **Table 9.13 Number to Plant**

Taxon	Survivorship Category	Target	Total Number to Plant per Reintro-duction	Number to Plant per Initial Out-planting*	Number of Reintro-ductions Proposed	Minimum Number of Plants Needed	Total Number of Seeds to Sow per Reintro.	Number of seeds per initial sowing
Alectryon macrococcus var. *macrococcus*	3	50	67	30	0	0		
Alsinidendron obovatum	2	100	120	40	5	600		
Cenchrus agrimonioides	1	50	56	30	4	224		
Chamaesyce celastroides var. *kaenana*	3	25	34	30	0	0		
Chamaesyce herbstii	3	25	34	30	3	102		
Cyanea grimesiana subsp. *grimesiana*	3	100	134	45	3	402		
Cyanea longiflora	3	75	101	34	3	303		
Cyanea superba subsp. *superba*	3	50	67	30	9	603		
Cyrtandra dentata	3	50	67	30	0	0		
Delissea subcordata	1	100	110	37	1	110		
Dubautia herbstobatae	3	50	67	30	2	134		
Flueggea neowawraea	3	50	67	30	0	0		
Hedyotis degeneri	3	50	67	30	0	0	20(50) = 1000	333
Hedyotis parvula	3	50	67	30	5	335	20(50) = 1000	333
Hesperomannia arbuscula	3	75	101	34	2	202		
Hibiscus brackenridgei subsp. *mokuleianus*	3	50	67	30	4	268		
Lipochaeta tenuifolia	3	50	67	30	0	0		
Neraudia angulata	3	100	134	45	3	402		
Nototrichium humile	3	25	34	30	0	0		
Phyllostegia kaalae	3	50	67	30	3	201		
Plantago princeps var. *princeps*	3	50	67	30	0	0		
Pritchardia kaalae	1	25	30	30	5	150	50(60) = 3,000	1,000
Sanicular mariversa	3	100	134	45	6	804	20(100) = 2000	667
Schiedea kaalae	3	50	67	30	4	268		
Schiedea nuttalii	2	50	63	30	6	378		
Tetramolopium filiforme	3	50	67	30	2	134	20(50) = 1000	333
Viola chamissoniana subsp. *chamissoniana*	3	50	67	30	1	67		
Totals:						5,687		6,736

*1/3 of total or a minimum of 30

9.7 Approach to Plant Stabilization

Development of the stabilization plans

To guide the actions for stabilization, the Implementation Team (IT) gathered information on the threats and habitat needs of the target taxa. The IT then developed a standard template for plants outlining each target taxon's current status, stabilization needs and credits, and required actions for stabilization. Each plant stabilization plan (SP) also includes threat abatement needs, candidate sites for reintroductions, previous propagation and reintroduction attempts, options for seed or other propagation storage, genetic or sanitation issues, and outplanting techniques. The result is 27 plant SPs compiled in Section 2, Chapter 2 of this plan. Protocols to support these stabilization actions were developed for phytosanitation, propagule collection and storage, and monitoring (see Section 3, Appendices 2.2 and 2.1, and Section 2, Chapter 4, respectively). Because *Achatinella mustelina* is the only animal in the Implementation Plan (IP), its SP format differs from that of the plants. ***Each SP must be adhered to, or the IT and the U.S. Fish and Wildlife Service (USFWS) must approve any changes.***

How to use the SPs

Each SP can be used as a stand-alone document that outlines the goals, taxon status, and recommended stabilization actions. These actions have been included in the Implementation Actions Detailed Cost Estimates and Time Schedule in Section 4 of this plan, which provides a detailed summation of the actions and resources needed for the total stabilization effort. For the purposes of specific stabilization actions for each target taxon, that taxon's SP provides the primary guide for management actions.

The goal of each SP is to provide the information and necessary actions to achieve stabilization for each taxon. The strategy is to undertake specific and quantifiable taxon-specific actions, that along with habitat level management actions and adaptive management against changing conditions and/or population unit status, will result in stability for each target taxon. To assist in measuring success and assessing compliance, the use of population unit (PU) credits as a measure of stability allows for clearer documentation of efforts involved (see Chapter 9.2: The Credit System for Plants). To effectively and fairly measure progress, a program of monitoring has been designed to give the IT sufficient data to rigorously assess the success of actions and strategies and guide adaptive management (see Section 2, Chapter 4). Each plan follows a similar outline that provides the following information:

- summarize the current status of known PUs inside and outside of the action area (AA)
- designate specific PUs for *in situ* management actions
- sequencing of actions
- propose and set priorities for reintroductions, if needed
- review taxon-specific data on all stabilization procedures
- define specific methods for the stabilization efforts
- identify needed research and experimentation

What follows is a general description of a typical plant SP, including samples and annotations (marked with the symbol ∇) on the contents of each major section. It follows the framework of an actual SP, and so can be used to help interpret any of the plant SPs.

Stabilization plan for *[target taxon name]*

∇ The title of each SP clearly indicates the target taxon being addressed.

Requirements for Stability

- 3 populations
- [25-100] reproducing individuals ([life span, life form, other factors])
- Threats controlled
- Complete genetic representation in storage

∇ The information presented in this section outlines the criteria for reaching the goal of stability. These are:

1) Number of population units.
2) Number of mature/reproducing individuals per PU, ranging from 25 to 100 based on justifications for the selection of the target number of individuals (see Table 9.1).
3) A statement linking threat control actions to stabilization of population units.
4) A statement requiring complete genetic storage, *i.e.* collection of propagules from a wide enough sample of PUs to guard against loss of wild stock and provide for reintroduction and augmentation actions (following Section 3, Appendix 2.1: Plant Propagule Collection Protocols and any additional details in Step 3 of the stabilization steps, below).

Population Credit System Calculation - *Example Table*							
Current Status							
	Inside Action Area (higher risk or lower risk)			Outside Action Area			
Population Type	Reintro.	Not Stable	Stable	Reintro.	Not Stable	Stable	
Credit Value	0.17 or 0.25	0.25 or 0.375	0.50 or 0.75	0.33	0.50	1.00	
Makua		0.25					
Kaumoku Nui						1.00	
Kaimuhole and Palikea Gulch					0.50		
Kealia					0.50		
Subtotals	0.00	0.25	0.00	0.00	1.00	1.00	TOTAL
		Inside AA	0.25		Outside AA	2.00	2.25
Implementation Targets							
	Inside Action Area (higher risk or lower risk)			Outside Action Area			
Population Type	Reintro.	Not Stable	Stable	Reintro.	Not Stable	Stable	
Credit Value	0.17 or 0.25	0.25 or 0.375	0.50 or 0.75	0.33	0.50	1.00	
Makua		0.25					
Kaumoku Nui						1.00	
Kaimuhole and Palikea Gulch					0.50		
Kealia					0.50		
Reintroduction #1 (in AA) Kaluakauila	0.17						
Reintroduction #2 Lower Keaau				0.33			
Reintroduction #3 Haili to Kawaihapai				0.33			
Reintroduction #4 Kamoukunui and Manuwai				0.33			
Subtotals	0.17	0.25	0.00	1.00	1.00	1.00	TOTAL
		Inside AA	0.42		Outside AA	3.00	3.42

∇ The overview calculation of the credit table is of central importance to the SP, since it reports on the current status of the target taxon (as of the preparation of the IP in early 2002), and then presents the overview of starting implementation targets, totaling at least 3.0 credits (typically greater than that, as explained in Chapter 9.2: The Credit System for Plants). The columns provide key data such as the PU name; its status as stable, not stable or a proposed reintroduction; and the credits assigned according to its stability status and location relative to the AA. Note that the current status portion of the population credit system calculation table outlines the credits received for management of designated *in situ* populations. If the current status credit total is less than the required 3.0 credits, additional management, in the form of reintroductions, is included to meet the requirement. The Implementation Targets table outlines the number of reintroductions needed to bring the credit total to at least the required 3.0 and identifies the most likely sites for reintroduction attempts. This table is not included for taxa with no planned reintroductions.

Management Designations for Existing Population Units - *Example Table*

Population Unit	Management Designation	Management Sequencing			Credits	Number of Individuals (mature/immature)
		A	B	C		
In AA						
Makua	Manage for stability	F	F	FS	0.25	4/3
Out of AA						
Kaumoku Nui	Manage for stability	B	P	FS	0.50	50-100
Kaimuhole and Palikea Gulch	Manage for stability	F	F	FS	0.50	3/5
Kihakapu	Manage as propagule source	B	B	B	0.00	1/2
Kawaihapai	Manage for GSC*	B	NA	NA	0.00	2/0
Kealia	Manage for stability	F	F	F	0.50	2/0

Management sequencing abbreviations: B = baseline PU management, P = partial PU management, F = full PU management, FS = full taxon stabilization, NA = not applicable.
*GSC = genetic storage collection

∇ The Management Designations for Existing Population Units Table describes the *in situ* PUs known for the target taxon that are identified for some level of management. The PU names are given in the "Population Unit" column, followed by the management designation in the "Management Designation" column. This table indicates the recommended management in three categories: manage for stability, manage as a propagule source, and manage for genetic storage collection (for definitions of these categories, see Chapter 9.3: Management Designations). Management Sequencing identifies the level of PU management in each of three phases for PUs designated as manage for stability: B=baseline PU management, P=partial PU management, F=full PU management, and FS=full taxon stabilization (see Chapter 9.4: Sequencing of Actions, for definitions of these categories). Manage as a propagule source PUs receive baseline PU management from the beginning of implementation of the IP through the first phase in which the target taxa receives full taxon-level stabilization. Manage for genetic storage collection PUs receive baseline PU management in Phase A only. The "Credits" column corresponds to the credit system assigned by the USFWS to the efforts needed to achieve stability, and reflects the credits assigned in the Population Credit System Calculation table above. The number of credits varies according to the location of the PU relative to the AA, therefore the table subdivides the PU column into two categories - inside the AA and outside the AA. The “Numbers of Individuals” column provides the most current count of the number of mature (left side of the slash) and immature (right side of the slash) plants, not including seedlings. If there is no slash and only one number or range of numbers, the number of immature vs. mature individuals is not known for that PU.

Reintroduction Site Ranking - *Example Table*

Site	Rank	Number of Sites Available	Habitat Status	Size of Habitat	Proximity to Wild Populations	Appropriat e-ness	TOTAL BIOLOGICAL SCORE
Makua type (short)							
Kaluakauila (AA)	1	1	4	3	5	5	17
Lower Keaau	1	2	3	3	5	5	16
Lower Makaha	2	1	3	3	3	5	14
Kealia type (medium)							
Kawaihapai and Kealia	1	1	3	3	5	5	16
Kaena and Keawaula (Manini)	2	1	3	3	4	5	15
Waialua type (tall)							
Kaumoku Nui and Manuwai	1	1	3	4	5	5	17
Lower Kapuna	1	1	3	4	5	5	17

Habitat status: Scored by percent cover of native vs. alien species: 5 = most native.
Size of habitat: Acres of appropriate habitat in candidate area. Scored by size: 5 = largest.
Proximity to wild populations: in meters from nearest edge of natural population (current or historical). Consideration given to proximity to large, thriving populations vs. marginal populations. Concern over potential augmentation at historical sites. Scored by proximity to current or historical natural populations: 5 = closest (within augmentation guidelines).
Appropriateness: elevation, slope, aspect, substrate conditions, physiognomy, composition, other indications of appropriate habitat. Scored by appropriateness of potential reintroduction site for the target taxa: 5 = most appropriate.

∇ The Reintroduction Site Ranking table is broken into categories most pertinent to the taxon, such as in or out of the AA, North or South Waianae Range, or morphological type. If credit calculations indicate no reintroductions are needed (*i.e.,* there are sufficient numbers of *in situ* population units to manage to meet credit requirements), then the remainder of this document does not address reintroduction details. If there is an immediate need or an expected future need for reintroduction, a Reintroduction Site Ranking table provides a candidate list of reintroduction sites based on the habitat needs for the target taxon. The rankings for the above reintroduction sites are based on biological considerations such as habitat status, and proximity to wild populations (see Reintroduction Site Ranking Table above), and result in the IT's determination of the preferred sites for initial reintroduction attempts. ***The highest ranked (selected) sites must be pursued as sites for the required reintroductions, and the remaining (backup) sites can only be pursued with strong justification, approval of the IT, and concurrence of the USFWS before a lower ranked site is considered.*** The selected and backup sites are displayed on the SP maps for each taxon. Reintroductions in the AA are avoided if there are sites of equal or higher rank outside of the AA.

Taxon-specific issues

∇ This section allows the IT to explain and justify any taxon-specific exceptions to guidelines related to credits and reintroduction, or distances between PUs and/or reintroduction sites or outplanting locations. It typically provides details on those sites in the table above that receive a rank that is inconsistent with the total biological score, or provides justification for assigning different ranks to sites with equivalent total biological scores.

Management requirements

∇ In brief paragraph form, the IT makes its summary recommendation for *in situ* management of PUs, reintroductions (if any) and location of actions relative to the AA.

Previous reintroduction/augmentation activities involving this taxon

∇ Because several of the target taxa have been the focus of previous reintroductions or augmentations, this section provides an opportunity to include details on sites, numbers of plants outplanted, method used, and any information about the success of the effort(s).

STABILIZATION STEPS

∇ The final section of the SP takes the form of an outline that deals with genetic (propagule) storage, propagation for reintroduction, actual reintroduction (including site and habitat preparation), post planting care, and research. In the outline below, notes on the typical information content of the SP are shown.

1) Genetic storage options and recommendations

∇ This item summarizes information relating to previous attempts to test seed storage potential by Lyon Arboretum and/or the National Seed Storage Laboratory (NSSL), with notes on potential for long-term drying and freezing. Alternate storage options are described when methods have been tested and found viable (*e.g.*, *in vitro* culture, cultivation, micropropagation). In this section, the IT makes its recommendations for the best storage option based on currently available information, with the assumption that knowledge gained from the storage testing will be reviewed by the IT before making final decisions on storage methods for each taxon.

2) Storage and propagation protocol development

∇ This section gives recommendations for collection of (typically) 50 to 200 seeds for genetic storage testing and propagation testing are specified here, following collection guidelines (see Section 3, Appendix 2.1: Plant Propagule Collection Protocols). If storage options are not already known, see stabilization step 1. These guidelines are recommendations based on the best available knowledge, and deviations from them will be reviewed by the IT.

3) Propagule collection for genetic storage in initial years of each phase until goal is reached

∇ This section identifies propagule collection methods for storage from fruiting or non-fruiting individuals, as well as numbers of propagules to collect from various PUs, based on management designation and PU size, following the guidelines in Section 3, Appendix 2.1: Plant Propagule Collection Protocols. The guidelines to minimize harm to wild plants (see Section 3, Appendix 2.4: HRPRG Collecting and Handling Protocols) should be adhered to for all collections.

4) Propagule collection for reintroduction and augmentation
(over successive years until goal is reached, with care to integrate seed collection, avoiding over-collection)

∇ This section identifies propagule collection methods for reintroduction/augmentation from fruiting or non-fruiting individuals, as well as numbers of propagules to collect from source PUs. Source PUs are identified below in 6b, the Founding Population section, following the guidelines in Section 3, Appendix 2.1: Plant Propagule Collection Protocols. The guidelines for collection to minimize harm to wild plants (see Section 3, Appendix 2.4: HRPRG Collecting and Handling Protocols) should be adhered to for all collections.

5) Considerations for propagation for reintroduction and augmentation
(treatment must be consistent and documented for all individuals)

∇ Specific instructions for propagation for outplantings are made here, including size at outplanting, pot size and shape, options to fertilize, plant hardening, potting medium, *etc*.

6) Reintroduction and augmentation

∇ Details of reintroduction protocols are presented here, including the following major factors:

a) Micro-site characteristics (consistent with Hawaii Rare Plant Restoration Group (HRPRG) Field Data form).
Characteristics of an appropriate planting site are provided, such as habitat type, slope, aspect, sun/shade, substrate, associated taxa, and degree of acceptable degradation.

b) Founding population (maternal parentage)
Specific PUs are identified from which to develop outplanting stock at specific reintroduction/augmentation sites.

c) Number of propagules to plant
Initial numbers are based on the specific goal of individuals per site, and observed or expected taxon survival ratios (see Table 9.13).

d) Site preparation and management
Site preparation details such as planting hole diameter and depth, seed pre-treatment, watering regimes, composting, fertilization, and threat control are provided.

e) When to plant
Time of year to plant and planting schedules over the first years of reintroduction are identified.

7) Research and experimentation

∇ This item varies greatly from taxon to taxon according to known research needs, but may include small-scale seed sowing experiments, or specific research on limiting factors such as pest control.

8) Other priority actions

∇ Actions beyond standard stabilization measures are given here, such as surveys for new populations or genetic studies. Actions are required unless indicated as optional.

END OF STABILIZATION PLAN

10.0 Long-term Threat Management Goals in Management Units

The level of threat control varies according to the type of threat, the current methods of control and their efficacy, as well as the purpose of the threat control. It is feasible and necessary to eradicate ungulates within the entirety of fenced management units (MUs) to achieve adequate protection of target taxa and maintenance and improvement of their habitat. The level of weed control will be more intensive in the immediate vicinity of target taxa population units (PUs) but this level of weed control is not feasible or reasonable for the larger MUs for weeds that are not imminent threats to the maintenance and improvement of the habitat. For smaller MUs, the PU proximity distance fills the MU, and therefore larger-scale habitat management for weeds will not be undertaken. While many invertebrates are serious pests to the target taxa and the component taxa of their habitat, broad-scale control methods for these taxa are unknown at this time. Goals for threat control vary according to the threat type and the size of the area being managed.

Three levels of threat management were developed: 1) the immediate vicinity of individual plants of target taxa, 2) the entire area of a PU of a taxon, which may vary from a small cluster of individuals within a few square meters to a larger area containing hundreds of individual plants, but considered a single PU, and 3) an entire MU or MU subunit. As may be expected, threat control can be exercised most fully within a small area and goals for threat control include total eradication of all weeds within two meters of individuals of target taxa. In contrast, only incipient invasive weeds shall be eradicated at the scale of the PU (50 meter proximity) and the MU of MU subunit. For other weeds, the goals are expressed in terms of cover in the surrounding vegetation: no more than 25% of existing cover in the proximity of PUs, and no more than 50% total cover across the MU or MU subunit. Cover percentage includes canopy and subcanopy layers as appropriate.

Because threat management goals may take years to realize, they are characterized as long-term targets even though they will be initiated shortly after phased management has begun in a given MU or PU. Table 10.1 summarizes the threat control goals at the three scales described above, for all major types of threats. Some threats are only controllable at the smallest scales and no goals are appropriate or applicable at larger ones. Where control is not applicable, the cell is filled "NA." ***The Implementation Team (IT) must approve the final decisions as to what level of control is acceptable in a given MU or MU subunit.***

Table 10.1 Threat Management Goals at Three Scales of Management

	Proximity of Individuals (2 m radius)	Proximity of PUs (50 m buffer)	Within the MU or MU subunit
Threats:			
Fire	zero incidence	zero incidence	zero incidence
Ungulates	total removal	total removal	total removal
Incipient invasive weeds	total removal	total removal	total removal
Percent cover of other weeds	0%	25%	50%
Small mammals*	total removal	total removal	NA
*Euglandina rosea**	total removal	total removal	NA
Other invertebrates*	total removal	NA	NA
Human impacts (other than management)	no impact	no impact	no impact

* Control only if threatening target taxon

The target percentages for alien vegetation are viewed as a general guideline, and the IT recognizes that modifications may be made upon development of the specific MU management plans. For example, certain native target taxa might be particularly sensitive to alien competition and alien-dominated habitat, while others might be able to tolerate high percentages of certain alien taxa. Taxon-specific weed target guidelines can be designated for each of the target taxa, and applied at the PU level upward. Assuming that MUs contain some large areas of alien-dominated vegetation, and a wide spectrum from completely non-native to mostly native-dominated areas, weed control will have to be defined by an average of weed frequency and cover over the entire MU. Alternately, the most important MU areas can be stratified according to habitat type and quality, and weed control can occur with greater intensity in those areas most appropriate for stabilization of the target taxa. ***Any changes of this type recommended in MU threat management plans must be approved by the IT.***

11.0 Monitoring and Adaptive Management

Adaptive management is management designed to change with conditions and information, using the results of monitoring and other new information to refine the design, scope, or implementation of management actions or the monitoring program for an area or a taxon. Dynamic systems may be difficult to predict, but there are underlying rules and guidelines that can direct changes in management actions according to the results from previous actions. The population status and trends of the target taxa and their habitats are not static, but changing, and we have some idea of their likely response to the management recommended. However, the kind of management, and the intensity and timing of application depend on how the target taxa respond initially to the first actions applied. Accurately assessing the changes in status of target population units (PUs), or the response of other factors affected by management, is the intent of monitoring. Monitoring is an essential and integral part of adaptive management.

Monitoring of the *in situ* and reintroduction populations will be conducted to determine progress toward attaining taxon stability. Monitoring will also be conducted to assess the status of the management unit (MU) relative to control of alien taxa and to habitat restoration (for detailed monitoring protocols see Section 2, Chapter 4: Monitoring). Data to be collected will include number, vigor, and phenological phase of all or samples of the individuals in the PU by size class. This information will be evaluated using an appropriate statistical analysis to assess current and projected status of the monitored PU. Adaptive modifications to the *in situ* management, augmentation, or reintroduction strategies for the PUs for each taxon and each MU will be made based on the results of the monitoring program, and as research results in new information on reintroduction methods and threat control methods. While the stabilization of the PU is the end goal, changes in management of the PU, threats to the PU, and the surrounding habitat must be monitored to determine which factors are affecting the ability to reach stability. Adaptive management options to consider include, but are not limited to:

- increasing or decreasing the number of plants outplanted into a site annually during the initial reintroduction phase
- (re)initiating reintroduction or augmentation efforts for a particular PU;
- intensifying or changing post-planting care (*e.g.*, watering)
- increasing or decreasing the control of specific threats as indicated by threat monitoring

The comprehensive monitoring plan developed by the Implementation Team (IT) can be found in Section 2, Chapter 4. ***Final decisions to change management actions must be approved by the IT and the U.S. Fish and Wildlife Service.***

12.0 Information Management

Makua implementation database

At the outset of this multi-year project, the Implementation Team (IT) anticipated that there would be a tremendous amount of data generated by the overall taxon stabilization planning effort, as well as over the decades of implementation management to come. In response, a single database system called the Makua Implementation Database was created along with supporting geographic information system (GIS) map layers to help compile, manage, analyze, and display the data. The database module currently in use tracks the location, status, threats, and management of the individual *in situ* target taxa, population units (PUs), management units, and reintroduction sites throughout the Waianae Mountains on Oahu, and at other locations in the islands specified for management activities. Various supporting database tables, menus, forms, queries and reports were developed specific to this effort as outlined by the IT.

GIS map layers were also developed to assist the IT with the complex geographic and managerial issues associated with the location of the target taxa and their proximity to training areas, corresponding land use designations, management practices, and land ownership. For example, it is much easier to plan the best route of a new fence when that route is overlaid on topographic and ownership map layers to help avoid locating fences on unsuitable terrain that would increase costs, as well as to identify the appropriate party with whom the U.S. Army (Army) would have to negotiate to seek permission for the fence building project. Another example involves the location of target taxa relative to low and high-risk fire zones which effects the type of management planned for that particular population unit. The GIS map layers developed for this project provide location and attribute information on both natural and cultural features such as fire risk and history, the action area boundary, rare taxa, ownership and lessee information, management type and/or jurisdiction, land use, vegetation, elevation, roads, streams, and topography, as well as population units, proposed management units, and existing and proposed fence lines. The Makua Implementation Database and GIS were utilized throughout the development of the Implementation Plan (IP) to help facilitate discussion at meetings, planning, and decision-making.

Data integration and inter-agency cooperation

The success of the IP depends on the cooperation of multiple agencies, combining efforts to eliminate duplication of effort, sharing lessons learned, and thus increasing effectiveness. The IT is a good example of this spirit of cooperation, but it needs to go further to effectively coordinate diverse agencies with differing management protocols, monitoring procedures, collection guidelines, and strategies. Currently, most of the IT members and contractors already collect data on target taxa under their jurisdiction. The data is stored in various forms, at different office locations. Much of it is still in field notebooks and field forms, some of which has found its way into spreadsheets, flat files, and burgeoning databases and GIS map layers.

There is a real need to standardize data collection, and mapping and database procedures among the partner agencies so that this data can be incorporated into an integrated, uniform GIS and database management system accessible by the various contributors. The wealth of data can then be more readily compiled, analyzed, and synthesized, thus turning it into a tool to assist the Army and IT members in making wise management decisions. The development of a centralized

GIS and monitoring database for the storage, management, analysis, visualization, and reporting of monitoring, collection, and propagation data to facilitate the management of the target taxa PUs is vital to the implementation of the IP.

Of primary importance is the monitoring module of the database that will aid the Army in future adaptive management needs. Such a system would allow the Army and the IT to gauge the effectiveness of management practices such as threat control, assess the effectiveness of sampling strategies, and fine-tune sampling rates. The collection and propagule module will allow the Army and IT to track the life cycle of a seed, propagule, or individual "from cradle to grave," including its parentage, time spent and treatment while in the nursery, outplanting or release location, and survival and growth over time. As field protocols and monitoring procedures are implemented, related database procedures will be included and/or modified to ensure data integrity and efficient data entry and analysis. There will be feedback loops built in and critical success factors established to allow for automated flagging of changes needed in management practices. This capability is essential for adaptive management strategies.

Development of the centralized monitoring database and GIS

A centralized monitoring database and GIS must be developed to handle the copious amounts of data that this implementation process will generate. This will include database protocols, field names, forms, tables, and reports necessary for the successful implementation of this multi-agency monitoring effort. Procedures for the use of global positioning systems (GPS) and hand-held electronic devices for collecting field data will also be developed to increase the accuracy and efficiency of the monitoring process, eliminate redundancy of effort (*e.g.*, data entry of hand-written field notes), and reduce the likelihood of data entry errors for the monitoring data. The foundation for fields and database structure of the collection and propagation module will be the existing guidelines and field forms of the Hawaii Rare Plant Restoration Group (HRPRG). (see Section 3, Appendix 2.3: HRPRG Guidelines for Rare Plant Inventory, Monitoring and Collecting.)

During the development of the centralized GIS and monitoring database system, the original ownership of the data will be preserved if requested. “Preserving the ownership" means that the person or organization responsible for the collection and/or maintenance of that data on a day-to-day basis retains possession and control of the original data, and sends periodic updates to a central data repository on a platform accessible by all potential users.

The monitoring module as well as the collection and propagation module will be built upon the existing Makua Implementation Database in MicroSoft Access 2000 or higher. The GIS will continue to be built using Environmental Systems Research Institute (ESRI) ArcView software, version 3.2 or higher. The database will be integrated into the GIS so that the map layers access the primary database information directly from MicroSoft Access. Mapping and data entry will take place from this integrated GIS-database platform.

The centralized GIS and monitoring database system will be housed on an Internet Map Server at a site yet to be specified, and the data will be made available through the Internet to IT members and to involved landowners via a password-protected website. The website will allow the user to design customized maps, query data, and conduct analyses such as buffering and other spatial queries, as well as to download selected data to their computer systems for further study using ArcView, ArcExplorer or any other GIS software package that supports the ESRI shapefile format. Access to change data will be restricted to authorized users. The site will integrate U.S. Geological Service 7.5 minute digital maps, satellite imagery, and other publicly available geographic or topographic information to enhance the user's sense of location. Customized tools and instructions will be created to assist the user with common tasks and queries.

Copies of the centralized GIS and monitoring database system will also be given to those IT members who wish to work on their own computer systems and/or maintain responsibility for data entry of monitoring data for sites on their land. Each distributed database will have export features facilitating the transfer of data from the IT members to the centralized database. A set of procedures will be created and followed to guarantee quality assurance and quality control of all data provided to the centralized database from the Army, IT members, and landowners.

13.0 Measures of Success

The long-term goal of stabilization of the target taxa is likely to be realized only after decades of management action. The short- and intermediate-term measures of success are defined by the successful completion of the actions during the early periods of each phase of the implementation schedule proposed by the Implementation Plan (IP), supported and assessed by monitoring data that indicate the positive effects of such management. Given the many variables related to the achievement of stability, the Implementation Team (IT) cannot offer specific biological expectations for the response of the different target taxa to management. Instead, implementation of management actions according to the implementation schedule will be used by the IT and U.S. Fish and Wildlife Service (USFWS) to assess success in the short term. However, it is intended that biological criteria will be used to a greater extent to assess success in the intermediate and long term. Monitoring of the change in status of taxa and habitats is the key to quantified assessment of results of management against expectations.

Milestones in the measures of success

The following is an outline of expected milestones in the short-, intermediate-, and long-term that will be monitored by the U.S. Army, the IT, and the USFWS, and used to assess compliance with the Endangered Species Act. It is expected that after goals are achieved, maintenance of the actions will continue as needed to ensure stabilization of the target taxa. Except for urgent actions, all periods of completion are denoted relative to year 0, where year 0 starts at the time USFWS approves the final IP. Urgent actions are defined as those actions that are best implemented before completion of the IP because, where imminent threats are serious for a subset of target taxa and populations, certain management actions are urgently needed. Because 38 of 52 management units (MUs)/subunits (*i.e.*, 73%) are being implemented in Phase A, a period of several years is allowed for completion of most MU actions in this phase whereas a single year is allotted for completion of the same action in Phases B and C.

A prioritized action table (see Section 4) was developed by the IT to summarize the specific actions for target taxa and MUs required in the initial years of the IP implementation and in each of the implementation phases. This serves as the basis for the short, intermediate, and long-term goals as outlined in the table below.

SHORT-TERM GOALS: Urgent actions, initiation of research and collection, and initiation of administrative programs

	Phase A (Years 1-13)	Phase B (Years 14-23)	Phase C (Years 24-33)
Urgent actions – set 1	(Year 2002)		
Urgent actions – set 2	(Year 2003)		
Urgent actions – set 3	(Year 2004)		
Start up: Hire/train initial staff, select sites for and set up infrastructure	0-1		
Complete programmatic NEPA process	0-1		
Complete landowner negotiations	0-1		
Initiate baseline management and monitoring for all managed populations (*manage for stability, manage as a propagule source* and *collect for genetic storage populations*)	1-2		
Complete genetic storage testing	1-2		
Complete all required surveys	1-2		
Complete collection of all taxa for genetic storage	1-3	14-16 (refresh stock)	24-26 (refresh stock)
Initiate proposed research / experimentation	1-3		
Complete Fire Management Plan and Annexes	1-3	12 (update annexes)	22 (update annexes)
Complete propagation testing	1-4		

SHORT-TERM GOALS: Management unit startup

	Phase A (Years 1-13)	Phase B (Years 14-23)	Phase C (Years 24-33)
Scope fencelines	2-3	12	22
Obtain MU/subunit CDUAs	3-4	13	22
Clear MU/subunit fencelines	3-5	14	24
Implement MU-level monitoring for entire MU/subunit	2-5	14	24
Implement FMU Fire Management Plans	2-5	14	24
Develop MU/subunit Alien Plant Control Plans	2-5	14	24
Develop MU/subunit Ungulate Control Plans	2-5	14	24
Construct MU/subunit fences	4-8	15	25
Implement MU/subunit ungulate control	3-8	15	25
Develop Overall MU/subunit Plan	3-8	15	25
Refine sampling framework for MU monitoring program	by year 8	-	-

SHORT-TERM GOALS: Initiation of population unit (PU) actions

	Phase A (Years 1-13)	Phase B (Years 14-23)	Phase C (Years 24-33)
Initiate full stabilization actions (MU/subunit threat control and full PU management)	4-7	14-16	24-26
Initial outplanting effort [1]	By year 7 (FS)[2] By year 10 (other)	-	-
Initiate remaining reintroductions	9-11	19-21	29-31
Refine sampling framework for PU monitoring program	by year 8	-	-

INTERMEDIATE-TERM GOALS: 10-25 Years After Initiation of Full Stabilization [3]

	Full Stabilization in Phase A	Full Stabilization in Phase B	Full Stabilization in Phase C
Achieve MU threat target levels	14-32	24-41	34-51
Reverse and reduce decline trends			
Demonstrate regeneration, improved vigor and improved habitat condition			
Achieve stabilization of short-lived taxa by 25 years after initiation of full stabilization	By 29-34	By 39-41	By 49-51

LONG-TERM GOALS: >25 Years After Initiation of Full Stabilization [3]

	Full Stabilization in Phase A	Full Stabilization in Phase B	Full Stabilization in Phase C
Achieve stabilization of long-lived taxa by 50 years after initiation of full stabilization	By 54-59	By 64-66	By 74-76

[1] For all taxa requiring reintroduction
[2] Full Stabilization taxa
[3] Assumed to be the time when full stabilization actions are initiated at *in situ* populations

14.0 The Future of the Implementation Team

The actions identified by the Implementation Team (IT) in the Implementation Plan (IP) are expected to take decades to implement, and the adaptive management process requires ongoing biological management applied at both the individual (population unit (PU)) and habitat (management unit (MU)) levels. The IP requires an annual review workshop (*ca.* one week-long) prepared and conducted by the U.S. Army (Army) and with the U.S. Fish and Wildlife Service (USFWS) and the IT, regarding aspects of the Makua IP, and involving all major participants of the implementation programs. The intent of the annual meetings is to review: 1) progress reports prepared by the Army and its contractors on actions over the past year, 2) monitoring results, and 3) proposed actions for coming years. The timeframe for this annual meeting will probably coincide with the closing quarter of the federal fiscal year (*e.g.*, August-September). These workshops will result in modifications of the IP and the actions and timetables, based on previous results and progress. If there are significant deviations from the IP in between annual meetings, the Army should consider, in consultation with the USFWS, the need to convene special meetings with the IT to ensure that progress is being made toward stabilization goals so that the Army maintains compliance with the Endangered Species Act.

Some conditions under which the IT may be convened beyond annual meetings:

- major change of target PU or MU status (*e.g.*, hurricane, large fire, extensive failure of a management effort or reintroduction attempt)
- major divergence from the IP action list or timetable (*e.g.*, reassessment of sites for reintroduction, inability to develop agreement with landowner for any MU)
- landowner conflicts or changes in MU agreements
- potential or actual legal challenges to the IP

It is clear that in a process intended to take decades to accomplish, the current IT cannot be expected to serve over the entire course of the implementation. As members change, the composition of the future IT should follow the current model with modifications to ensure ongoing representation of the major stakeholders and the expertise listed below. Involvement of specific stakeholders or experts depends on the issues being addressed in specific meetings, but at a minimum must include:

- Army representation
- USFWS representation
- Current or potentially collaborating landowners
- Rare plant expertise
- Native ecosystem expertise
- *Achatinella* snail expertise
- Wildland fire expertise
- Monitoring/data analysis expertise
- GIS/data management expertise
- Facilitation expertise
- Trainees/apprentices/successors as potential future members of the IT

46 Given the composition of future ITs as identified above, the adaptive management recommended in this plan will have continuity of guidance to see it through its long-term goals.

15.0 Conclusion

The Implementation Team (IT) believes that stabilization of the 28 Makua target taxa can be achieved through a program of adaptive management applied at both the individual levels of target taxa (population unit (PU)) and habitat levels (management unit (MU)). The categories of management actions needed include:

- a program of threat abatement directed at individuals, PUs, and MUs,
- a reintroduction program establishing multiple managed populations,
- an augmentation program bolstering selected PUs as needed,
- a genetic storage program securing the source for future propagation efforts,
- selected research directed at threat abatement and rare taxon biology, and
- a monitoring program to assess response to taxon and habitat management actions and to determine if stabilization goals are met.

These efforts represent thousands of separate, but related tasks, arranged as a cascade of subtasks on the initiation of any of the major programs outlined above. The IT, utilizing biological criteria, established priorities for implementation of these tasks and subtasks over a 33-year period (see Section 4), which carry the process from its inception to the achievement of stabilization, decades from now. With such a long-term goal, no static plan can deal with the many contingencies and decisions that biological management generates. Only a program of monitoring and dynamic response to feedback under the guidance of experts such as those serving on the Makua IT will provide the most appropriate course toward stabilization and compliance.

The Implementation Plan (IP) requires the U.S. Army (Army) to continue as an active member of regional conservation efforts in support of stabilization of the target taxa. 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 Hawaii. Successful implementation of the IP assures that the Army will be in compliance with the Endangered Species Act and still accomplish its training mission.

16.0 Taxon Summaries

Development methods

For each of the 28 target taxa (27 plants and 1 snail), background information summaries were compiled. Implementation Team (IT) experts utilized their extensive experience with the target taxa in the field to provide key assessments of the biology, history, and current status of the taxa. Taxon summaries information was further supplemented by biological summaries originally provided in the U.S. Fish and Wildlife Service (USFWS) Biological Opinion (1999b), the Makua Endangered Taxon Stabilization Plan (USFWS 1999), and the Hawaii Natural Heritage Program (HINHP) database. For each taxon, the following information was determined and compiled:

- **Image**: a photograph of the target taxon.
- **Scientific name**: genus and species, with subspecific epithets as necessary, and author.
- **Hawaiian name**: if available.
- **Family**: name of the family to which the target taxon belongs, followed by its common name.
- **Federal status**: official USFWS published status designation (*e.g.*, listed endangered)
- **Description and biology**: habit (*e.g.*, tree, shrub, *etc*.), life-span (*e.g.*, annual, perennial, short-lived), followed by any details on the biology of the taxon, including pollination biology, dispersal, and specific environmental requirements (if known). This section is largely based on Wagner *et al*. (1990).
- **Known distribution**: the recorded historic range of the taxon, according to HINHP.
- **Population trends**: the trends in the numbers and status of the taxon, according to HINHP.
- **Current status**: the current distribution of the taxon, and numbers of known plants, according to HINHP.
- **Habitat**: typical elevation, moisture, and habitat details (Lau, Kawelo, Rohrer, Yoshioka, Takahama, pers. comm.).
- **Threats**: known threats to the target taxon are listed, including feral ungulates, rats, predators, insect pests, diseases, fire, and human disturbance, as applicable.
- **Taxonomic background**: variation in morphology and nomenclature, and any issues or ambiguities in taxonomy.
- **Outplanting considerations**: concerns regarding unwanted hybridization with closely related taxa or other potential hybridization relationships are discussed.
- **Table 1: Current Population Units:** This table includes a summary of the population units (PUs), the number of individuals in each PU, and the proposed management status.
- **Table 2: Site Characteristics for Population Units Proposed for Management for Stability.** Only PUs designated for management to stability are included in this table (see Chapter 9.3 for definition of manage for stability). This table contains a summary of information for site characteristics assigned by the IT such as habitat quality, terrain, accessibility, and existing fences. Definitions for table entries are as follows:

Habitat Quality Type	Habitat Quality Type Definition
High	>75% native cover in management focus
High-Medium	50-75% native cover in management focus
Medium-Low	25-50% native cover in management focus
Low	<25% native cover in management focus

Terrain Type	Terrain Type Definition
Flat	0-10 degrees
Moderate	10-45 degrees
Steep	45-70 degrees
Vertical	70-90 degrees

Accessibility Type	Accessibility Type Definition
High	2 hour round trip or less
Medium	Day trip, 2-8 hour round trip
Low	8+ hour back pack, or helicopter, or cliff site

Fence Type	Existing Fence Description
Small	Small fence <10 acres
Large	Large fence >10 acres
None	None, no fence yet

- **Table 3: Threats to Population Units Proposed for Management for Stability.** This table summarizes threats to PUs, including ungulates, fire, rats, insect pests, erosion, and human disturbance. Only PUs designated for management to stability are included in this (see Chapter 9.3 for definition of manage for stability). Definitions for table entries are as follows:

Pig and Goat Threat Type	Pig and Goat Threat Definition
High	Sign seen each visitation at immediate vicinity and imminent risk of extirpation of population
Medium	Sign not seen in immediate vicinity but seen within area of management focus (*i.e.,* habitat) and/or risk of extirpation of populations in the foreseeable future
Low	No sign seen or population within a fence
Unknown	Research or monitoring needed, but possible threat
N/A	Not Applicable, not a threat

Weed Threat Type	Weed Threat Type Definition
High	Intense competition, high potential for loss
Medium	Moderate competition
Low	Minimal competition
Unknown	Research or monitoring needed, but possible threat
N/A	Not Applicable, not a threat

Rat Type	Rat Type Definition
High	Taxon susceptible, site impact observed
Low	Taxon susceptible, site impact not observed
Unknown	Research or monitoring needed, but possible threat.
Unknown A	Taxon groups not known or suspected to be susceptible, but more information needed
Unknown B	Taxon susceptible, site impact unknown
N/A	Best information indicated, taxon not threatened

Black Twig Borer Type	Black Twig Borer Type Definition
High	Taxon susceptible, site impact observed
Low	Taxon susceptible, site impact not observed
Unknown A	Taxon groups not known or suspected to be susceptible, but more information needed
Unknown B	Taxon susceptible, site impact unknown
N/A	Best information indicated, taxon not threatened

Other Arthropods	Other Arthropods Definition
High	Taxon susceptible, site impact observed
Low	Taxon susceptible, site impact not observed
Unknown	Research or monitoring needed, but possible threat.
Unknown A	Taxon groups not known or suspected to be susceptible, but more information needed
Unknown B	Taxon susceptible, site impact unknown
N/A	Best information indicated, taxon not threatened

Slug and Snail Type	Slug & Snail Type Definition
High	Taxon susceptible, site impact observed
Low	Taxon susceptible, site impact not observed
Unknown	Research or monitoring needed, but possible threat.
Unknown A	Taxon groups not known or suspected to be susceptible, but more information needed
Unknown B	Taxon susceptible, site impact unknown
N/A	Best information indicated, taxon not threatened

Fire Ignition Type	Fire Ignition Type Definition
Very High	Live fire military training, history of arson
High	Campfires, history of agricultural fires
Medium	Dirt bikes, off-road vehicles
Low	General recreational use (hikes, hunters)
Unknown	Research or monitoring needed, but possible threat
N/A	Not Applicable, not a threat

Fire Fuel Type	Fire Fuel Type Definition
Very High	Continuous cover of flashy fuels
High	Dry natural community, or natural community/cliff area adjacent to flashy fuels, or south aspect
Medium	Mesic natural community, or areas buffered by light flashy fuels, or north aspect
Low	Wet natural community, and/or area geographically separated from light flashy fuels
Unknown	Research or monitoring needed, but possible threat
N/A	Not Applicable, not a threat

Erosion Type	Erosion Type Definition
High	Immediate vicinity eroding
Medium	Habitat impacted by erosion
Low	No erosional impact observed or suspected, minimal threat
Unknown	Research or monitoring needed, but possible threat
N/A	Not Applicable, not a threat

Human Disturbance Type	Human Disturbance Type Definition
High	Adjacent to road or trail
Medium	Off trail, or hunting accessible
Low	Remote or far from trail, or on cliff
Unknown	Research or monitoring needed, but possible threat
N/A	Not Applicable, not a threat

The taxon summaries reflect the current status of each of the target taxa and are meant to supercede any previous summaries of their status. Population declines, increases, and new populations are included in the summaries. When information was considered incomplete or outdated (using a 10-year general guideline), field surveys by members of the IT and the U.S. Army were conducted. Project surveys investigated historical sites, attempting to confirm the persistence of individuals, and expanded on surveys in the action area (AA). These surveys resulted not only in documentation of additional individuals, but also in the discovery of two endangered taxa requiring stabilization that were not previously documented in the AA (*Chamaesyce celastroides* var. *kaenana* and *Hibiscus brackenridgei* subsp. *mokuleianus*). Both taxa were added to the target taxon list and incorporated into the Implementation Plan.

To assess the current status of the endangered snail *Achatinella mustelina*, a combination of field surveys, management assessments, and genetic sampling was conducted throughout the Waianae Mountains. The results are reflected in the *A. mustelina* taxon summary, and the stabilization plan in Section 2, Chapter 2.1.

16.1 Taxon Summary: *Achatinella mustelina*

Photographer: M. Hadfield

Scientific name: *Achatinella mustelina* Mighels, 1845
Hawaiian name: *pupu kanioe, pupu kuahiwi, kahuli*
Family: Achatinellidae (Endemic Hawaiian Tree Snails are in the subfamily Achatinellinae)
Federal status: Listed endangered (all species of the genus *Achatinella*)

Description and biology: *Achatinella mustelina* is a species of long-lived tree snail. Adults are relatively large, reaching lengths of up to 22 mm at maturity. Shell color is variable, often dark brown with a light band or white with numerous transverse brown or black lines. Shell morphology and geographic location are used to distinguish *A. mustelina* from other species of *Achatinella* (USFWS 1993a).

A. mustelina is primarily nocturnal, preferring cool, humid conditions when moving about. During the day, the snails usually seal themselves to leaves or trunks and remain motionless until nightfall (USFWS 1993a). Individuals are hermaphroditic, but it has not been determined if they are capable of self-fertilization. Like all members of its genus, *A. mustelina* bears live young after a lengthy gestation. Individuals are about 4.5 mm long at birth and grow slowly to lengths of 19-22 mm long when they become reproductively mature at 3-5 years of age. Mature snails produce 4-7 offspring per year and can live to be over ten years of age (Hadfield *et al.* 1993).

Known distribution: *A. mustelina* has been recorded throughout the Waianae range on Oahu (Pilsbry and Cooke 1912-1914). The range of this species was once nearly continuous from the southernmost Waianaes through to the northernmost Waianaes.

Field surveys conducted from April through June 2000 located populations of *A. mustelina* in 23 locations (some quite close together). Tissue samples were taken from snails in 18 locations, and genetic analyses were done on three snails in each population (see Section 2, Chapter 2.1: Stabilization Plan for *Achatinella mustelina*). The results indicated the presence of eight ecologically significant units (ESUs), that is, genetically distinct groups distributed down the length of the Waianae Range.

Population trends: Many of the populations that have been observed on multiple occasions in recent years have declined significantly. This species is currently not found anywhere below 1,800 ft in elevation. A population of snails at Pahole Natural Area Reserve has recently declined significantly due to rat predation (Takahama pers. comm. 2000). The population of *A. mustelina* in the Makua Military Reservation at Ohikilolo has declined due to dieback of its host tree, *Myrsine lessertiana,* in recent years (Kawelo pers. comm. 2000), caused in part from browsing by feral goats.

Current status: Currently, this species is known from 23 populations in the Waianae Mountains, totaling approximately 950 individuals. Four populations, with a total of 430 individuals, are found within the Makua action area. The population units of *A. mustelina* are listed in Table 16.1, and their distribution is shown on Map 16.1. Table 16.2 identifies site characteristics for all sites selected for management or candidates for management, and Table 16.3 identifies threats to the snails at those sites.

Habitat: *A. mustelina* is arboreal; these snails spend most of their lives in trees or bushes where they feed on fungi scraped from the surfaces of leaves (Pilsbry and Cooke 1912-1914). *A. mustelina* is generally found in mesic forests on a few species of native trees and shrubs and is rarely seen on alien vegetation. Trees and shrubs *A. mustelina* commonly inhabits include *Metrosideros polymorpha, Coprosma* spp., *Dubautia plantanginea, Myrsine lessertiana, Pisonia sandwicensis, Antidesma platyphyllum* and *Nestegis sandwicensis.*

Taxonomic background: The genus *Achatinella* is restricted to the island of Oahu in the Hawaiian Islands. This genus originally included 41 species, each endemic to a small region of either the Koolau or Waianae Mountain ranges (Hadfield *et al*. 1993). Over-collection of the snails for their shells, predation, and habitat degradation have been the major causes of decline for this species. All 41 species in the genus are federally listed as endangered. As of 1993, 16 species were extinct, five had not been seen in over 15 years, and 18 of the remaining 20 species were on the verge of extinction (USFWS 1993a). Only *A. mustelina* and *A. sowerbyana* still exist in substantial numbers, though their numbers are declining (USFWS 1993a, Hadfield *et al*. 1993).

Reintroduction considerations: Habitat is an important consideration in choosing potential reintroduction sites. Sites with a similar elevation to the source snail population should be selected. Vegetation should be composed mostly of known host vegetation for *A. mustelina*, preferably similar to that of the source population. There should be a low incidence of invasive weeds and trees, and no evidence of rats or carnivorous snails. When introducing captive snails into the wild, care must be taken to avoid the introduction of pathogens.

Previous reintroductions of *A. mustelina* have shown that in the absence of predation, reintroduction can be successful (see Section 2, Chapter 2.0: Approach to *Achatinella mustelina* Stabilization). It is therefore important to bait rats and carnivorous snails at all reintroduction sites, and to build a snail predator exclosure if topography allows it.

It is important that no mixing of ESUs take place during augmentation of existing populations or during reintroductions into new sites. To avoid mixing, only individuals from an ESU or their progeny should be used at any location within the range of that ESU. An effort should be made to establish maximum genetic diversity within each reintroduction group based on molecular genetic data of laboratory stocks. It is optimal to introduce mainly adult or large sub-adult snails.

Threats: The major threats to *A. mustelina* include habitat destruction by feral ungulates and human activities, loss of host plants due to competition from alien plant species, fire, and predation. The carnivorous snail *Euglandina rosea*, the Polynesian rat (*Rattus exulans*), the European rat (*Rattus rattus),* and the Norwegian rat (*Rattus norvegicus*) all prey upon *A. mustelina.* The terrestrial flatworm *Platydemis manokwari* is a known predator of arboreal snails in other areas and is a potential threat to all *Achatinella* species if it ever becomes established within the snail's range (Hadfield pers. comm. 2000). Low reproductive rates and limited dispersal abilities make *A. mustelina* very sensitive to loss of habitat, shell collecting, and predation (Hadfield 1986).

Table 16.1 Current Population Units of *Achatinella mustelina*. Populations selected for management or candidates for management are shaded.

ESU	Site No.	Population Name	Total Number of Individuals	No Management Proposed	Management Proposed
A	1	Kahanahaiki	55	0	55
A	2	Pahole	50	0	50
A	3	Kapuna	25	25	0
B	4	Ohikilolo	300	0	300
B	5	Central Makaleha (culvert 39)	81	0	81
B	6	East Makaleha (culvert 45)	29	0	29
B	7	East Makaleha (culvert 67)	40	0	40
C	8	Schofield West Range/ Haleauau	18	0	18
D	9	Alaiheihe	25	0	25
E	10	Palikea Gulch	7	0	7
F	11	Waianae Kai	12	0	12
F	12	Waianae Kai	20	0	20
F	13	Puu Kalena	37	37	0
F	14	Puu Hapapa	36	36	0
F	15	Schofield South Range	32	0	32
F	16	Kaluaa and Waieli	50	0	50
G	17	Puu Kaua	12	0	12
H	18	Puu Palikea	40	0	40
?	19	Makaha	17	0	17
?	20	Mohiakea	10	0	10
?	21	Puu Kumakalii	20	20	0
?	22	Central and North Kaluaa	5	0	5
?	23	Huliwai	30	0	30

Table 16.2 Site Characteristics for Populations of *Achatinella mustelina* Selected for Management or Candidates for Management.

Population: [ESU identifier]	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Alaiheihe [D]	Low	Steep	Medium	None
Central and North Kaluaa	High-Medium	Moderate-Steep	Medium	None
Central Makaleha (culvert 39) [B]	High-Medium	Moderate-Steep	High	None
East Makaleha (culvert 45) [B]	High-Medium	Moderate	High	None
East Makaleha (culvert 67) [B]	High-Medium	Moderate-Steep	Medium	None
Huliwai	Medium-Low	Moderate	Low	None
Kahanahaiki [A]	High-Medium	Flat	High	Large
Kaluaa and Waieli [F]	High-Medium	Flat	Medium	None
Makaha	High-Medium	Moderate	Medium	None
Mohiakea	Medium-Low	Moderate	Medium	None
Ohikilolo [B]	High-Medium	Moderate-Steep	Low	Large
Pahole [A]	High-Medium	Flat	High	Large
Palikea Gulch [E]	High-Medium	Steep	Medium	None
Puu Kaua [G]	High-Medium	Moderate-Steep	Medium	None
Puu Palikea [H]	High-Medium	Flat, Moderate, Steep	High	None
Schofield South Range [F]	High-Medium	Moderate	Medium	None
Schofield West Range (Haleauau) [C]	High-Medium	Moderate	Medium	None
Waianae Kai [F]	High	Steep, Flat, Moderate	Medium	None

108 **Table 16.3 Threats to Populations of *Achatinella mustelina* Selected for Management or Candidates for Management.**

Population:	Threats:										
[ESU identifier]	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Alaiheihe [D]	High	High	High	High	N/A	High	N/A	Low	Medium	Medium	Medium
Central and North Kaluaa	High	N/A	Medium	High	N/A	High	N/A	Low	Medium	Low	Medium
Central Makaleha (culvert 39) [B]	High	High	Medium	High	N/A	High	N/A	Low	Medium	High	Medium
East Makaleha (culvert 45) [B]	High	High	Medium	High	N/A	High	N/A	Low	Medium	High	Medium
East Makaleha (culvert 67) [B]	High	Medium	Medium	High	N/A	Medium	N/A	Low	Low	High	Low
Huliwai	High	N/A	High	High	N/A	Medium	N/A	Low	Medium	Low	Medium
Kahanahaiki [A]	Low	Low	Medium	High	N/A	High	N/A	High	Medium	Medium	Medium
Kaluaa and Waieli [F]	High	Low	Medium	High	N/A	High	N/A	Low	Low	Medium	Medium
Makaha	High	Low	Medium	High	N/A	Medium	N/A	Low	Medium	Low	Medium
Mohiakea	High	Low	Medium	High	N/A	High	N/A	High	Medium	Medium	Medium
Ohikilolo [B]	Medium	Medium	Medium	High	N/A	Low	N/A	Very High	Medium	Low	Medium
Pahole [A]	Low	Low	Medium	High	N/A	High	N/A	Very High	Medium	Medium	Medium
Palikea Gulch [E]	High	Medium	Medium	High	N/A	High	N/A	Very High	Medium	High	Low
Puu Kaua [G]	High	Low	Medium	High	N/A	High	N/A	Low	Medium	Medium	Medium
Puu Palikea [H]	Medium	Low	High	High	N/A	Medium	N/A	Low	Medium	Low	High
Schofield South Range [F]	High	Low	High	High	N/A	High	N/A	Low	Medium	High	Medium
Schofield West Range (Haleauau) [C]	High	Medium	High	High	N/A	High	N/A	High	Medium	Medium	Medium
Waianae Kai [F]	High	High	Low	Unknown B	N/A	High	N/A	Very High	Medium	Low	High

Map removed to protect location of rare species. Available upon request.

16.2 Taxon Summary: *Alectryon macrococcus* var. *macrococcus*

Photographer: J. Obata

Scientific name: *Alectryon macrococcus* Radlk. var. *macrococcus*
Hawaiian name: *Mahoe, alaalahua*
Family: Sapindaceae (Soapberry family)
Federal status: Listed endangered

Description and biology: *Alectryon macrococcus* var. *macrococcus* is a tree up to 11 m (34 ft) tall. Fully mature trees are usually multi-trunked. The trunks have a sinewy appearance. The leaves are compound, with 2-5 pairs of leaflets, each of which measure 10-28 cm (3.9-10.9 in) long. The flowers are borne in panicles up to 30 cm (11.7 in) long. Flowers are either perfect (possessing male and female reproductive parts), or staminate (possessing only male reproductive parts). Pollination of the taxon is probably carried out by insects. The roundish fruits are 2.5-7 cm (0.9-2.7 in) in diameter. On Kauai the fruits have been observed to be uniformly small on all of the fruiting trees, averaging about 2.5 cm (1.0 in) in diameter (Wood pers. comm. 2000). On the other islands the fruits are much larger, averaging about 4 cm (1.6 in) in diameter (Lau pers. comm. 2000). The hard rind of the fruit often cracks open when the fruit is ripe to expose the contents of the fruit. Most of the volume within the hard rind is taken up by the aril, or the fleshy part of the fruit; and a single flattish seed at the end of the fruit takes up the remainder. The aril is red, and has a pleasant taste somewhat like that of a mountain apple (*Syzygium malaccense*). Upon maturity the fruit sometimes cracks open to expose the bright red, glossy-surfaced aril next to the glossy dark brown to blackish outer surface of the seed. It is hypothesized that the large flightless ducks extant in Hawaii before human settlement acted as dispersal agents for *A. macrococcus* var. *macrococcus*.

A substantial percentage of the trees flower but never bear fruit despite appearing relatively healthy (Lau pers. comm. 2000). Although the cause of this is not documented, it may be that some trees only bear flowers that are functionally male.

There is little information on growth rates of wild plants and their age of maturation. However, two trees in cultivation have been observed to flower for the first time when they were about 15 years old. At that age they were about 6 m (20 ft) tall. They were single-trunked, with the trunks measuring about 14 cm (5.5 in) in diameter (Lau pers. comm. 2000). Wild trees undoubtedly live for decades based on observed growth rates and tree sizes (Lau pers. comm. 2000).

Known distribution: *Alectryon macrococcus* var. *macrococcus* is known from Kauai, Oahu, Molokai, and West Maui. On Kauai it has been found on the western side of the island from Olokele Canyon to Kalalau Valley. On Oahu it is known primarily from the Waianae Mountains, where it has been recorded throughout the mountain range, on both the windward and leeward sides. There are only two historical records of the taxon in the Koolau Mountains. On Molokai it has been documented only from the western portion of East Molokai. On West Maui it has been found in the valleys and gulches on the eastern, southern, and western sides of the West Maui Mountains. Recorded elevations for *A. macrococcus* var. *macrococcus* range from 366 to 1,036 m (1,200 to 3,400 ft).

Population trends: This taxon has been steadily declining since the introduction of the black twig borer, *Xylosandrus compactus*. Many of the mature trees are dying. Young trees are not common, and seldom do seedlings reach sapling size before being killed by the twig borer.

Current status: *Alectryon macrococcus* var. *macrococcus* is still extant throughout its recorded range except for the Koolau Mountains of Oahu. The taxon apparently has always been relatively rare on Molokai and West Maui. Over the last three decades, only about ten plants have been observed on Molokai and fewer than 20 have been observed on West Maui. This species is most common on parts of Kauai and in the Waianae Mountains of Oahu. Approximately 80 plants are thought to remain on Kauai. It is estimated that about 300 plants still remain in the Waianae Mountains, with more than half occurring in the three population units of Central Kaluaa to Central Waieli, Makaha, and West Makaleha. About 77 plants are in the Makua action area. The current populations units of *A. macrococcus* var. *macrococcus* are listed in Table 16.4 and their sites are plotted on Maps 16.2, 16.3, 16.4, and 16.5. The sites of the population units proposed for management for stability are characterized in Table 16.5 and threats to the taxon at these sites are identified in Table 16.6.

Habitat: *Alectryon macrococcus* var. *macrococcus* occurs in gulch bottoms and on lower gulch slopes in native mesic forests. These forests are often composed of a mix of tree species such as *alaa* (*Pouteria sandwicensis*), *papala kepau* (*Pisonia* spp.), *lama* (*Diospyros sandwicensis* and *D. hillebrandii*), *kopiko* (*Psychotria* spp.), *ohia* (*Metrosideros* spp.), and *kolea* (*Myrsine* spp.). As with most rare Hawaiian mesic forest plants, *A. macrococcus* var. *macrococcus* is found primarily on the north-facing sides of gulches.

Taxonomic background: *Alectryon macrococcus* is the only species of the genus occurring in Hawaii. The species is comprised of two varieties: the Makua target taxon, var. *macrococcus*, and var. *auwahiensis*, which is endemic to the south and northwestern slopes of East Maui. The two varieties are distinguished only by the hairiness of the leaf underside, with var. *auwahiensis* being the hairier of the two (Linney 1987).

Outplanting considerations: No outplantings of *A. macrococcus* var. *macrococcus* are proposed due to the threat of black twig borer herbivory. If outplantings were to be carried out, there are no concerns with respect to inadvertently allowing unnatural hybridization between the two varieties, as their ranges are well separated. *Alectryon macrococcus* does not have any close relatives in Hawaii that could potentially hybridize with it.

Threats: The most serious threat to *A. macrococcus* var. *macrococcus* is the black twig borer. This minute beetle was discovered to be present on Oahu in 1961 and is now widespread in Hawaii (Nelson and Davis 1972). The female black twig borer tunnels into the center of living twigs and lays eggs in the hollowed twigs. The physical damage caused by tunneling coupled with the introduction of pathogens often results in the death of the twigs. Chronic infestation leads to a gradual weakening of the tree, and eventual premature death. All trees of this taxon are being affected by the black twig borer to some degree.

Other threats to *A. macrococcus* var. *macrococcus* include invasive alien animal species, which degrade the target taxon’s habitat, and harm the plants by feeding on them, trampling them, or uprooting them while rooting for food. Alien plants also threaten the taxon by altering its habitat, and competing with it for sunlight, moisture, nutrients, and growing space. Also, some alien plants, such as tall grasses, can cause and increase the size and frequency of fires. Feral pigs and goats threaten the taxon by disturbing and altering the taxon's habitat and potentially feeding upon it. Additional threats include rats (which eat the seeds of the taxon), cattle grazing, and fire. At least one Kauai population unit (Haeleele) may be suffering from the presence of black-tailed deer, and axis deer threaten certain population units on Molokai and Maui.

Table 16.4 Current Population Units of *Alectryon macroccocus* var. *macroccocus.* The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Kauai:	Haeleele	3	0	3
	Kalalau	11	0	11
	Koaie	65	0	65
Oahu:	Alaiheihe	10	10	0
	Central and East Makaleha	21	21	0
	Central Kaluaa to Central Waieli	53 - 58	0	53 - 58
	Ekahanui	4	4	0
	Halona	1	1	0
	Huliwai	6	6	0
	Kaawa	3	3	0
	Kahanahaiki	2	0	2
	Kapuna	6	0	6
	Kaumoku Nui	1	1	0
	Keaau	2	2	0
	Makaha	77	0	77
	Makua	15	0	15
	Manawai	2	2	0
	Mikilua	2	2	0
	Napepeiauolelo	1	1	0
	North Mohiakea	2	2	0
	North Palawai	1	1	0
	North Waieli	3	3	0
	Pahole	7	0	7
	Palikea Gulch	2	2	0
	South Kaluaa	17	17	0
	South Mohiakea	17	0	17
	Waianae Kai	11	1	16
	West Makaleha	45	1	44
Molokai:	Kahuaawi	1	0	1
	Kaunakakai to Kawela	8	0	8
	Kawela and Makolelau	1	0	1
Maui:	Haena Nui	15	0	15
	Honokowai	2	0	2
	Iao	2	0	2
	Launiupoko	1	0	1
	Waikapu	1	0	1

Table 16.5 Site Characteristics for Population Units of *Alectryon macrococcus* var. *macrococcus* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Central Kaluaa to Central Waieli	Medium-Low	Moderate	High	Large, None
Makaha	High-Medium	Moderate	High	None
Makua	High-Medium	Steep	Medium	None
Pahole	High-Medium	Moderate	High	Large
West Makaleha	High-Medium	Moderate	High	None

Table 16.6 Threats to Population Units of *Alectryon macrococcus* var. *macrococcus* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Central Kaluaa to Central Waieli	Low, Medium	N/A	Medium	Low	High	Unknown A	Unknown A	High	Medium	Low	Medium
Makaha	Medium	High	Medium	High	High	Unknown A	Unknown A	Very high	Medium	Low	Medium
Makua	Medium	Medium	Medium	High	High	Unknown A	Unknown A	Very high	Medium	Low	Medium
Pahole	Low	Low	Medium	High	High	Unknown A	Unknown A	Very high	Medium	Low	Medium
West Makaleha	Medium	Medium	Medium	Unknown B	High	Unknown A	Unknown A	Very high	Medium	Low	Medium

Map removed to protect location of rare species. Available upon request.

Map removed to protect location of rare species. Available upon request.

Map removed to protect location of rare species. Available upon request.

Map removed to protect location of rare species. Available upon request.

16.3 Taxon Summary: *Alsinidendron obovatum*

Photographer: J. Obata

Scientific name: *Alsinidendron obovatum* Sherff
Hawaiian name: None known
Family: Caryophyllaceae (Pink family)
Federal status: Listed endangered

Description and biology: *Alsinidendron obovatum* is a shrub reaching up to 1 m (3.3 ft) tall. Its leaves are oppositely arranged, usually elliptic to broadly elliptic in shape, and measure 4-11 cm (1.6-4.3 in) long. The congested inflorescences arise in the leaf axils and bear 7-12 flowers. The flowers lack petals, but the calyx lobes are petal-like in appearance. These calyx lobes measure 7-8 mm (ca. 0.3 in) long, are initially green and white in color, and become purple and fleshy as the capsule matures. The capsules are egg-shaped or roundish, measure 9-12 mm (0.4-0.5 in) long, and contain numerous black seeds.

Alsinidendron obovatum flowers and fruits year round, but flowering is usually heaviest in the winter and spring. The species has perfect (possessing both male and female reproductive parts) flowers and is normally self-fertilizing (Weller pers. comm. 2000). Since it is a selfing taxon, it is likely that it has no regular pollinating agent. As the fruit matures, the calyx lobes stay alive and become purple and fleshy. This ‘false berry’ is very likely to attract fruit-eating birds that may disperse the species' seeds (Carlquist 1970). The longevity of individual plants is unknown, but since the plants are small shrubs, it is assumed they live less than 10 years. The plants are thus short-lived for the purposes of the Implementation Plan.

Known distribution: *Alsinidendron obovatum* has been recorded from two separate areas in the Waianae Mountains. The northern portion of its range includes the gulches of Pahole, Kahanahaiki, Keawapilau, and West Makaleha. The southern portion of its range extends from

Palehua to Kaaikukai Gulch. The species has been recorded at elevations of 560-760 m (1,850-2,500 ft).

Population trends: The number of known plants of *A. obovatum* in the north has decreased significantly in the last two decades. It is no longer found at some of its recorded locations, including all of its sites in Pahole Gulch. In 1977 and 1978, 59 plants were counted in the subgulch where the last known Pahole plants were growing (Nagata 1980). In 1999 the plants in the subgulch numbered 20 or less, and by 2001 all of them had disappeared.

The southern *A. obovatum* stock was last observed in the 1970's in the Palehua area. There is perhaps still some chance that plants remain in the Palehua area or elsewhere in the southern Waianae Mountains.

Current status: Fewer than 5 individuals of this species are known to remain. They are in the gulches of Pahole, Kahanahaiki, Keawapilau, and West Makaleha, all of which are within the Makua action area. The species' current population units are listed in Table 16.7 and their sites are plotted on Map 16.6. All of the current population units are proposed for management for stability. Their sites are characterized in Table 16.8 and threats to the species at these sites are identified in Table 16.9.

Habitat: *Alsinidendron obovatum* typically grows on slopes on or near the ridge crests. It is usually in the understory of mesic *koa/ohia* (*Acacia koa*/*Metrosideros polymorpha*) forests.

Taxonomic background: The endemic Hawaiian genera *Schiedea* and *Alsinidendron* constitute a complex of species descended from a single colonizing ancestor (Wagner *et al.* 1995). There are four species of *Alsinidendron*: two on Kauai and two on Oahu. The Oahu species are *A. obovatum* and the closely related *A. trinerve*.

Outplanting considerations: Since *A. obovatum* is a naturally selfing plant (Weller pers. comm. 2000), plants from different stocks should not be mixed together in outplantings.

Alsinidendron trinerve, like *A. obovatum*, is an endangered plant. The ranges of the two species do not overlap geographically. *Alsinidendron trinerve* is known only on the sides of Kaala and on the ridge between Kaala and Puu Kalena to the south. The two *Alsinidendron*s also occur in different habitats. *Alsinidendron trinerve* occurs in wetter forests and at higher elevations than *A. obovatum*. *Alsinidendron obovatum* should not be reintroduced within the range or habitat of *A. trinerve*.

In many cases *A. obovatum* is located in the same drainages as its relatives *Schiedea nuttallii*, *S. pubescens* var. *purpurascens*, and *S. kaalae*. Natural hybridization between species of *Schiedea* has been documented in the Waianae Mountains. Although hybrids between *Alsinidendron* and *Schiedea* have yet to be found in nature or created experimentally, the possibility of hybridization between the two exists, so *Alsinidendron* should not be outplanted near *Schiedea* species.

Due to the large gap between the northern plants and the possibly extirpated southern plants, it is presumed that the southern plants are, or were, genetically distinct. If rediscovered, the southern stock should be preserved separately from the northern stocks. Northern stock should not be planted in the southern Waianae Mountains as long as there remains some chance that southern plants still persist. Outplanting lines have been drawn limiting the outplanting of the northern and southern stocks to their respective ends of the mountain range.

Threats: Major threats to *A. obovatum* include feral pigs, which degrade the species' habitat, and harm the plants by feeding on them, trampling them, or uprooting them while rooting for food. Alien plants also threaten the species by altering its habitat and competing with it for sunlight, moisture, nutrients, and growing space.

Nowadays seedlings and immature plants of *A. obovatum* are uncommon. This may be the result of predation by introduced slugs and snails upon the seedlings (Weller pers. comm. 2000). Experiments have been conducted using barriers to prevent mollusks from gaining access to the areas around mature plants of *A. obovatum*. The installation of these barriers has resulted in the appearance of numerous seedlings within the barriers, whereas the areas under neighboring plants not so protected have shown no regeneration (Rohrer pers. comm. 2000).

The decline and possible extirpation of the southern stock of *A. obovatum* can at least partially be attributed to human actions. Most of the southern *A. obovatum* territory is now included in the residential portion of Palehua, where there are a number of scattered residences. Other portions of what used to be *A. obovatum*'s favored habitat in the Palehua area are now occupied by military installations. Most of the land at Palehua not being utilized for residences or military installations is forested with alien trees planted in reforestation efforts of the early 1900's. Although alien-dominated, these forests do contain some remnants of the original native vegetation, and could possibly harbor surviving plants of *A. obovatum*.

Table 16.7 Current Population Units of *Alsinidendron obovatum*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kahanahaiki	0+	0	0+
	Keawapilau	0*	0	0*
	Pahole	0*	0	0*
	West Makaleha	3	0	3

+ The original naturally-occurring plant died in 2001. However, since viable seeds may still exist in a seed bank at the site and since the original plant's progeny were outplanted at the site prior to the plant's death, the population unit will continue to be treated as a managed for stability population unit.
* The plants have died. However, since viable seeds may still exist in a seed bank at the site, the population unit will continue to be treated as a managed for stability population unit.

Table 16.8. Site Characteristics for Population Units of *Alsinidendron obovatum* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kahanahaiki	High – Medium	Steep	High	Large
Keawapilau	High – Medium	Moderate	High	None
Pahole	Medium – Low	Moderate	High	Large
West Makaleha	Medium – Low	Steep	High	None

Table 16.9 Threats to Population Units of *Alsinidendron obovatum* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kahanahaiki	Low	Low	Medium	N/A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium
Keawapilau	High	Medium	Medium	N/A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium
Pahole	Low	Low	Medium	N/A	Unknown A	Unknown A	Unknown A	Very high	Medium	High	Medium
West Makaleha	High	Medium	Medium	N/A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium

Map removed to protect location of rare species. Available upon request.

16.4 Taxon Summary: *Cenchrus agrimonioides* var. *agrimonioides*

Photographer: J. Obata

Scientific name: *Cenchrus agrimonioides* Trin. var. *agrimonioides*
Hawaiian name: *Kamanomano, umealu,*
Family: Poaceae (Grass family)
Federal status: Listed endangered

Description and biology: *Cenchrus agrimonioides* var. *agrimonioides* is a perennial bunchgrass. An individual plant usually consists of few to many stems originating from a common base. The stems have been observed in the wild in the Waianae Mountains to reach up to 2 m (6.6 ft) long, but are usually only up to 0.5 m (1.6 ft) long. Initially upright or at an angle, the stems recline on the ground as they lengthen. The flowers are encased in spiny burs borne on slender spikes that measure 5-10 cm (2-4 in) long. Each bur contains two flowers, one fertile and one sterile. The fertile flowers are perfect (possessing male and female reproductive parts).

The taxon's reproduction appears to be mostly sexual. Reproduction of the plants by vegetative means is seldom observed. As with most grasses, *C. agrimonioides* var. *agrimonioides* is wind-pollinated. Isolated cultivated plants have been observed to self-pollinate and produce viable seeds (Lau pers. comm. 2000). Flowering has been reported from January through July (Nagata 1980).

The spiny burs that contain the seeds of this taxon stick to the fur of mammals or the feathers of birds. With the complete absence of ground mammals in pre-human Hawaii, it is hypothesized that these burrs may have been dispersed by the many now-extinct species of flightless Hawaiian birds.

Certain plants currently in cultivation are four years old and still vigorous (Lau pers. comm. 2000). The longevity of this taxon in the wild is undocumented, but is assumed to be less than 10 years since it is a relatively small, non-woody plant. The taxon is thus short-lived for the purposes of the Implementation Plan.

Known distribution: *Cenchrus agrimonioides* var. *agrimonioides* has been collected from four general areas: the Waianae Mountains of Oahu; West Maui (where it was recently discovered in 1996); the south slope of Haleakala on East Maui; and the island of Lanai. W. Hillebrand reported it from Hawaii Island in the 1800's (Hillebrand 1888), but no voucher specimens from that island are known to exist in herbarium collections today. Recorded elevations for this taxon range from 560-872 m (1,830-2,860 ft).

Population trends: A significant decline has been seen in the population units for which data has been collected over at least the last 10 years. In the late 1970's a total of about 130 plants were known in Pahole Gulch, and their colonies were described as appearing stable, whereas today only 10 wild plants are known to exist in the gulch. In 1987 the Waianae Kai subunit of the Makaha and Waianae Kai population unit was reported to consist of about 15 plants. In 1999 only four plants were reported.

Current status: The total number of individuals of *C. agrimonioides* var. *agrimonioides* in the Waianae Mountains is about 96. The 37 plants of the Kahanahaiki and Pahole population unit are within the Makua action area. On West Maui, there is only one known population unit, which contains six plants. Only a single plant is known to survive on East Maui, and none are currently known on Lanai. The taxon's current population units are listed in Table 16.10 and their sites are plotted on Maps 16.7 and 16.8. The sites of the population units proposed for management for stability are characterized in Table 16.11 and threats to the taxon at these sites are identified in Table 16.12.

Habitat: *Cenchrus agrimonioides* var. *agrimonioides* is usually found on ridges and on upper gulch slopes, often in the understory of mesic forests consisting of *ohia* (*Metrosideros polymorpha*), *koa* (*Acacia koa*), *lama* (*Diospyros sandwicensis*), or some combination of the three. A specimen collected in 1912 from the "Leilehua Plain" (*Wilder 65*, BISH) indicates that the taxon may also have occurred away from the mountains and in locations drier than where it is known today.

Taxonomic background: The species *C. agrimonioides* is known only from the Hawaiian Islands. Two varieties are currently recognized: var. *agrimonioides* and the probably extinct var. *laysanensis*, which was found on several of the northwestern Hawaiian Islands, and was last documented in 1961. The two varieties are distinguished by plant size and the size of the plant parts such as the leaf blades and burs, with var. *laysanensis* being the more robust of the two (Wagner *et al.* 1990).

Outplanting considerations: Since no other closely related native taxa are known in the main Hawaiian Islands there are no concerns with respect to unnatural hybridization involving related native taxa.

Some morphological differences are observable between populations in the Waianae Mountains, with some populations with hairy leaves, and others with almost hairless leaves. Due to these obvious differences, stock used in outplantings should be restricted to plants growing at nearby sites with ecological conditions similar to those of the selected outplanting sites.

There are two common weedy alien species of *Cenchrus* in Hawaii, *C. echinatus*, and *C. ciliaris*. It is unknown whether these species could possibly hybridize with *C. agrimonioides* var. *agrimonioides* and thereby endanger its genetic integrity. The target taxon should not be outplanted near the alien species of *Cenchrus*, at least until the potential for these species' hybridizing with the target taxon is known.

Threats: Major threats to *C. agrimonioides* var. *agrimonioides* include feral pigs and goats. These ungulates degrade the taxon's habitat, and harm the plants by feeding on them, trampling them, or uprooting them while rooting for food. Alien plants threaten the taxon by altering the species' habitat and competing with it for sunlight, moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires. The Makaha and Waianae Kai population unit is threatened by trampling from hikers, as most of the plants in this population unit are found right at the side of a major trail. Additional threats to plants include cattle grazing on East Maui, and herbivory by axis deer on East and West Maui.

Table 16.10 Current Population Units of *Cenchrus agrimonioides* var. *agrimonioides*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Central Ekahanui	20	0	20
	Kahanahaiki and Pahole	37	0	37
	Makaha and Waianae Kai	12	0	12
	South Huliwai	27	0	27
Maui:	Kanaio	1	0	1
	Papalaua	6	0	6

Table 16.11 Site Characteristics for Population Units of *Cenchrus agrimonioides* var. *agrimonioides* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Central Ekahanui	Medium – Low	Moderate to Steep	High	None
Kahanahaiki and Pahole	High – Medium	Flat to Moderate	High	Large
Makaha and Waianae Kai	High	Flat to Moderate	High	None
South Huliwai	Medium – Low	Moderate	High	None

Table 16.12 Threats to Population Units of *Cenchrus agrimonioides* var. *agrimonioides* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Central Ekahanui	High	N/A	High	Unknown A	N/A	Unknown A	Unknown A	High	Medium	Low	Medium
Kahanahaiki and Pahole	Low	Low	Medium	Unknown A	N/A	Unknown A	Unknown A	Very high	Medium	Medium	Medium
Makaha and Waianae Kai	High	Unknown	Medium	Unknown A	N/A	Unknown A	Unknown A	Very high	Medium	Low to Medium	High
South Huliwai	High	N/A	High	Unknown A	N/A	Unknown A	Unknown A	High	Medium	Medium	Medium

Map removed to protect location of rare species. Available upon request.

Map removed to protect location of rare species. Available upon request.

16.5 Taxon Summary: *Chamaesyce celastroides* var. *kaenana*

Photographer: M. Bruegmann

Scientific name: *Chamaesyce celastroides* (Boiss.) Croizat & Degener var. *kaenana* (Sherff) Degener & I. Degener
Hawaiian name: *Akoko*
Family: Euphorbiaceae (Spurge family)
Federal status: Listed endangered

Description and biology: *Chamaesyce celastroides* var. *kaenana* is a milky-sapped, prostrate to erect shrub usually 1-2 m (3.3-6.6 ft) tall. The stems are thick and knobby. The leaves measure 20-65 mm (0.8-2.6 in) long, and are oppositely arranged in a horizontal plane. The flowers are borne on compact side branches, each of which bears 5-10 cyathia (specialized flower-like inflorescences with a single central female flower surrounded by much-reduced male flowers). The capsules measure 2-2.5 mm (ca. 0.1 in) long and contain three seeds.

Chamaesyce celastroides var. *lorifolia* on the south slope of Haleakala, Maui has been observed reproducing vegetatively by root suckers (Medeiros *et al.* 1986). With *C. celastroides* var. *kaenana*, however, vegetative reproduction has not yet been reported.

Most plants grow in the low elevation dry zone and are summer-deciduous, losing their leaves before the height of the dry season. Plants at high elevation mesic sites are leafed out year-round (Lau pers. comm. 2000). Flowering and fruiting are year-round but peak during the summer, when the plants are leafless.

Little is known about the breeding system of *C. celastroides* var. *kaenana*. However, the genus as a whole is usually monoecious (male and female flowers on different parts of the cyathium), or rarely dioecious (male and female flowers on separate plants). It is not known if the taxon is capable of self-fertilization.

Bees and flies visit the flowers of *C. celastroides* var. *kaenana* (Lau pers. comm. 2000), and presumably act as pollination agents for the taxon.

Chamaesyce capsules split open explosively when they dry upon maturity, flinging the seeds for a short distance. The seed or seeds of the colonizing ancestor of *C. celastroides* var. *kaenana* probably arrived in Hawaii attached to a bird (Carlquist 1970), as most *Chamaesyce*s have a sticky coating on their seeds when wet. Some Hawaiian species, especially certain lowland ones, still retain this feature, while most upland forest species have lost it, exemplifying the frequent loss of dispersability in upland oceanic island plants whose ancestors were weedy lowland plants (Carlquist 1970). *Chamaesyce celastroides* var. *kaenana* is one of the taxa retaining this feature. Dispersal of its seeds in pre-human times is thus theorized to have been carried out by birds, including the many now-extinct flightless Hawaiian birds.

The taxon occurs in scattered or isolated groups, usually with no additional plants in the intervening stretches.

Based on long-term observations of the growth rates of particular individuals in the wild, the plants appear to live at least two or three decades, and perhaps considerably longer (Lau pers. comm. 2000).

Known distribution: *Chamaesyce celastroides* var. *kaenana* has been recorded only from the Waianae Mountains, with the exception of a single specimen collected by W. Hillebrand in the 1800's at Niu Valley in the southeastern Koolau Mountains. In the Waianae Mountains it has been recorded primarily from the Kaena Point area. It has been recorded at several spots further east in Mokuleia, as far east as the Kawaihapai area (inland of the Dillingham Airfield). The taxon has long been known in the Keawaula land section on the leeward side of Kaena Point. It was only in 1991 that it was discovered further south in the Waianae Mountains when it was found in Waianae Kai. In 2000 and 2001 it was discovered in the Makua action area at Kaluakauila and Punapohaku Gulches, on the ridge separating Kahanahaiki Valley from Makua Valley, and on the seaward end of Ohikilolo Ridge. The recorded elevations for this taxon range from near sea level, such as at the Kaena and Keawaula sites, to about 790 m (2,600 ft) at the Waianae Kai site.

Population trends: *Chamaesyce celastroides* var. *kaenana* is a fairly hardy plant, able to persist in the much altered lowland and coastal areas in the face of serious threats. Its cliff populations have also been protected against the effects of cattle and feral goats. On the whole, the taxon has not declined as steeply as the other target taxa.

Current status: The majority of the extant plants of *C. celastroides* var. *kaenana* are concentrated in a single large colony at Kaena Point (a subunit of the Kaena and Keawaula population unit). The number of plants in this colony is estimated to be about 300-450. Many of the remaining plants are found in scattered colonies in Keawaula. Estimates of the total number of plants of this taxon range from 870-1020. About 440 plants are in the Makua action area.

The current population units of *C. celastroides* var. *kaenana* are listed in Table 16.13 and their sites are plotted on Map 16.9. The sites of the population units proposed for management for stability are characterized in Table 16.14 and threats to the taxon at these sites are identified in Table 16.15.

Habitat: *Chamaesyce celastroides* var. *kaenana* occurs mainly in very dry coastal areas though the Waianae Kai population unit is located within the drier end of the mesic zone. Most plants, including the plants in the large colony at Kaena Point, grow on gentle to moderately steep slopes consisting of soil and rock. Others, including many of the plants on the leeward side of the Waianae Mountains, grow on nearly vertical cliff faces.

Most sites are now dominated by alien plants, particularly alien grasses and the shrub koa haole (*Leucaena leucocephala*), but many still have a fair percentage of native shrubs and grasses remaining. Some sites on the nearly vertical cliffs are still native dominated. The vegetation on these cliffs is usually sparse, consisting mostly of native shrubs, grasses, and sedges.

Taxonomic background: There are 16 native species of *Chamaesyce* in Hawaii; all are endemic. Several alien species of this genus are also found in Hawaii. The genus *Chamaesyce* is considered by some to be a subgenus of the large genus *Euphorbia* (Koutnik 1987). The elevation of *Chamaesyce* to the genus level leaves only a single native Hawaiian *Euphorbia*, *E. haeleeleana*, which occurs only on Kauai and in the Waianae Mountains of Oahu.

Chamaesyce celastroides is endemic to the Hawaiian Islands, occurring on all the main islands as well as on Nihoa in the Northwestern Hawaiian Islands. *Chamaesyce celastroides* var. *kaenana* is one of its eight currently recognized varieties (Koutnik 1987).

W. Hillebrand's Koolau Range specimen, which was destroyed in Berlin in World War II, had leaves measuring about 2.5 cm (1 in) long, much shorter than leaves of the Waianae Range plants, which measure 3-6.5 cm (1.2-2.5 in) long (Sherff 1938).

Outplanting considerations: Hawaiian *Chamaesyce*s have been successfully crossed experimentally in many combinations (Koutnik 1987), and there are also several known cases of natural hybridization between co-occurring Hawaiian *Chamaesyce*s. In some cases hybridization has resulted in hybrid populations such as ones involving *C. rockii* and *C. clusiifolia* in the Koolau Mountains (Lau pers. comm. 2000). Another situation involving hybrids in Hawaiian *Chamaesyce*s is observed in the transition zone between two habitats, where hybrids form a zone of intergradation between the *Chamaesyce* of one habitat and the *Chamaesyce* of the other habitat. Such intergradation zones involving *C. multiformis* var. *multiformis* of the forest understory and *C. celastroides* var. *amplectans* of the exposed rocky ridgetops are common in the Waianae Mountains (Lau pers. comm. 2000).

Aside from *C. celastroides* var. *kaenana*, there are seven *Chamaesyce* taxa native to the northern Waianae Mountains or adjacent coastal areas. They are *C. herbstii*, *C. kuwaleana*, *C. multiformis* var. *multiformis*, *C. multiformis* var. *microphylla*, *C. degeneri*, *C. celastroides* var. *amplectens*, and the possibly extinct *C. celastroides* var. *tomentella*. The *Chamaesyce* relative *Euphorbia haeleeleana* is also native to the northern Waianae Mountains.

Chamaesyce celastroides var. *amplectens*, *C. degeneri*, and *E. haeleeleana* are known to grow naturally with or near *C. celastroides* var. *kaenana*. However, no hybridization has yet been reported between these taxa and *C. celastroides* var. *kaenana*. It appears that under natural conditions, reproductive barriers and/or ecological differentiation between *C. celastroides* var. *kaenana* and its relatives with which it occurs are at levels high enough for the persistence of the taxa as separate entities.

Chamaesyce celastroides var. *kaenana* should not be reintroduced near the rare and localized listed endangered *C. kuwaleana* in order to avoid genetic contamination. *Chamaesyce kuwaleana* occurs on Kauaopuu Ridge, which forms the southern boundary of Waianae Kai, and on the nearby peaks of Mauna Kuwale and Puu Kailio. An outplanting line has been drawn through Waianae Kai, south of which no outplantings are to be conducted. From Waianae Kai, the outplanting line extends in a northwesterly direction through the leeward Waianaes, and then bends around onto the windward side of the mountain range. The higher elevations of the windward Waianae Mountains, including Pahole NAR, Makaleha Valley, and Mt. Kaala NAR, are excluded from lands considered appropriate for the outplanting of *C. celastroides* var. *kaenana*. This exclusion is due to the occurrence or potential occurrence in these areas of another Makua target taxon, *C. herbstii*.

Since *C. celastroides* var. *kaenana* has not been found in the southern Waianae Mountains, potential outplanting sites have been limited to the northern Waianae Mountains. Outplanting in the Koolaus should be considered only if the morphologically distinctive Koolau Range plants are rediscovered.

Threats: Feral goats and pigs, competition from alien plants, and fire threaten *C. celastroides* var. *kaenana*. Fire has burned into several population units in the last two decades, namely the units of Kaena (East of Alau), Kaena and Keawaula, Lower Ohikilolo, Punapohaku, and possibly Kaluakauila and Kahanahaiki (Lau pers. comm. 2000). With the increasing amount of alien grass in the lowlands of the Waianae Range, the fire threat to the taxon is increasing accordingly. Cattle grazing used to be a major threat to the taxon, but cattle are no longer grazed in *C. celastroides* var. *kaenana* areas. It is not known if the weedy alien *Chamaesyce*s could possibly hybridize with the native taxa.

Table 16.13 Current Population Units of *Chamaesyce celastroides* var.
156 ***kaenana.*** The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	East Kahanahaiki	2	0	2
	Kaena (East of Alau)	26	0	26
	Kaena and Keawaula	375-525	0	375-525
	Kaluakauila	18	0	18
	North Kahanahaiki	218	0	218
	Makua	40	0	40
	Puaakanoa	157	0	157
	Waianae Kai	48-58	0	48-58

Table 16.14 Site Characteristics for Population Units of *Chamaesyce celastroides* var. *kaenana* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kaena (East of Alau)	Medium-Low	Flat	High	None
Kaena and Keawaula	Low to High – Medium	Flat to Moderate	High	None
Makua	Medium-Low	Moderate	High	Large
Waianae Kai	High – Medium	Vertical	Low	None

Table 16.15 Threats to Population Units of *Chamaesyce celastroides* var. *kaenana* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kaena (East of Alau)	Low	N/A	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	High	Low	High
Kaena and Keawaula	Low	N/A	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	High to Very high	Low	High
Makua	Low	Low	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Very high	Low	Medium
Waianae Kai	Low	Medium	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	High	Low	Low

Map removed to protect location of rare species. Available upon request.

16.6 Taxon Summary: *Chamaesyce herbstii*

Photographer: J. Obata

Scientific name: *Chamaesyce herbstii* W. L. Wagner
Hawaiian name: *Akoko*
Family: Euphorbiaceae (Spurge family)
Federal status: Listed endangered

Description and biology: *Chamaesyce herbstii* is a milky-sapped tree 3-8 m (9.8-26 ft) tall. The leaves are usually 8-19.5 cm (3.1-7.6 in) long, oppositely arranged, and held in a horizontal plane. The inflorescences are open, branched, measure 7-17 cm (2.7-6.6 in) long, and bear 3-15 cyathia (specialized flower-like inflorescences with a single central female flower surrounded by much-reduced male flowers). The capsules measure 5-10 mm (0.2-0.4 in) long, and up to 8 mm (0.3 in) in diameter, are colored green or green and red, and contain three seeds.

Chamaesyce celastroides var. *lorifolia* on the south slope of Haleakala, Maui has been observed reproducing vegetatively by root suckers (Medeiros *et al.* 1986). With *C. herbstii*, however, vegetative reproduction has not yet been reported.

Little is known about the breeding system of *C. herbstii*. However, the genus as a whole is usually monoecious (male and female flowers on different parts of the cyathium), or rarely dioecious (male and female flowers on separate plants). It is not known if the taxon is capable of self-fertilization.

Flowering has been recorded as being from August to October (Nagata 1980). Bees and flies visit the flowers of *C. herbstii* (Lau pers. comm. 2000), and presumably act as pollination agents for the taxon.

Fruiting is reported from October to January (Nagata 1980). Mature *Chamaesyce* capsules split open explosively when they dry, flinging the seeds for a short distance. The seed or seeds of the colonizing ancestor of *C. herbstii* probably arrived in Hawaii attached to a bird (Carlquist 1970), as most *Chamaesyce*s have a sticky coating on their seeds when wet. Some Hawaiian species, especially certain lowland ones, still retain this feature, while most upland forest species have lost it, exemplifying the frequent loss of dispersibility in upland oceanic island plants whose ancestors were weedy lowland plants (Carlquist 1970). However, in spite of being an upland forest species, *C. herbstii* has a copious amount of the sticky substance on its seeds (Koutnik 1987). Dispersal of its seeds in pre-human times is thus theorized to have been carried out by birds, including the many now extinct flightless Hawaiian birds. *Chamaesyce herbstii* can live for at least one or two decades (Lau pers. comm. 2000).

Known distribution: *Chamaesyce herbstii* has a disjunct range. The main portion of the species' range is in the extreme northern portion of the Waianae Mountains in the Mokuleia region. It has never been found south of the Mokuleia region except for the recently extirpated colony in the southern Waianaes in South Ekahanui Gulch in Honouliuli. It has been recorded from elevations of 530-700 m (1,750-2,300 ft).

Population trends: It appears that *C. herbstii*'s population units have been decreasing in number, and the numbers of plants in them have been shrinking. Two recorded *C. herbstii* population units in the Mokuleia area are not known to be in existence today. One of these, at East Makaleha, has not been seen since 1950 when it was described as being "locally dominant" in a very small area (Hatheway 1952). The only population unit that has been well tracked over the last two decades is at South Ekahanui Gulch. When first discovered in the late 1970's, 15 mature trees and several seedlings were reported. In 1987 the number was reported to be about 11 trees. The number declined to four trees by 1991, and two trees by 2000. The last two trees died in 2001.

Current status: All known living individuals of *C. herbstii* are in either Pahole Gulch or Kapuna Gulch, both of which are in the Makua action area. These plants total less than 170. The current population units of *C. herbstii* are listed in Table 16.16 and their sites are plotted on Map 16.10. All of them are proposed for management for stability. Their sites are characterized in Table 16.17 and threats to the species at these sites are identified in Table 16.18.

Habitat: *Chamaesyce herbstii* typically grows in gulch bottoms and on gulch slopes. It usually occurs in mesic forests dominated by a diverse mix of tree species.

Taxonomic background: There are 16 native species of *Chamaesyce* in Hawaii; all are endemic. Several alien species of this genus are also found in Hawaii. The genus *Chamaesyce* is considered by some to be a subgenus of the large genus *Euphorbia* (Koutnik 1987). The elevation of *Chamaesyce* to the genus level leaves only a single Hawaiian *Euphorbia*, *E. haeleeleana*, which occurs only on Kauai and the Waianae Mountains of Oahu.

Outplanting considerations: Hawaiian *Chamaesyce*s have been successfully crossed experimentally in many combinations (Koutnik 1987), and there are also several known cases of natural hybridization between co-occurring Hawaiian *Chamaesyce*s. In some cases hybridization has resulted in hybrid populations such as ones involving *C. rockii* and *C. clusiifolia* in the Koolau Mountains. Another situation involving hybrids in Hawaiian *Chamaesyce*s is observed in the transition zone between two habitats, where hybrids form a zone of intergradation between the *Chamaesyce* of one habitat and the *Chamaesyce* of the other habitat. Such intergradation zones involving *C. multiformis* var. *multiformis* of the forest understory and *C. celastroides* var. *amplectans* of the exposed rocky ridge tops are common in the Waianae Mountains. So far, no hybrids involving *C. herbstii* are known, even though the common *C. multiformis* var. *multiformis* often grows with or near *C. herbstii*. In any case, since it is normal for the two to be growing next to one another, potential reintroduction of *C. herbstii* in areas where *C. multiformis* var. *multiformis* occurs does not put *C. herbstii* at risk of unnatural genetic mixing.

When selecting locations for the outplanting of *C. herbstii*, the *Chamaesyce* taxon most important to avoid is *C. celastroides* var. *kaenana*, since it is an endangered *Chamaesyce* that occurs in the same part of the Waianae Mountains where *C. herbstii* occurs. *Chamaesyce celastroides* var. *kaenana* is a plant growing primarily in locations much drier than where *C. herbstii* occurs, but it also rarely occurs in the drier parts of mesic habitats, and it is possible that its range originally bordered upon *C. herbstii*'s range. The areas where *C. celastroides* var. *kaenana* potentially occurs have been excluded from the land considered acceptable for the outplanting of *C. herbstii* by an outplanting line.

The extensive gap between the two areas in which *C. herbstii* occurs leads to the presumption that the southern stock is genetically distinct from the northern stock, and is possibly better adapted to southern ecological conditions than the northern stock. Therefore the southern stock should be preserved separately from the northern stock. Northern stock should not be introduced into the southern Waianaes, at least until it becomes clearly warranted based on research of the species and its genetics.

The large gap between the two bodies of the species is not considered part of the species' natural range, so two outplanting lines were drawn restricting northern stock reintroductions to the north and southern stock reintroductions to the south.

Threats: Major threats to *C. herbstii* include feral pigs and goats. These ungulates degrade the species’ habitat, and harm the plants by feeding on them, trampling them, or uprooting them while rooting for food. Alien plants threaten the species by altering the species’ habitat and competing with it for sunlight, moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires.

Table 16.16 Current Population Units of *Chamaesyce herbstii*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kapuna	110	0	110
	Pahole	60	0	60
	South Branch of South Ekahanui	0*	0	0*

* The last mature plant has died. However, since viable seeds may still exist in a seed bank at the site, the population unit will continue to be treated as a managed for stability population unit.

Table 16.17 Site Characteristics for Population Units of *Chamaesyce herbstii* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kapuna	High – Medium	Moderate	Medium to High	None
Pahole	High – Medium	Moderate	Medium to High	Large
South Branch of South Ekahanui	High – Medium	Moderate	High	Large

Table 16.18 Threats to Population Units of *Chamaesyce herbstii* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kapuna	High	Medium	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium to High
Pahole	Low	Low	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium
South Branch of South Ekahanui	Low	Low	High	Unknown A	Unknown A	Unknown A	Unknown A	High	Medium	Low	Medium

Map removed to protect location of rare species. Available upon request.

16.7 Taxon Summary: *Cyanea grimesiana* subsp. *obatae*

Photographer: J. Obata

Scientific name: *Cyanea grimesiana* Gaud. subsp. *obatae* (St. John) Lammers
Hawaiian name: *Haha, ohawai*
Family: Campanulaceae (Bellflower family)
Federal status: Listed endangered

Description and biology: *Cyanea grimesiana* subsp. *obatae* is a shrub 1-3.2 m (3.3-10.5 ft) tall, and is either single-stemmed or sparingly branched. The leaves are pinnately divided, measure 27-58 cm (11-23 in) long, and are clustered towards the tips of the stems. The six to 12 flowered inflorescences are borne among the leaves. The corollas are curved, usually yellowish white, and measure 55-80 mm (2.2-3.2 in) long. The berries are orange at maturity, and measure 18-30 mm (0.7-1.2 in) long.

As with other *Cyanea*s with their long tubular flowers, this taxon is thought to have been pollinated by nectar-feeding birds. It is capable of self-pollination, evidenced by the fact that isolated plants produce viable seeds. The taxon's orange berries are indicative of seed dispersal by fruit-eating birds. *Cyanea grimesiana* subsp. *obatae* presumably lives for less than 10 years like other *Cyanea*s of its size, and is thus a short-lived taxon for the purposes of the Implementation Plan.

Known distribution: Until the 1990s, *C. grimesiana* subsp. *obatae* was known only from the southern Waianae Mountains. It is now also known to occur in the Mokuleia region of the northern Waianae Mountains. It ranges from 550-670 m (1,800-2,200 ft) in elevation.

Population trends: Most of the *C. grimesiana* subsp. *obatae* population units have not been known for very long, but those that have been tracked for at least 15 or 20 years have either died out or have declined markedly.

Current status: There are a total of about 50 individuals of *C. grimesiana* subsp. *obatae*. The Makua action area contains 13 of the plants. The current population units of *C. grimesiana* subsp. *obatae* are listed in Table 16.19 and their sites are plotted on Map 16.11. All of them are proposed for management for stability. Their sites are characterized in Table 16.20 and threats to the plants at these sites are identified in Table 16.21.

Habitat: *Cyanea grimesiana* subsp. *obatae* grows in mesic forests, usually in shady locations in gulch bottoms or on gulch slopes. The plants often grow on steep to vertical embankments consisting of rock or a mix of rock and soil.

Taxonomic background: *Cyanea grimesiana* includes one subspecies in addition to subsp. *obatae*, namely subsp. *grimesiana*, which has been recorded primarily in the Koolau Mountains of Oahu, but which has also been found in the northern and central Waianae Mountains and on Molokai. The two subspecies are distinguished by the size and shape of their calyx lobes. Certain *Cyanea* populations on Molokai, Maui, Lanai, and Hawaii formerly included in *C. grimesiana* have recently been recognized as constituting three separate species (Lammers 1998).

Outplanting considerations: *Cyanea*s and *Cyanea* relatives potentially occurring with or near *C. grimesiana* subsp. *obatae* are *C. longiflora*, *C. superba* subsp. *superba*, *C. angustifolia*, *C. membranacea*, *C. calycina*, *C. acuminata*, the *Delissea*s *D. subcordata* and *D. sinuata*, and the *Clermontia*s *C. persicifolia*, *C. oblongifolia*, *C. kakeana*, and *C. fauriei* (Lau pers. comm. 2000). It is common to find several *Cyanea* species and *Cyanea* relatives growing together, yet to date there is no good evidence of hybridization between *Cyanea* taxa or between a *Cyanea* and a *Cyanea* relative. Consequently, concerns with respect to the possibility of inadvertently allowing unnatural hybridization to occur through the outplanting of *C. grimesiana* subsp. *obatae* are minimal.

Both *C. grimesiana* subsp. *obatae and C. grimesiana* subsp. *grimesiana* have been recorded in the northern and central Waianae Mountains. Although no subsp. *grimesiana* is known to be extant in the Waianae Mountains, there remains a chance that plants still survive there. It is unclear what the relationship was between the two subspecies with respect to distribution and genetics. In any case, prior to establishing outplanting sites for *C. grimesiana* subsp. *obatae* the potential area should be well searched for both subspecies.

Threats: Major threats to *C. grimesiana* subsp. *obatae* include feral pigs and goats. These ungulates degrade the taxon's habitat and harm the plants through feeding on them, trampling them, or uprooting them when rooting for food. Alien plants threaten the *C. grimesiana* subsp. *obatae* by altering the taxon’s habitat and competing with it for sunlight, moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires. Rats pose a threat to the species through their predation of plant parts and fruits. Introduced slugs and snails threaten the species by feeding on its leaves, stems, and seedlings.

The long-billed, nectar-feeding native Hawaiian birds, which are the presumed pollinators of *C. grimesiana* subsp. *obatae*, have been almost totally eliminated from the Waianae Mountains. Although the taxon is capable of selfing, the loss of its normal pollinating vectors is likely to result in decreases in the genetic variability within its populations over successive generations.

The small number of individuals of *C. grimesiana* subsp. *obatae* remaining could potentially lead to inbreeding depression in the taxon's naturally-occurring or reintroduced populations. If inbreeding depression in these populations is indicated, experiments on the ramifications of mixing the taxon's different stocks should be conducted.

Table 16.19 Current Population Units of *Cyanea grimesiana* subsp. *obatae*.
The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	North Branch of South Ekahanui	5	0	5
	Pahole	6	0	6
	Palikea (South Palawai)	28	0	28
	Palikea Gulch	1	0	1
	South Kaluaa	2	0	2
	West Makaleha	7	0	7

Table 16.20 Site Characteristics for Population Units of *Cyanea grimesiana* subsp. *obatae* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
North Branch of South Ekahanui	Medium – Low	Moderate to Steep	Medium	Small
Pahole	High – Medium	Moderate to Steep	High	Large
Palikea (South Palawai)	Medium – Low	Moderate to Steep	High	Small
Palikea Gulch	High – Medium	Moderate	Medium	Small
West Makaleha	High – Medium	Moderate to Steep	High	None

Table 16.21 Threats to Population Units of *Cyanea grimesiana* subsp. *obatae* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
North Branch of South Ekahanui	Low	N/A	High	Unknown B	N/A	Unknown B	Unknown B	High	Medium	High	Medium
Pahole	Low	Low	High	Unknown B	N/A	Unknown B	Unknown B	Very High	Medium	High	Medium
Palikea (South Palawai)	Low	N/A	Medium	Unknown B	N/A	Unknown B	High	High	Low	High	High
Palikea Gulch	Low	High	High	Unknown B	N/A	Unknown B	Unknown B	Very High	Medium	Medium	Medium
West Makaleha	High	Medium	Medium	High	N/A	Unknown B	Unknown B	Very high	Medium	Medium	Medium

Map removed to protect location of rare species. Available upon request.

16.10 Taxon Summary: *Cyrtandra dentata*

Photographer: J. Jacobi

Scientific name: *Cyrtandra dentata* St. John & Storey
Hawaiian name: *Haiwale*
Family: Gesneriaceae (African violet family)
Federal status: Listed endangered

Description and biology: *Cyrtandra dentata* is a shrub 1.5-5 m (4.9-16.4 ft) tall. Its leaves are oppositely arranged, with leaf blades measuring 9-33 cm (3.5-12.9 in) long, and 6-17 cm (2.4-6.7 in) wide. The inflorescences are borne in the leaf axils, and each bear 3-9 white flowers. The berries measure 1-2.6 cm (0.4-2.4 in) long, are white, and contain many minute seeds.

Flowering and fruiting specimens of *C. dentata* have been collected at all times of the year. The reproductive biology of most Hawaiian *Cyrtandra*s, including *C. dentata*, has not been studied. However, a study of the reproductive biology of an Oahu *Cyrtandra*, *C. grandiflora*, showed that it is self-compatible and that both self-pollination and cross-pollination requires an unknown insect pollinator. It was also found that there is a strong tendency for a flower's pollen to be shed before the flower's stigma becomes receptive to pollen, thereby decreasing the likelihood of self-pollination (Roelofs 1979). *Cyrtandra dentata*'s dispersal agents are unknown, although its white berries suggest dispersal by fruit-eating birds. The longevity of individuals of this species is unknown, but since the plant is a shrub, its longevity is presumed to be less than 10 years, and it is therefore a short-lived species for the purposes of the Implementation Plan.

Known distribution: *Cyrtandra dentata* is endemic to Oahu. It has been recorded from the northwestern Koolau Mountains, and from the drainages of Kahanahaiki, Pahole, Kapuna, Keawapilau, and West Makaleha in the northern Waianae Mountains. A specimen collected from Ekahanui Gulch in the southern Waianaes (*Obata s.n.*, BISH) has been identified as *C. dentata*. However, the identity of this specimen needs to be confirmed, since there are no recent reports of the species in Ekahanui Gulch, and since the gulch is far from the species' well-documented locations in the northern Waianae Mountains. The specimen may represent an atypical specimen of *C. waianaeensis* (Lau pers. comm. 2000). The species ranges from 580-720 m (1,900-2,360 ft) in elevation.

Population trends: There is very little information on population trends for this species. It is possible that the species' numbers are rising in places that have been fenced within the last decade to exclude pigs, such as Pahole Gulch in the Pahole Natural Area Reserve and Kahanahaiki Gulch in the Makua Military Reservation.

Current status: *Cyrtandra dentata* is fairly common where it occurs in the Waianae Mountains, with an estimated total of about 400 plants, all of which are in the Makua action area. In the Koolau Mountains, between 70 and 80 plants of *C. dentata* are known. However, information on the species' numbers in the Koolaus is lacking since botanists seldom visit the areas where the species has been recorded. The current population units of *C. dentata* are listed in Table 16.28 and their sites are plotted on Map 16.14. All of them are proposed for management for stability. Their sites are characterized in Table 16.29 and threats to the plants at these sites are identified in Table 16.30.

Habitat: In the Waianae Mountains *C. dentata* grows in mesic forests, while in the Koolaus, the species is found in mesic to wet forests. In both ranges it is most common in gulch bottoms and on lower gulch slopes.

Taxonomic background: *Cyrtandra* is one of the two largest genera in the native Hawaiian flora, including about 60 species, all of which occur only in the Hawaiian Islands. Twenty-four of these species occur on Oahu. *Cyrtandra dentata* is closely related to *C. propinqua* of the Koolau Mountains. The range of *C. dentata* overlaps that of *C. propinqua* and their relationship should be studied (Wagner *et al.* 1990).

Outplanting considerations: In the Waianae Mountains, *C. dentata*'s range overlaps or borders upon those of *C. garnottiana* and *C. waianaeensis*, both of which are common species. In the Koolau Mountains, the species potentially occurs with *C. laxiflora*, *C. garnottiana*, *C. propinqua*, *C. paludosa*, and *C. hawaiensis*, all of which are common. Hybridization between Hawaiian *Cyrtandra*s in the wild is very common. More than 60 hybrid combinations have been detected among Hawaiian *Cyrtandra*s (Wagner *et al.* 1990). One of these hybrid combinations involves *C. dentata* hybridizing with *C. laxiflora* in the Koolau Mountains.

No outplantings of *C. dentata* are proposed. If outplantings of *C. dentata* were to be carried out, potential hybridization with common *Cyrtandra* species already occurring at the outplanting sites would not be a large concern since hybridization between Hawaiian *Cyrtandra*s is common in the wild.

Cyrtandra dentata's well-documented range within the Waianae Mountains is limited to a small portion of the mountain range. The same is true of the species' range in the Koolau Mountains. If outplantings of *C. dentata* are to be established in the future, it would be best to limit them to the areas thought to constitute the species' natural range. Outplanting lines have been drawn demarcating an approximation of the species' natural range based on current and historical records of the species.

Threats: Major threats to *C. dentata* include feral pigs and goats, which degrade the species' habitat and harm the plants through predation, trampling, and rooting for food. Alien plants also threaten the species by altering its habitat and competing with it for moisture, nutrients, light, and space. Rats pose a threat to the species through predation of its plant parts and fruits; and introduced slugs and snails threaten the species by feeding on its leaves, stems, and seedlings.

Table 16.28 Current Population Units of *Cyrtandra dentata*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kahanahaiki	97	0	97
	Kawaiiki (Koolaus)	50	0	50
	Opaeula (Koolaus)	26	0	26
	Pahole to West Makaleha	300	0	300

Table 16.29 Site Characteristics for Population Units of *Cyrtandra dentata* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kahanahaiki	High – Medium	Moderate to Vertical	High	Large
Kawaiiki (Koolaus)	High – Medium	Moderate to Vertical	Medium	None
Opaeula (Koolaus)	High – Medium	Moderate to Vertical	Low	None
Pahole to West Makaleha	High – Medium	Moderate to Vertical	Medium to High	None, Large

Table 16.30 Threats to Population Units of *Cyrtandra dentata* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kahanahaiki	Low	Low	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium
Kawaiiki (Koolaus)	High	N/A	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Low	Medium	Low	Low
Opaeula (Koolaus)	High	N/A	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Low	Medium	Low	Low
Pahole to West Makaleha	Low to High	Low to Medium	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium to High

Map removed to protect location of rare species. Available upon request.

16.11 Taxon Summary: *Delissea subcordata*

Photographer: J. Lau

Scientific name: *Delissea subcordata* Gaud.
Hawaiian name: *Haha, ohawai*
Family: Campanulaceae (Bellflower family)
Federal status: Listed endangered

Description and biology: *Delissea subcordata* is a shrub 1-3 m (3.3-9.8 ft) tall, with a single stem; or it is occasionally branched, usually as the result of an injury. The stems are erect and topped by a cluster of leaves. The leaf blades measure 12-30 cm (4.7-11.7 in) long, and their margins are toothed or cut to various degrees. The inflorescences are six to 18 flowered, and are borne close to the stem among the leaves. The corollas are white to green, curved, and measure 45-60 mm (1.8-2.4 in) long. The berries measure 12-16 mm (0.5-0.6 in) long, and are purple when ripe.

Flowering and fruiting has been documented at various times of the year, with most flowering recorded from February through June, and fruiting from June through August. As with other *Delissea*s with their long tubular flowers, this species is thought to have been pollinated by nectar-feeding birds. It is capable of self-pollination, as evidenced by the production of viable seeds by isolated plants. The purple berries of *D. subcordata* are indicative of seed dispersal by fruit-eating birds. The longevity of individual plants is unknown. The species presumably lives for less than 10 years like other taxa of its size in the genus *Delissea* and in the closely-related genus *Cyanea*, and is thus a short-lived species for the purposes of the Implementation Plan.

Known distribution: *Delissea subcordata* has been recorded from both mountain ranges on Oahu. In the Koolaus it has been found at scattered sites, primarily in the southeastern Koolau Mountains and in both the windward and leeward central Koolaus. In the Waianae Mountains it has been found primarily along the windward side of the range. The only recorded leeward sites for the plant are in Kahanahaiki Valley on the Makua Military Reservation. The species has been documented from elevations of 430-760 m (1,400-2,500 ft).

Population trends: Although now quite rare, *D. subcordata* has fared better than most of the other members of the genus. Most of the *Delissea* species are thought to be extinct. The long-term trend for *D. subcordata* populations has been downward. For instance, 29 plants were counted in Pahole Gulch in the late 1970’s, but only six are known today. Also, no plants are known today at a number of locations throughout the Waianaes where plants were still extant in the 1970's and 1980's.

Delissea subcordata populations are known to fluctuate. A colony of the species in North Ekahanui Gulch was observed in 2000 to contain nine mature or nearly mature plants. However, it appears that they were all descended from a single mother plant whose remains were lying next to the patch of living plants.

Current status: *Delissea subcordata* has not been observed in the Koolau Mountains since 1934. In the Waianae Mountains it is still found throughout the mountain range. The total number of known plants stands at 55. Sixteen of them are in the Makua action area. The species' current population units are listed in Table 16.31 and their sites are plotted on Map 16.15. The sites of the population units proposed for management for stability are characterized in Table 16.32 and threats to the plants at these sites are identified in Table 16.33.

Habitat: *Delissea subcordata* is usually found growing on north-facing gulch slopes, and sometimes in gulch bottoms. It occurs in mesic forests dominated by *lama* (*Diospyros sandwicensis*), *ohia* (*Metrosideros polymorpha*), and/or *koa* (*Acacia koa*). It can also occur in forests composed of a diverse mix of trees. It grows either under the forest canopy or in sunny openings in the forest.

Taxonomic background: There are 11 species in the endemic Hawaiian genus *Delissea* (Lammers 1990, 1998). Three species have been recorded from Oahu in addition to *D. subcordata*. They are *D. laciniata*, *D. lauliiana*, and *D. sinuata*. *Delissea laciniata* and *D. lauliiana* have been documented only from the southeastern Koolau Mountains. *Delissea sinuata*, which has been documented only from the northern Waianae Mountains, was last collected in 1937.

The various populations of *D. subcordata* exhibit a fair amount of morphological variation. The most readily apparent variation is in the leaf characters, including the leaves’ size and shape, and the degree to which their margins are toothed or cut (Lau pers. comm. 2000).

Outplanting considerations: *Delissea*s and *Delissea* relatives potentially occurring with or near *D. subcordata* in the Waianae Mountains are *D. sinuata*, the *Cyanea*s *C. grimesiana* subsp. *grimesiana*, *C. grimesiana* subsp. *obatae*, *C. superba* subsp. *superba*, *C. angustifolia*, *C. membranacea*, *C. calycina*, and *C. longiflora*, and the *Clermontia*s *C. persicifolia*, *C. kakeana*, *C. oblongifolia*, and *C. fauriei* (Lau pers. comm. 2000). It is common to find *Delissea*s and *Delissea* relatives growing together, yet to date there is no good evidence of hybridization occurring between species of *Delissea* or between a *Delissea* and a *Delissea* relative.

Consequently, concerns are minimal with respect to the possibility of inadvertently allowing unnatural hybridization to occur through the outplanting of *D. subcordata*.

Threats: Road construction and maintenance are known to have resulted in the death of *D. subcordata* plants. This happened in the 1980s when a colony of *D. subcordata* plants was destroyed by road construction in the Kuaokala Forest Reserve (*Takeuchi et al. 3422*, BISH). Other colonies of plants last recorded in the 1980s were just off the decades-old major road between Pahole Natural Area Reserve and the Kuaokala area. Those colonies may have been similarly affected over the years.

Other major threats to *D. subcordata* include feral pigs and goats, which degrade the species' habitat and harm the plants through predation, trampling, and rooting for food. Alien plants also threaten the species by altering its habitat and competing with it for nutrients, light, and space. Rats pose a threat to the species through predation of its plant parts and fruits; and introduced slugs and snails threaten the species by feeding on its leaves, stems, and seedlings.

The long-billed, nectar-feeding native Hawaiian birds, which are the presumed pollinators of *D. subcordata*, have been almost totally eliminated from the Waianae Mountains. Although the species is capable of selfing, the loss of its normal pollinating vectors is likely to result in decreases in the genetic variability within its populations over successive generations.

The small number of individuals of *D. subcordata* remaining could potentially lead to inbreeding depression in the species' naturally occurring or reintroduced populations. If inbreeding depression in these populations is indicated, experiments on the ramifications of mixing the species' various stocks should be conducted.

Table 16.31 Current Population Units of *Delissea subcordata*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Ekahanui	14	0	14
	Huliwai	7	0	7
	Kaawa	2	0	2
	Kahanahaiki	1	0	1
	Kaluaa	1	0	1
	Kapuna and Keawapilau	9	0	9
	Pahole	6	0	6
	Palawai	1	0	1
	Palikea Gulch	2	0	2
	South Mohiakea	2	0	2

Table 16.32 Site Characteristics for Population Units of *Delissea subcordata* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Ekahanui	Medium – Low	Moderate	High	None
Huliwai	Medium - Low	Moderate	Medium	None
Kahanahaiki	High - Medium	Moderate	High	Large
Kaluaa	High - Medium	Steep	Medium	Large
Kapuna and Keawapilau	Medium – Low to High - Medium	Moderate	High	None
Palikea Gulch	High - Medium	Moderate	Medium	None
Pahole	Medium – Low to High - Medium	Moderate	High	Large

Table 16.33 Threats to Population Units of *Delissea subcordata* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Ekahanui	High	Low	High	Unknown B	N/A	Unknown B	Unknown A	High	Medium	Low	Medium
Huliwai	High	Low	High	Unknown B	N/A	Unknown B	Unknown A	High	Medium	Low	Medium
Kahanahaiki	Low	Low	Medium	Unknown B	N/A	Unknown B	Unknown A	Very high	Medium	Low	Medium
Kaluaa	Low	Low	High	Unknown B	N/A	Unknown B	Unknown A	High	Medium	Low	Medium
Kapuna and Keawapilau	High	Medium	High	Unknown B	N/A	Unknown B	Unknown A	Very high	Medium	Low	Medium
Pahole	Low	Low	High	Unknown B	N/A	Unknown B	Unknown A	Very high	Medium	Low	Medium
Palikea Gulch	High	High	High	Unknown B	N/A	Unknown B	Unknown A	Very high	Medium	Low	Medium

Map removed to protect location of rare species. Available upon request.

16.12 Taxon Summary: *Dubautia herbstobatae*

Photographer: Hawaii Natural Heritage Program

Scientific name: *Dubautia herbstobatae* G. Carr
Hawaiian name: *Naenae, kupaoa*
Family: Asteraceae (Sunflower family)
Federal status: Listed endangered

Description and biology: *Dubautia herbstobatae* is shrub that can be either upright or sprawling. It has stems reaching up to 0.5 m (1.6 ft) long. Its leaves are opposite, or are rarely ternate (three per node), and measure 2-5.5 cm (0.8-2.1 in) long. The inflorescences are borne on the stem tips, and contain 5-15 yellowish-orange flower heads. The flower heads contain 4-20 disk florets, and lack ray florets. The achenes (a type of dry, seed-like fruit) are 4-6 mm (ca. 0.2 in) long, and are tipped by feather-like bristles.

Flowering usually occurs in May and June (Carr 1979). The species is almost certainly pollinated by insects, as are most other yellow-flowered members of the sunflower family, along with those *Dubautia*s whose pollination has been studied. The breeding system of *D. herbstobatae* has not been studied. However, with respect to the *Dubautia*s whose breeding systems have been studied, some are obligate out-crossers, and others are capable of self-pollination (Carr 1985).

Bristle-bearing achenes are characteristic of wind-dispersed members of the sunflower family. The bristles may also serve to attach the achenes onto the feathers of birds (Lowrey 1986). The longevity of individuals of the species is also unknown, but since the plant is a small shrub, its longevity is presumed to be less than 10 years, and it is therefore a short-lived taxon for the purposes of the Implementation Plan.

Known distribution: *Dubautia herbstobatae* is endemic to the leeward side of the northern Waianae Mountains on only two ridge systems: the system including Ohikilolo Ridge and the ridges in and around Keaau Valley; and the ridge system of Kamaileunu (including the Kamaileunu and Waianae Kai population units). It has been found at elevations of 580-910 m (1,900-3,000 ft).

Population trends: *Dubautia herbstobatae* was unknown to science until it was discovered in 1971, when botanists first inventoried the flora of Ohikilolo Ridge (Carr 1979). Since its discovery its numbers have declined due to an increase in the goat population on the ridge, but fortunately, many of the plants are on steep cliffs inaccessible to goats, and there is still a relatively large number of plants on the ridge. The number of plants may now be on the increase since the goats on the Makua side of the ridge have been almost totally eradicated.

It was not until 1985 when the first *D. herbstobatae* was found on Kamaileunu Ridge. Since then only six more plants have been found on the ridge system. These six still survive, as they are on sheer cliffs inaccessible to goats, but the plant discovered in 1985, which was easily accessible, was found to have disappeared when the site was revisited for the first time in 1999. The large increase in the goat population on the ridge since 1985 is likely to have been responsible for the plant’s death, as the goats have seriously damaged the native vegetation in the area since 1985, and have devastated other rare plant populations on the easily-accessed parts of the ridge (Lau pers. comm. 2000).

Current status: 1,000-2,000 plants of *D. herbstobatae* are thought to grow on Ohikilolo Ridge in the Makua action area. An estimated 70-120 additional plants occur in Keaau Valley, which is also in the action area. Merely six individuals are known outside the Makua action area. These six are all on the Kamaileunu Ridge system, which includes both the Waianae Kai and the Kamaileunu population units. The current population units of *D. herbstobatae* are listed in Table 16.34 and their sites are plotted on Map 16.16. All but one of them are proposed for management for stability. Their sites are characterized in Table 16.35 and threats to the plants at these sites are identified in Table 16.36.

Habitat: *Dubautia herbstobatae* occurs in dry-mesic to mesic areas, and are often found on open rocky slopes and cliff faces. These slopes and cliffs are usually more or less north facing. The vegetation of these habitats is usually rather sparse shrublands and scrubby forests.

Taxonomic background: *Dubautia herbstobatae* belongs to the silversword alliance, which is a diverse complex of species derived from a single ancestral colonizing species. This complex comprises the genera *Dubautia* (the *naenae* or *kupaoa* on all the major islands), *Argyroxiphium* (the silverswords and the greenswords of Maui and Hawaii), and the genus *Wilkesia* (the *iliau* of Kauai). *Dubautia herbstobatae* is a very distinctive species whose closest affinities are difficult to assess (Carr 1979).

Outplanting considerations: Hybrids between members of the silversword alliance are fairly frequently encountered. There are three species of *Dubautia* native to the Waianae Mountains aside from *D. herbstobatae*. They are *D. laxa* and *D. plantaginea*, both of which are common and widespread, and *D. sherffiana*, which is a rare species occurring only in the Waianae

Mountains. *Dubautia sherffiana* and *D. plantaginea* can be found growing next to *D. herbstobatae*, but the occurrence of *D. laxa* near *D. herbstobatae* has not yet been reported (Kawelo pers. comm. 2000). *Dubautia plantaginea* and *D. laxa* have a different number of chromosomes than *D. herbstobatae*, but such a difference is not sufficient to prevent hybridization between two *Dubautia* species (Carr 1985). Outplanting concerns for *D. plantaginea* are minimal since the species occurs naturally at some of *D. herbstobatae*'s wetter sites, and since it is not a rare species.

Dubautia sherffiana is the species of most concern because of its rarity. Although it is more widespread than *D. herbstobatae*, its number of known individuals is lower. Its range includes most of the Waianae Mountains outside of *D. herbstobatae*'s range. The ranges of the two species overlap to just a small degree. Unlike *D. plantaginea* and *D. laxa*, *D. sherffiana* has the same number of chromosomes as *D. herbstobatae*, which likely increases the likelihood of hybridization. Naturally occurring hybrids between the two species have not been the subject of intensive search. However, there have been no incidental reports of hybridization in the wild to date.

In the establishment of *D. herbstobatae* outplantings, the welfare of *D. sherffiana* should be kept in mind. If *D. herbstobatae* were to be outplanted further inland than any of its documented locations, *D. sherffiana* will potentially be impacted. Besides the concern about increasing the incidence of hybridization beyond what is natural, there are also ecological concerns. Both species usually grow on steep, rocky, open slopes and ridges, so the establishment of *D. herbstobatae* deeper into *D. sherffiana*'s range than is natural could possibly result in an increase in competitive pressure on *D. sherffiana*. With these concerns in mind, an outplanting line for *D. herbstobatae* was drawn intersecting the ridges of Ohikilolo and Kamaileunu at the *D. herbstobatae* sites furthest inland. On the ridge between Makua Valley and Kahanahaiki Valley, where neither species has been documented, the outplanting line replicates the spatial relationship of the two species on Ohikilolo and Kamaileunu Ridges. On those two ridges, *D. herbstobatae* occupies the drier, seaward portions of the ridges, and *D. sherffiana* occupies the wetter, inland portions of the ridges.

Threats: Feral goats had been the major threat to *D. herbstobatae* for much of the last two decades. Although many plants grow on steep cliffs where they cannot be reached by ungulates, many others are well within their reach, and are thus susceptible to browsing. Furthermore, the animals degrade the plants' habitat by hastening the spread of invasive weeds and by disturbing the substrate above the cliffs, thus increasing the size and frequency of landslides and rock falls, which directly affect even the inaccessible plants and their steep cliff habitat. The threat to *D. herbstobatae* posed by feral goats has been virtually eliminated, as all but a few of the plants on Ohikilolo Ridge are on the protected Makua side of the ridge, where the goats are nearly eradicated. Feral pigs may still pose a threat to some of the lower elevation plants. However, most of the plants are on the upper elevations of the ridge, which are not frequented by pigs, or are growing on steep inaccessible terrain. Alien plants threaten *D. herbstobatae* by altering the species' habitat and competing with it for moisture, nutrients, and growing space. Moreover, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires.

Table 16.34 Current Population Units of *Dubautia herbstobatae*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kamaileunu	1	0	1
	Keaau	70-120	0	70-120
	Ohikilolo Makai	700+	0	700+
	Ohikilolo Mauka	1300+	1	1300+
	Waianae Kai	5	0	5

Table 16.35 Site Characteristics for Population Units of *Dubautia herbstobatae* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kamaileunu	High- Medium	Vertical	Low	None
Keaau	Medium- Low	Vertical	Low	None
Ohikilolo Makai	Medium-Low to High-Medium	Steep to Vertical	Low to Medium	Large
Ohikilolo Mauka	Medium-Low to High-Medium	Steep to Vertical	Low to Medium	Large

Table 16.36 Threats to Population Units of *Dubautia herbstobatae* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire ignition	Fire fuels	Erosion	Human Distur-bance
Kamaileunu	Low	High	High	N/A	N/A	N/A	N/A	Low	Medium	Medium	Low
Keaau	Low	Medium	High	N/A	N/A	N/A	N/A	Very high	High	Medium	Low
Ohikilolo Makai	Low	Low	High	N/A	N/A	N/A	N/A	Very high	High	Medium	Low
Ohikilolo Mauka	Low	Low	High	N/A	N/A	N/A	N/A	Very high	High	Medium	Low

Map removed to protect location of rare species. Available upon request.

16.13 Taxon Summary: *Flueggea neowawraea*

Photographer: Hawaii Natural Heritage Program

Scientific name: *Flueggea neowawraea* W. Hayden
Hawaiian name: *Mehamehame*
Family: Euphorbiaceae (Spurge family)
Federal status: Listed endangered

Description and biology: *Flueggea neowawraea* is a tree growing up to 30 m (98 ft) tall, with a trunk up to 2 m (6.6 ft) in diameter. The trees are often multi-trunked. The species' bark is rough and reddish-brown, and its wood is brown and often has a wavy grain. The leaves are 4-14 cm (1.6-5.5 in) long, and are arranged alternately along the stems. The flowers of an individual plant are usually all female or all male. They are borne in axillary clusters of 2-6. The fruits are globose, measure 3-6 mm (0.12-0.24 in) in diameter, are juicy, usually contain 6 seeds, and are reddish brown to black when ripe.

According to the literature on *F. neowawraea*, the species is dioecious, bearing either all male flowers or all female flowers. However, the species apparently is not completely dioecious, as a cultivated plant isolated from others has been observed to produce viable seeds (Chung pers. comm. 2000). Flowering occurs over a brief period sometime in the late summer through the fall. The timing of the flowering in a given area is apparently dependent on the area's weather patterns and the distribution of rainfall in the particular year. The flowering of the different trees in a given area is normally well synchronized (Lau pers. comm. 2000). The pollination biology of *F. neowawraea* has not been studied, but insects presumably pollinate the flowers, as with most species with small, inconspicuous flowers. The species' juicy fruits are suggestive of seed dispersal by fruit-eating birds.

Little is known of *F. neowawraea*'s growth rate and age of maturation in the wild. In cultivation, however, the species grows rapidly and matures early. Within three years of germination, an individual can attain a height of over 2 m (6.6 ft) and be mature enough to flower and fruit (Lau pers. comm. 2000).

Flueggea neowawraea are often the most massive trees in the forests in which they are found. Many of the remaining live trees are partially dead, with a strip or strips of bark extending up the trunks to crowns that have died back. The remaining living branches are often relatively healthy (Lau pers. comm. 2000). For this species, dying back may be a means of coping with environmental stresses. *Flueggea neowawraea*'s wood is very hard and lasts a long time after the death of the tree. It rots in a very distinctive fashion, and as a result, the decayed trunks and limbs of the species are readily identified. Old logs on the ground and pieces of wood in gulch bottoms and in streambeds document the former occurrence of the species throughout the Waianae Mountains.

Known distribution: *Flueggea neowawraea* has been documented from Kauai, the Waianae Mountains of Oahu, Molokai, East Maui, and the leeward side of the island of Hawaii. In the Waianae Mountains it has been found throughout the mountain range. The species has been recorded from 305-732 m (1,000-2,400 ft) in elevation.

Population trends: The remaining living trees and the dead remains of *F. neowawraea* indicate that the species was formerly not uncommon in at least some parts of the Hawaiian Islands (Lau pers. comm. 2000). The recorded history of *F. neowawraea* is relatively short for a native Hawaiian tree, as it was not discovered until 1912. Reports of the species in the first half of the 1900's indicate that it had already been declining in numbers and health for a considerable time prior to its discovery. There were many reports of large mature trees, portions of which were already long dead; and there were no reports of younger trees and immature plants. The only record of immature plants to date is the report of a pair of plants in Pahole Gulch in the 1970's (Nagata 1980). One plant was reportedly a tree 6.1 m (20 ft) tall, with a main trunk measuring 5.1 cm (2 in) in diameter; and the other plant a sapling about 1.5 m (5 ft) tall with a trunk measuring 2.5 cm (1 in) in diameter.

The decline of *F. neowawraea* has undoubtedly been greatly accelerated by the introduction of the black twig borer (*Xylosandrus compactus*) in 1961. Of the individuals alive 20 years ago, more than half are now dead (Lau pers. comm. 2000).

Current status: *Flueggea neowawraea* is still extant throughout its recorded range except on Molokai, where only a single tree has ever been found. That individual was documented with a voucher specimen in 1931 and it died sometime prior to 1939. Only two trees are known to persist on the southern flank of Haleakala, East Maui. Five to nine trees are known on the island of Hawaii. The species is most common on Kauai where an estimated 60-80 trees are known. On Oahu, a total of 30 trees are known to survive, nine of which are in the Makua action area. The current population units of *F. neowawraea* are listed in Table 16.37 and their sites are plotted on Maps 16.17, 16.18, 16.19, 16.20, and 16.21. The sites of the population units proposed for management for stability are characterized in Table 16.38 and threats to the plants at these sites are identified in Table 16.39.

Habitat: *Flueggea neowawraea*'s center of abundance is in the drier parts of the mesic forests, which are often dominated by *lama* (*Diospyros sandwicensis*) or dominated by *lama* and *ohia* (*Metrosideros polymorpha*). Only a few live trees remain in the dry forests. The species was formerly more common in the dry forest than today, as evidenced by numerous old logs and standing dead trunks. Most trees occur either in gulch bottoms or on north facing lower to mid-gulch slopes.

Taxonomic background: *Flueggea neowawraea* is the only member of the genus occurring in Hawaii. There are no obvious morphological differences between plants on the different islands (Lau pers. comm. 2000).

Outplanting considerations: No outplantings are proposed for *F. neowawraea*. If outplantings were to be established there would be no hybridization issues since the species does not have any close relatives in Hawaii.

Threats: The primary threat to *F. neowawraea* is the introduced black twig borer (*Xylosandrus compactus*), which has affected all populations of *F. neowawraea*. The female black twig borer tunnels into the center of living twigs and lays its eggs in the hollowed twig. Physical damage, accompanied by the introduction of pathogens, often contributes to the death of the twig. Chronic infestation leads to a gradual weakening of the tree, and its eventual premature death (Hara and Beardesly 1979).

Another threat to *F. neowawraea* is the Chinese rose beetle (*Adoretus sinicus*), which arrived in Hawaii before 1896 (Koebele 1897). This beetle feeds on the leaves of the tree, sometimes reducing them to skeletons. Other major threats include feral pigs and goats, alien plant species, cattle grazing, and fire. On the island of Hawaii much of the species' habitat in Kona and Kau has been destroyed or severely degraded by farming, ranching, and residential development. The species is further endangered by the need for cross-pollination between male and female trees in populations whose numbers have decreased greatly and are now comprised of widely separated trees, which in some cases, may be too far apart to be effectively cross-pollinated.

Table 16.37 Current Population Units of *Flueggea neowawraea*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Kauai:	Kalalau	15	0	15
	Koaie	25-40	0	25-40
	Kuia and Mahanaloa	1	0	1
	Pohakuao	7	0	7
	Poomau	10-15	0	10-15
Oahu:	Central and East Makaleha	6	0	6
	Halona	2	0	2
	Kahanahaiki to Kapuna	6	0	6
	Kauhiuhi	1	0	1
	Makaha and Waianae Kai	5	0	5
	Mikilua	1	0	1
	Mohiakea	1	0	1
	Mt. Kaala NAR	4	1	3
	Nanakuli (South Branch)	1	0	1
	North Kaluaa	1	0	1
	North West Makaleha	1	0	1
	Ohikilolo	3	0	3
	West Makaleha	3	0	3
Maui:	Auahi (Auwahi)	2	0	2
Hawaii:	Honomalino	3-7	0	3-7
	Manuka NAR	1	0	1
	Kaupulehu	1	0	1

Table 16.38 Site Characteristics for Population Units of *Flueggea neowawraea* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Central and East Makaleha	Medium-Low to High-Medium	Moderate	Medium to High	None
Kahanahaiki to Kapuna	Low to High	Moderate	High	None, Large
Kuia and Mahanaloa	Medium-Low to High-Medium	Moderate	High	None
Makaha and Waianae Kai	Medium-Low to High-Medium	Moderate	High	None
Mt. Kaala NAR	Medium- Low to High-Medium	Moderate	Medium to High	None
North West Makaleha	Medium-Low to High-Medium	Moderate to Steep	High	None
Ohikilolo	Low to High	Moderate to Steep	High	Large
West Makaleha	Medium-Low to High-Medium	Moderate	High	None

Table 16.39 Threats to Population Units of *Flueggea neowawraea* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthropods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Central and East Makaleha	High	High	High	Unknown A	High	Unknown A	Unknown B	Low	Medium	Low	Medium
Kahanahaiki to Kapuna	Low to High	N/A to Low	High	Unknown A	High	Unknown A	Unknown B	Very high	Medium	Low	Medium
Kuia and Mahanaloa	High	Medium	High	Unknown A	High	Unknown A	Unknown B	Low	Medium	Low	Medium
Makaha and Waianae Kai	High	Medium	High	Unknown A	High	Unknown A	Unknown B	Very high	Medium	Low	Medium
Mt. Kaala NAR	High	High	High	Unknown A	High	Unknown A	Unknown B	Very high	Medium	High	Medium
North West Makaleha	High	High	High	Unknown A	High	Unknown A	Unknown B	Very high	Medium	Low	Medium
Ohikilolo	High	Low	High	Unknown A	High	Unknown A	High	Very high	Medium	Low	Medium
West Makaleha	High	Low	High	Unknown A	High	Unknown A	Unknown B	Very high	Medium	Low	Medium

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Map removed to protect location of rare species. Available upon request.

120

Map removed to protect location of rare species. Available upon request.

122

Map removed to protect location of rare species. Available upon request.

Map removed to protect location of rare species. Available upon request.

126

Map removed to protect location of rare species. Available upon request.

16.14 Taxon Summary: *Hedyotis degeneri* var. *degeneri*

Photographer: J. Jacobi

Scientific name: *Hedyotis degeneri* Fosberg var. *degeneri*
Hawaiian name: None known
Family: Rubiaceae (Coffee family)
Federal status: Listed endangered

Description and biology: *Hedyotis degeneri* var. *degeneri* is a shrub with long and lax stems. The stems sprawl on the ground, or are supported by surrounding vegetation. They bear short leafy shoots in their leaf axils, and the older stems have peeling, corky layers of bark. The leaves are oppositely arranged, and measure 1-3 cm (0.4-1.2 in) long. The inflorescences are borne at the branch tips, and bear 1-10 greenish flowers. Some flowers are perfect (possessing both male and female reproductive parts), and others are pistillate (possessing only female reproductive parts). The corollas are greenish or yellowish. The capsules are almost round, and split open across the top when mature.

Flowering and fruiting has been recorded at various times of the year. The flowers are likely to be insect-pollinated. Dispersal agents for this taxon are unknown. The longevity of individuals of the taxon is unknown, but since the plant is a small shrub, its longevity is presumed to be less than 10 years, and it is therefore a short-lived taxon for the purposes of the Implementation Plan.

Known distribution: *Hedyotis degeneri* var. *degeneri* is endemic to the northern Waianae Mountains, and has been found primarily on the windward side of the range, from the mountains inland of Waialua in the east, to as far west as Pahole Gulch. The plants in Kahanahaiki are the only ones recorded on the leeward side of the Waianaes. The taxon has been recorded from 570-720 m (1,870-2,360 ft) in elevation.

Population trends: All except one of the known population units of this taxon were found within the last five years. Not enough time has passed for population trends to become evident.

Current status: Known individuals of *H. degeneri* var. *degeneri* total about 280. About 160 of these are within the Makua action area. The taxon's current population units are listed in Table 16.40 and their sites are plotted on Map 16.22. All of them are proposed for management for stability. Their sites are characterized in Table 16.41 and threats to the plants at these sites are identified in Table 16.42.

Habitat: *Hedyotis degeneri* var. *degeneri* grows on upper gulch slopes and on ridgetops. It usually occurs in the understory of mesic forests dominated by *lama* (*Diospyros sandwicensis*) and/or *ohia* (*Metrosideros* spp.). It can also be found in situations where scrubby forest of the upper gulch slopes grades into shrubland on ridgecrests.

Taxonomic background: *Hedyotis degeneri* is comprised of two varieties: var. *degeneri* and the extremely rare or extinct var. *coprosmifolia*. However, recent results from molecular genetic analysis indicate that the two varieties are not very closely related, in which case, var. *coprosmifolia* would best be reclassified as a separate species (Motley pers. comm. 2000). The taxonomy of the species and its two varieties should be further studied. *Hedyotis degeneri* var. *degeneri* is closely related to and is morphologically similar to the common *H. schlectendahliana*. Distinguishing the two can sometimes be difficult and their taxonomic relationship should be further researched as well.

Outplanting considerations: The co-occurrence of two or more species of *Hedyotis* is very common in Hawaii. Certain herbarium specimens of Hawaiian *Hedyotis* have been identified as probable hybrids (Wagner and Lorence 1998), but there has been no in-depth study of hybridization in the genus in Hawaii or the potential for it, either in the wild or in greenhouse experiments. No outplantings are proposed for *H. degeneri* var. *degeneri*, but if outplantings were to be carried out, it would be important to avoid outplanting close to any populations of *H. degeneri* var. *coprosmifolia* because of its extreme rarity. Both varieties have been documented in the Mokuleia region. Little is known of var. *coprosmifolia*'s habitat requirements and original distribution. No plants of var. *coprosmifolia* are currently known, but since specimens have been collected as recently as the 1980's, and since there is much unsearched territory where it potentially survives, it is likely that there are unrecorded plants still in existence. The general area around any potential outplanting site for var. *degeneri* should be well searched for var. *coprosmifolia* prior to its selection. Two additional rare *Hedyotis* taxa may grow near naturally occurring *H. degeneri* var. *degeneri* or near its potential outplanting sites. One is the Makua target taxon, *H. parvula*, and the other is *H. coriacea*. Although no plants of *H. coriacea* are currently known in the Waianae Mountains, unrecorded plants may still exist.

Additionally, in order to minimize the threat of compromising the identity of the outplanted *H. degeneri* var. *degeneri* population, care should be taken not to outplant near populations of the common, closely related *H. schlectendahliana*. *Hedyotis degeneri* var. *degeneri* occupies habitats drier than those of *H. schlectendahliana* (Lau pers. comm. 2000), so hybridization concerns would be minimized by the careful selection of sites. Additional common species of *Hedyotis* naturally co-occurring with *H. degeneri* include *H. acuminata* and *H. terminalis*. Outplanting concerns with respect to these two are minimal.

Threats: Major threats to *H. degeneri* var. *degeneri* include feral pigs and goats, which degrade the species' habitat and harm the plants through feeding on them, trampling them, or uprooting them when rooting for food. The species is also threatened by alien plants, which can alter the taxon's habitat and compete with the taxon for moisture, light, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires.

Table 16.40 Current Population Units of *Hedyotis degeneri* var. *degeneri*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Alaiheihe and Manawai	60	0	60
	Central Makaleha and West Branch of East Makaleha	47	0	47
	East Branch of East Makaleha	10	0	10
	Kahanahaiki	11	0	11
	Pahole	150	0	150

Table 16.41 Site Characteristics for Population Units of *Hedyotis degeneri* var. *degeneri* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Alaiheihe and Manawai	High – Medium	Moderate	Medium	None
Central Makaleha and West Branch of East Makaleha	High – Medium	Moderate to Steep	High	None
East Branch of East Makaleha	High – Medium	Moderate	Medium	None
Kahanahaiki	High	Moderate	High	None
Pahole	High	Steep to Vertical	Low to High	Large

Table 16.42 Threats to Population Units of *Hedyotis degeneri* var. *degeneri* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Alaiheihe and Manawai	High	High	High	Unknown A	Unknown A	Unknown A	Unknown A	Low	Medium	Medium	Medium
Central Makaleha and West Branch of East Makaleha	High	High	High	Unknown A	Unknown A	Unknown A	Unknown A	Low	Medium	Medium	Medium
East Branch of East Makaleha	High	High	High	Unknown A	Unknown A	Unknown A	Unknown A	Low	Medium	Medium	Medium
Kahanahaiki	Medium	Medium	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium
Pahole	Low	Low	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Medium	Low to Medium

Map removed to protect location of rare species. Available upon request.

16.15 Taxon Summary: *Hedyotis parvula*

Photographer: J. Obata

Scientific name: *Hedyotis parvula* (A. Gray) Fosb.
Hawaiian name: None known
Family: Rubiaceae (Coffee family)
Federal status: Listed endangered

Description and biology: *Hedyotis parvula* is an erect to sprawling perennial shrub with branches measuring 10-30 cm (4-12 in) long. Its oppositely arranged leaves are 1-4 cm (0.4-1.6 in) long. Its inflorescences are borne at the tips of the branches. The flowers' corollas usually have four lobes, which are white to white tinged with purplish pink towards their tips, and measure 5-6 mm (ca. 0.2 in) long. The flowers are either perfect (possessing both male and female reproductive parts), or pistillate (possessing only female reproductive parts). The capsules are almost round, measure about 3.3-4.0 mm (0.1-0.2 in) long, split open across the top upon maturity, and contain small dull brown seeds.

As with certain other Hawaiian cliff species (*Viola chamissoniana* subsp. *chamissoniana* and *Brighamia* spp. for instance) the flowers of *H. parvula* are relatively large and white or light colored, and are prominently displayed above the plant's foliage, suggesting that the species' pollinating agent are night-flying moths. Flowering and fruiting has been recorded throughout the year. Little is known about *H. parvula*'s breeding system and seed dispersal agents. The longevity of individuals of this species is unknown, but since the plant is a small shrub, its longevity is presumed to be less than 10 years, and it is therefore a short-lived species for the purposes of the Implementation Plan.

Known distribution: *Hedyotis parvula* is endemic to the Waianae Mountains, and has been documented throughout the mountain range. Recorded elevations for this species range from 720-830 m (2,350-2,730 ft).

Population trends: All of the currently known populations of *H. parvula* were discovered within the past decade, so little information on the species' population trends is available. The only colony whose population trend is known is the eastern group of plants on Ohikilolo Ridge. The colony reportedly had more than 100 plants when it was discovered in 1993. Today it numbers fewer than 20 (Kawelo pers. comm. 2000).

Current status: Three *H. parvula* population units are known, totaling fewer than 150 individuals. About 60-70 are found on Ohikilolo Ridge on the Makua Military Reservation. The species' current population units are listed in Table 16.43 and their sites are plotted on Map 16.23. All of the sites are proposed for management for stability. Sites are characterized in Table 16.44 and threats to the plants at these sites are identified in Table 16.45.

Habitat: *Hedyotis parvula* typically grows on cliff faces or on exposed rocky ridges. The vegetation in these areas is mesic, usually short and sparse, and includes native herbs, grasses, sedges, and shrubs.

Taxonomic background: The genus *Hedyotis* is subdivided into a number of sections, several of which are present in Hawaii. *Hedyotis parvula* belongs to the section *Wiegmannii*, which includes three taxa native to the Waianae Mountains, namely *H. schlectendahliana*, *H. degeneri* var. *degeneri*, and *H. degeneri* var. *coprosmifolia*. Other *Hedyotis* taxa of the Waianaes include *H. terminalis* of the section *Gouldia*, *H. centranthoides* of the section *Gouldiopsis*, and *H. coriacea* of the section *Protokadua*. All of these relatives of *H. parvula* potentially occur near *H. parvula*.

Outplanting considerations: The most important *Hedyotis* taxa to avoid when selecting *H. parvula*'s potential outplanting sites are the rare ones. These are *H. degeneri* var. *degeneri*, which is moderately rare; *H. degeneri* var. *coprosmifolia*, which was last seen in the 1980's; and *H. coriacea*, which has not been reported on Oahu since the 1800's, and is still extant but very rare on Hawaii and West Maui.

The co-occurrence of two or more species of *Hedyotis* is very common in Hawaii. Certain herbarium specimens of Hawaiian *Hedyotis* have been identified as probable hybrids (Wagner and Lorence 1998), but there has been no in-depth study of hybridization in the genus in Hawaii or the potential for it, either in the wild or in greenhouse experiments. All species of *Hedyotis* native to the Waianae Mountains have small green or yellow flowers with the exception of *H. parvula*, with its large white flowers. These marked floral differences suggest that *H. parvula*'s pollinators are different from those of other species of *Hedyotis* with which *H. parvula* potentially occurs. The presumed difference in pollinators lessens the likelihood of hybridization between *H. parvula* and other *Hedyotis* species of the Waianae Mountains. The presence of common *Hedyotis* taxa at potential *H. parvula* outplanting sites does not appear to be cause for concern since it is natural for *H. parvula* to grow near other members of the genus. In any case, it would be impossible to find sites appropriate for *H. parvula* where common *Hedyotis* taxa are absent.

There are noticeable morphological differences among herbarium specimens of *H. parvula*. These differences may be genetically based. *Hedyotis parvula* forma *sessilis* is a form that was described based on its leaf shape (Fosberg 1943). It was thought that the plants from the southern Waianae Mountains represented this form, whereas the plants from the northern Waianaes represented the typical form *H. parvula* forma *parvula*. Findings from additional study of the morphological differences within the species may result in future alterations of the species' conservation plans.

Threats: Feral goats and pigs constitute major threats to *H. parvula*. Although many plants grow on steep cliffs where they cannot be reached by ungulates, many others are within their reach. Furthermore, the animals degrade the plants' habitat by hastening the spread of invasive weeds and by disturbing substrates above the cliffs, thus increasing the size and frequency of landslides and rock falls, which directly affect even the inaccessible plants and their steep cliff habitat. Alien plants threaten *H. parvula* by altering the species' habitat and competing with it for moisture, light, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires.

Table 16.43 Current Population Units of *Hedyotis parvula*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Halona	64-79	0	64-79
	Ohikilolo Makai	50	0	50
	Ohikilolo Mauka	17	0	17

Table 16.44 Site Characteristics for Population Units of *Hedyotis parvula* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Halona	Medium-Low to High-Medium	Steep to Vertical	Low to High	None
Ohikilolo Makai	High- Medium	Steep to Vertical	Low	Large
Ohikilolo Mauka	High- Medium	Steep to Vertical	Low	Large

Table 16.45 Threats to Population Units of *Hedyotis parvula* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Halona	Low to High	Low to Medium	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low to Medium
Ohikilolo Makai	Low	Low	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low
Ohikilolo Mauka	Low	Low	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Medium	Low

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Map removed to protect location of rare species. Available upon request.

16.16 Taxon Summary: *Hesperomannia arbuscula*

Photographer: J. Obata

Scientific name: *Hesperomannia arbuscula* Hillebr.
Hawaiian name: None known
Family: Asteraceae (Sunflower family)
Federal status: Listed endangered

Description and biology: *Hesperomannia arbuscula* is a shrub or small tree 2-3.3 m (6.6-10.8 ft) tall, and reportedly reaching up to 7.6 m (25 ft) tall (Degener 1946). The leaves measure 10-18 cm (3.9-7.0 in) long, 5.5-11.5 cm (2.1-4.5 in) wide, and are covered with minute hairs. The flower heads, which resemble those of thistles, are borne at the stem tips, usually in clusters of 4-5. The florets are yellow in color, and are perfect (possessing both male and female reproductive parts) and project beyond the bracts of the flower head. The plant's achenes (a type of dry, seed-like fruit) are 0.8-1 cm (0.3-0.4 in) long and are tipped by hair-like bristles about twice as long as the achene.

The flowers are visited by birds, and are presumably pollinated by them (Carlquist 1974). Bristle-bearing achenes are characteristic of the wind-dispersed members of the sunflower family. However, the achenes of *H. arbuscula* are very large and heavy in comparison to continental wind-dispersed members of the family, and seemingly would not be capable of being carried on the wind over long distances. Furthermore, this species usually grows in tight colonies (Lau pers. comm. 2000), supporting the supposition that the seeds are not widely dispersed. Judging from observed growth rates and the size of the largest plants, the plants may live 10 to 20 years, or more (Lau pers. comm. 2000).

Known distribution: *Hesperomannia arbuscula* is endemic to the Waianae Mountains and West Maui. The species is found throughout the Waianae Range, both on the windward and leeward sides, at elevations of 597-914 m (1,960-3,000 ft). The currently known plants of *H.*

arbuscula on West Maui, whose identity is in question, range from 488-762 m (1,250-2,500 ft) in elevation.

Population trends: All of the population units that have been observed for a number of years have declined in numbers. Thirteen plants were counted in the Kapuna Gulch colony in 1991, shortly after the colony was discovered, whereas only seven remained in 1998. The Waianae Kai population unit was reported to contain seven mature plants, eight saplings, and 12 seedlings in 1978, but in 1999, only nine mature plants and one immature plant were left. In 1977 the Makaha population unit reportedly contained 12 mature plants, 25 saplings, and 25 seedlings, while in 1999, only 13 mature plants and a single immature plant were counted. Finally, in 1977, the Kaluaa Gulch colony was reported to contain six mature plants and a single sapling, but by 1985, the colony had completely disappeared.

Current status: A total of 39 individuals of *H. arbuscula* are known to remain in the Waianae Mountains. The seven individuals in Kapuna Gulch are within the Makua action area. The questionable *H. arbuscula* on West Maui totals about 63 known individuals. The species' current population units are listed in Table 16.46 and their sites are plotted on Maps 16.24 and 16.25. The population units proposed for management for stability, which include all of the current populations in the Waianae Mountains, are characterized in Table 16.47 and threats to the plants at these sites are identified in Table 16.48. Since the identity of the West Maui plants is unclear, none of their population units are proposed for management for stability at this time.

Habitat: *Hesperomannia arbuscula* in the Waianae Mountains typically grows in mesic forests on upper gulch slopes, or on ridge tops. The dominant trees at these sites are usually *ohia* (*Metrosideros polymorpha*), *lama* (*Diospyros sandwicensis*), and/or *koa* (*Acacia koa*). The questionable *H. arbuscula* on West Maui occurs in wetter mesic forests to very wet rainforests, which are often dominated by *ohia*.

Taxonomic background: *Hesperomannia* is an endemic Hawaiian genus with two species besides *H. arbuscula*: *H. lydgatei*, which is endemic to Kauai, and *H. arborescens*, which has been recorded on Oahu, Molokai, Lanai, and West Maui.

The type specimen of *H. arbuscula*, which was collected inland of Lahaina in the 1800's, is the only firm basis for the inclusion of West Maui in the historic range of the species, as plants found since the collection of the type specimen are of dubious identity. Some taxonomists have identified the plants as *H. arbuscula*, while others think that they actually represent *H. arborescens* instead of *H. arbuscula*, perhaps with the exception of the plants in Iao Valley. The taxonomy of *Hesperomannia* on West Maui is in need of further study.

There are marked morphological differences between some of the populations of *H. arbuscula* in the Waianae Mountains, with the differences in their leaf characteristics most readily apparent (Lau pers. comm. 2000).

Outplanting considerations: Until recently, it was thought that on Oahu, *H. arborescens* was restricted to the wet forests of the Koolau Mountains, but in 2000, five plants were discovered growing in mesic forest at Palikea Gulch within Mt. Kaala NAR. These few Waianae Range individuals of *H. arborescens* are morphologically very different from plants of all other currently known populations in the Koolau Mountains, Molokai, and West Maui, and it is therefore very important that they be conserved. It is not known whether the ranges of the two *Hesperomannia* species in the Waianae Mountains originally overlapped, whether the two occurred in different habitats, and whether any hybridization was taking place between the two. These uncertainties, coupled with the importance of the distinctive *H. arborescens* of the Waianaes with respect to the conservation of the genus as a whole, necessitate a cautious approach in the establishment of *H. arbuscula* reintroduction sites in the northern Waianae Mountains. An outplanting line has been drawn well to the west of Palikea Gulch, limiting potential reintroduction sites of *H. arbuscula* to areas west of the line.

The distinctive morphological differences between the various Waianae Range populations should be maintained as much as possible by preserving the various stocks separately. However, if future research clearly shows that the species' populations are suffering from inbreeding depression, controlled experiments on the consequences of mixing the morphologically different stocks should be initiated.

Threats: The major threats to *H. arbuscula* in the Waianae Mountains include feral pigs and goats, which degrade the species' habitat, and harm the plants by feeding on them, trampling them, or uprooting them while rooting for food. Invasive alien plants threaten *H. arbuscula* by altering the species' habitat and competing with it for sunlight, moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires. The Waianae Kai plants, which constitute the second largest population unit, are vulnerable to human disturbance. A major hiking and hunting trail runs right through the population unit, and right alongside two of the plants. Some of the questionable *H. arbuscula* populations of West Maui may also be threatened by axis deer, whose numbers on Maui have been increasing over the last decade.

Table 16.46 Current Population Units of *Hesperomannia arbuscula*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kaaikukai	1	0	1
	Kapuna	7	0	7
	Makaha	14	0	14
	North Palawai	7	0	7
	Waianae Kai	10	0	10
Maui:	Honokohau	25	25	0
	Iao	3	3	0
	Kapilau	2	2	0
	Waihee	33	33	0

Table 16.47 Site Characteristics for Population Units of *Hesperomannia arbuscula* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kaaikukai	Low	Steep	High	None
Kapuna	High – Medium	Moderate	High	None
Makaha	High – Medium	Moderate	High	None
North Palawai	Medium - Low	Moderate to Steep	Medium	None
Waianae Kai	High – Medium	Moderate to Steep	High	None

Table 16.48 Threats to Population Units of *Hesperomannia arbuscula* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kaaikukai	Medium	N/A	High	Unknown A	Unknown A	Unknown A	Unknown A	High	Medium	Low	Medium
Kapuna	High	Low	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium
Makaha	High	Medium	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Medium	Medium
North Palawai	Medium	N/A	High	Unknown A	Unknown A	Unknown A	Unknown A	High	Medium	Medium	Medium
Waianae Kai	High	Medium	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Medium	High

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Map removed to protect location of rare species. Available upon request.

Map removed to protect location of rare species. Available upon request.

16.17 Taxon Summary: *Hibiscus brackenridgei* subsp. *mokuleianus*

Photographer: J. Obata

Scientific name: *Hibiscus brackenridgei* A. Gray subsp. *mokuleianus* (M. Roe) D. Bates
Hawaiian name: *Mao hau hele*
Family: Malvaceae (Mallow family)
Federal status: Listed endangered

Hibiscus brackenridgei is Hawaii's official state flower.

Description and biology: *Hibiscus brackenridgei* plants of each of the three areas on Oahu where the species is currently known differ from those of the other areas. The three areas are: 1) the Waialua area (including the plants at Kihakapu, Palikea, Kaimuhole and Kaumoku Nui Gulches), 2) the area of the Kealia land section inland of the Dillingham Airfield (including the Haili to Kawaiu population unit), and 3) Makua Valley. *Hibiscus brackenridgei* plants of Molokai are morphologically similar to the Makua plants (see the Taxonomic background section, below). The differences are evident in the plants' stature, branching pattern, and the morphology of the leaves, stems, and flowers. These differences are retained when plants from the three areas are grown together in a common garden (Lau pers. comm. 2000), showing that morphological differences among the plants of the three areas are attributable to underlying genetic differences. For the purpose of the Makua Implementation Plan (IP), each grouping of plants is referred to as a type. These types, however, likely represent parts of what originally was a morphological continuum, and the discovery of additional populations may blur the distinctions made here.

The plants of the Waialua area represent typical *H. brackenridgei* subsp. *mokuleianus* as described in the literature. The trees are usually single-trunked, commonly 4-7 m (13-23 ft) tall (Lau pers. comm. 2000), and reportedly reach up to 12 m (39 ft) in height (Roe 1961). The Kealia plants are shorter, and commonly measure 2-6 m (6.5-20 ft) tall. Most branch near ground level to form a small tree with multiple trunks. The main branches of both the Waialua and Kealia types grow upwards. The Makua-Molokai type is a rambling shrub whose main branches extend outwards to form a plant wider than tall. No fully mature wild or cultivated plants of this type have yet been seen, so the maximum size attained by the plants is unknown. However, one year-old cultivated plants have been measured to be 1.2-1.8 m (4-6 ft) tall and about 2.7 m (9 ft) wide. At that age, the plants were still increasing in size at a moderate rate (Lau pers. comm. 2000).

The stems of the Waialua plants are densely armed with spines, each of which arises from a red pustule. Stems of the Kealia plants range from moderately spiny to completely spineless, and the stems of the Makua-Molokai plants are completely spineless. Leaves of all of the types are shaped like a maple leaf, with 5-7 lobes. The leaves of the Waialua and Kealia types measure15-25 cm (5.9-9.8 in) across. Those of the Makua-Molokai type are smaller, measuring 10-15 cm (3.9-5.9 in) across. The flowers of all three types are borne in the leaf axils of the outermost stems, which often project beyond the crown of the plant. All types have five-petaled flowers measuring about 12-14 cm (4.7-5.5 in) in diameter. The flowers of the Waialua and Kealia types are yellow with streaks or splotches of dark red at the center, while the Makua-Molokai type's flowers are yellow with a solid dark red center.

Wild plants of all types go dormant and lose their leaves at the beginning of the summer dry season, usually by June. They remain dormant and leafless until new growth appears at the onset of the wet season, generally by October.

There are clear differences in growth rates between the types when they are grown in well watered common gardens, with the Waialua plants being the fastest growing and the Kealia plants being the slowest. With all of the types, wild plants are invariably slower growing than plants of the same stock in cultivation (Lau pers. comm. 2000).

The age at which cultivated plants flower also varies widely between the types. Waialua plants typically begin flowering when they are only half a year to two years old, while Kealia plants typically do not begin to flower until they are two to four years old. The majority of several cultivated plants of Makua stock were observed to flower before they were six months old (Lau pers. comm. 2000).

With all forms, the earliest flowering plants begin to flower in December. The latest flowering individuals do not start flowering until late March. Flowering continues until about June. The flowers do not open until 2:00-7:00 p.m. They remain open until early morning to about noon (Lau pers. comm. 2000). Sphinx moths or hawk moths (family Sphingidae) can be observed visiting the flowers of *H. brackenridgei* at dusk and into the evening (Lau pers. comm. 2000). These moths resemble hummingbirds as they hover in front of the flower while sipping the flowers' nectar with their long tongues. Presumably they pollinate the flowers when brushing up against the flower's anthers and stigmas as they feed. There are several native species of sphinx moths in addition to several introduced ones. In addition to observations of the flowers' being visited by sphinx moths, the light color of the flowers, their being borne conspicuously beyond the leaves of the plant, and particularly their opening in the afternoon, support the supposition that the primary pollinators of the target taxon are these moths.

The target taxon's capsules mature from February through June. The taxon's seed dispersal agents are unknown. The seeds of cultivated individuals of the target taxon have been observed to remain viable in garden soil for at least 15 years, and in the wild, seedlings are often found at locations where no mature plants have been seen in many years (Lau pers. comm. 2000). The longevity of plants in the wild is undocumented. For the purposes of the IP, *H. brackenridgei* is considered to be a short-lived species since the wild populations appear to undergo large fluctuations.

Known distribution: The target taxon has been recorded from scattered locations in the northern Waianae Mountains and on West Molokai. On the windward side of the Waianaes, the locations extend from the area inland of Waialua in the east, to the cliffs of Kealia in the west. The Waialua type has been recorded from 152-366 m (500-1,200 ft), and the Kealia type from 107-213 m (350-700 ft). The recent discovery of plants in Makua represents the first record of the target taxon on the leeward side of the mountain range. The Makua site extends from 98-146 m (320-480 ft) in elevation. The Molokai plants were known from the southwestern tip of the island at an elevation of about 60 m (200 ft).

Population trends: In 1950 the target taxon was observed in gulches in the Waialua area as being "a large tree, occurring in pure stands or in association with *Erythrina* [*wiliwili*]" (Hatheway 1952). During a survey in 2000 of these same gulches, only four mature trees and a few additional immature plants were found at five spots in three adjoining gulches. However, long-term population trends may be difficult to discern due to short-term fluctuations in the numbers of plants. When the Kealia plants were first found in 1986 there were 24 saplings, all one or two years old. There was no sign of mature plants at the site (Lau pers. comm. 2000), indicating that the colony had disappeared for a while, and had reappeared during a particularly good period for recruitment. It is likely that the size of a population is largely dependent on rainfall, with large numbers being found after a series of wet years, which would allow for the survival and rapid growth of seedlings and saplings.

Current status: Only 24 wild *H. brackenridgei* individuals are known on Oahu. The seven plants recently found in Makua Valley alongside the seaward portion of Ohikilolo Ridge are all that are known within the Makua action area. The current population units of the target taxon are listed in Table 16.49, and their sites are plotted on Map 16.26. The sites of the population units proposed for management for stability are characterized in Table 16.50, and threats to the plants at these sites are identified in Table 16.51.

Habitat: *Hibiscus brackenridgei* in the Waialua area occurs in dry gulches, in gulch bottoms and on lower to middle gulch slopes. The more intact portions of these gulches are dominated by native dry forest tree species such as *wiliwili* (*Erythrina sandwicensis*), *lonomea* (*Sapindus oahuensis*), and/or *lama* (*Diospyros sandwicensis*). The less intact portions are now dominated by alien trees, but include a mix of native trees as well. The Kealia plants are situated on rather open ledges and bluffs with a mix of native and alien grasses, shrubs, and trees. The Makua plants grow on rocky slopes in an area that is drier and more open than any of the other Oahu sites. The site has burned within the last two decades. The vegetation there now consists of a mix of native and alien shrubs and grasses, and a few lone *wiliwili* trees. The natural vegetation in this extremely dry area may have been a mix of grass and shrubs with scattered trees or groves of trees. The Molokai site is also very dry. The natural vegetation there may have been native shrubland or grassland. However, the site is now alien dominated.

Taxonomic background: *Hibiscus brackenridgei* occurs only in the Hawaiian Islands. The species includes two named subspecies and an unnamed one in addition to *H. brackenridgei* subsp. *mokuleianus* (Wilson 1993). The plants of Maui, Lanai, and Hawaii are assigned to *H. brackenridgei* subsp. *brackenridgei*. The possibly extinct Kauai population of *H. brackenridgei*, which was formerly assigned to *H. brackenridgei* subsp. *mokuleianus* (Bates 1990), has been reassessed as not belonging to any of the three currently named subspecies. It remains to be named (Wilson 1993).

The recently discovered Makua plants morphologically match *H. brackenridgei* subsp. *molokaianus*, which had been previously recorded only from West Molokai. For the purposes of the IP, the target taxon consists of the various Oahu and Molokai populations of typical *H. brackenridgei* subsp. *mokuleianus* and typical *H. brackenridgei* subsp. *molokaianus*, in addition to populations falling between these two morphological extremes. The target taxon is called *H. brackenridgei* subsp. *mokuleianus* in this plan, but the name is used in a sense wider than the original sense of the name. The name *H. brackenridgei* subsp. *mokuleianus* in the strict original sense applies only to the tall spiny-stemmed trees of the Waialua area.

Outplanting considerations: Potentially occurring in the wild with the target taxon are the native *H. furcellatus*, *H. arnottianus*, and *H. kokio*, and the possibly native *H. tiliaceus* (*hau*). These species are only distantly related to *H. brackenridgei*, with the exception of *H. furcellatus*. None of them are known to hybridize with *H. brackenridgei*, so outplanting concerns involving hybridization are minimal. However, there are major concerns with regard to the maintenance of the morphologies of the different types of the taxon. The low-growing Makua-Molokai type is better adapted than the taller types to the very dry, open grasslands and shrublands on the leeward sides of the islands where a tree would be exposed to the full force of the wind. Conversely, the taller plants are better adapted than the low-growing ones to forested settings where competition for sunlight is intense, and where an individual plant is sheltered from the wind by the neighboring trees. It is thus important to keep the three types of *H. brackenridgei* subsp. *mokuleianus* to their respective regions and habitat types to avoid wholesale genetic mixing between plants with very different growth forms.

Threats: The target taxon undoubtedly was more common and widespread in the dry lowland areas of Oahu and Molokai in pre-human times than it is now. This zone and its biota have been disturbed and altered by centuries of pre-western Hawaiian habitation and agriculture. Modern agriculture, and residential and urban development have led to further disturbance and alteration of the dry lowlands.

The target taxon is currently threatened by ungulates, including cattle, feral pigs, and feral goats. These ungulates degrade the taxon's habitat and harm the plants by feeding on them, trampling them, or uprooting them while rooting for food. If any plants of the target taxon survive on Molokai, they would be additionally threatened by axis deer. The taxon is also threatened by alien plants, which alter and degrade the taxon's habitat, compete with it, and in some cases increase the incidence and destructiveness of fires in the target taxon's habitat. Another threat to the taxon is the Chinese rose beetle, which arrived in Hawaii prior to 1896 (Koebele 1897). The beetles eat the leaves of the target taxon, sometimes reducing them to skeletons. The prevalence of this insect pest varies depending on the location.

Fire represents a growing threat to the taxon. The plant grows only in the drier parts of the Waianae Mountains, which are being invaded or have already been invaded by highly flammable alien grasses. The taxon's populations may be somewhat buffered from extirpation by fire because of the plant's characteristically ample seed bank. The Makua plants persist even though their site has burned within the last two decades.

Hibiscus brackenridgei is sold in Hawaii at plant nurseries and garden shops. Virtually all of the plants being sold are subsp. *brackenridgei* (Lau pers. comm. 2000), a subspecies not naturally occurring on Oahu or Molokai. *Hibiscus brackenridgei* subsp. *mokuleianus* occurs in the lowlands, sometimes not far from inhabited areas where subsp. *brackenridgei* is potentially cultivated. It appears to be more threatened by genetic contamination involving a related cultivated taxon than any other Makua target taxon.

Table 16.49 Current Population Units of *Hibiscus brackenridgei* subsp. *mokuleianus.* The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Mature Individuals	No Management Proposed	Management Proposed
Oahu:	Haili to Kawaiu	4	0	4
	Kaimuhole and Palikea Gulch	8	0	8
	Kaumoku Nui	2	0	2
	Kihakapu	3	0	3
	Makua	7	0	7

Table 16.50 Site Characteristics for Population Units of *Hibiscus brackenridgei* subsp. *mokuleianus* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Haili to Kawaiu	Medium-Low	Flat to Vertical	High	None
Kaimuhole and Palikea Gulch	Medium-Low	Flat to Vertical	High	None
Kaumoku Nui	Medium-Low	Flat to Vertical	High	None, Small
Makua	Low	Moderate	High	Large

Table 16.51 Threats to Population Units of *Hibiscus brackenridgei* subsp. *mokuleianus* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Haili to Kawaiu	Low	N/A	High	Unknown A	Unknown A	Unknown A	Unknown B	Very high	High	Low	Medium to High
Kaimuhole and Palikea Gulch	High	High	High	Unknown A	Unknown A	Unknown A	Unknown B	Very high	High	High	Medium
Kaumoku Nui	High	High	High	Unknown A	Unknown A	Unknown A	Unknown B	Medium	High	Medium	Medium
Makua	Low	Low	High	Unknown A	Unknown A	Unknown A	Low	Very high	Very high	N/A	Medium

Map removed to protect location of rare species. Available upon request.

Map removed to protect location of rare species. Available upon request.

16.18 Taxon Summary: *Lipochaeta tenuifolia*

Photographer: Hawaii Natural Heritage Program

Scientific name: *Lipochaeta tenuifolia* A. Gray
Hawaiian name: *Nehe*
Family: Asteraceae (Sunflower family)
Federal status: Listed endangered

Description and biology: *Lipochaeta tenuifolia* is a perennial herb whose main stems can grow several meters long. The longer stems rest on the ground or on other plants. Roots sprout along the undersides of the stems. The leaves of *L. tenuifolia* are very finely dissected. They appear as if they are borne in whorls of six per node, but actually there are only two opposite leaves per node. Each of the two leaves is divided down to the node into three leaflets. The leaflets measure 3-8.5 cm (1.2-3.3 in) long. The yellow flower heads are borne at the branch tips singly or in clusters of two. There are 8-10 ray florets and 20-30 disk florets per head. The achenes (a type of dry, seed-like fruit) measure 1.8-2.6 mm (0.07-0.1 in) long, and are winged along their edges.

Vegetative reproduction in this species is common. Its stems root where they touch the ground, often leading to the establishment of separate plants. In addition to vegetative reproduction, much sexual reproduction occurs, as seedlings are commonly seen. Due to the plants' long trailing stems, the plants often grow into tangled masses, which makes counting and estimating numbers of plants difficult.

Lipochaeta tenuifolia flowers for much of the year. Flowering is heaviest in late winter and spring, and it ends with the onset of the summer dry season. The flowers of this species are most likely insect pollinated, as are many other yellow-flowered composites. Little is known of the species' seed dispersal. The longevity of individuals of this species is unknown, but since the plant is an herb, its longevity is presumed to be less than 10 years, and it is therefore a short-lived species for the purposes of the Implementation Plan.

Known distribution: *Lipochaeta tenuifolia* is endemic to the northern Waianae Mountains. All except one population unit are on the leeward side of the range, extending from Keawaula in the north to Kamaileunu Ridge in the south. The sole windward population unit is in Mt. Kaala Natural Area Reserve inland of Waialua. Recorded locations for the species range from 152-914 m (500-3,000 ft).

Population trends: This species has been much reduced in numbers over the last two decades due to the burgeoning of the goat populations on Ohikilolo and Kamaileunu Ridges, where the vast majority of plants occur. Fires have also contributed to the decrease in numbers of plants during this time period.

Current status: *Lipochaeta tenuifolia* totals an estimated 4,000 individuals. The Makua action area contains about 2,500 of the plants. The current populations units of *L. tenuifolia* are listed in Table 16.52 and their sites are plotted on Map 16.28. The sites of the population units proposed for management for stability are characterized in Table 16.53 and threats to the plants at these sites are identified in Table 16.54.

Habitat: *Lipochaeta tenuifolia* grows in habitats ranging from very dry, for example at the seaward end of Ohikilolo Ridge, to mesic, for example at the site of the Mt. Kaala Natural Area Reserve plants. The majority of the plants are in dry-mesic habitats, and on north-facing slopes. The plants are often found growing on cliff faces and cliff ledges, or on the sides of steep rocky ridges. These open areas are vegetated with native shrubs, grasses, and sedges. The species also grows in forested areas, in which case it is most common in forest openings. Plants can also be found growing in the forest understory in places where the forest canopy is fairly open.

Taxonomic background: Experimental studies (Rabakonandrianina 1980, Rabakonandrianina and Carr 1981) suggest that the endemic Hawaiian genus *Lipochaeta* is actually an artificial grouping of two different lineages, each of which evolved independently of one another from separate introductions to the Hawaiian Islands. The sections *Aphanopappus* and *Lipochaeta* of the genus *Lipochaeta* each represent a lineage. *Lipochaeta tenuifolia* is a member of the section *Aphanopappus*, which is comprised of 14 species. It has been shown through experimental crossing that all of these species in the section *Aphanopappus* are interfertile. Any pair of species can hybridize and produce fertile progeny (Rabakonandrianina 1980). For these species to remain distinct entities there must either a geographical or ecological separation between them. The species of concern with respect to *L. tenuifolia* are the other Waianae Range taxa in section *Aphanopappus*, namely *L. remyi*, *L. integrifolia*, and *L. tenuis*. These three species and *L. tenuifolia* each occupy different parts of the Waianae Range. *Lipochaeta remyi* is known only from the Mokuleia area of the windward Waianae Mountains. Its documented range lies far away from any of the known populations of *L. tenuifolia*. *Lipochaeta integrifolia* is a coastal species native to several islands besides Oahu. It occurs along the Mokuleia coastline as far west as Kaena Point. Its documented range does not contact *L. tenuifolia*'s documented range. *Lipochaeta tenuis*, which grows in the same type of habitat in which *L. tenuifolia* grows, occurs in the central Waianae Mountains as far north as Kamaileunu Ridge, where its range meets that of *L. tenuifolia*. The contact between the two species has resulted in localized hybrid populations on the ridge. Although not a common find, plants that are obviously hybrids can also be seen growing in the midst of the *L. tenuifolia* plants on the ridge (Lau pers. comm. 2000).

The hybridization between these two species along their zone of contact appears to be a natural process, and it may result in the transferal of genetic material between them, thereby increasing the genetic variability of both species.

Naturally occurring amongst the *L. tenuifolia* plants on Kamaileunu Ridge is the rare *L. lobata* var. *leptophylla*, which is a member of the lineage represented by the section *Lipochaeta*. As with the rest of the species in its section, *L. lobata* has a different number of chromosomes than *L. tenuifolia* and the other species in the section *Lipochaeta*. Hybrids between the two sections are generally sterile (Rabakonandrianina 1980).

The Kamaileunu population unit of *L. tenuifolia* is proposed for management. The perpetuation of the hybrid populations along the ridge is not considered the U.S. Army's responsibility, but they shall be accommodated whenever possible in the management of the ridge for *L. tenuifolia*.

Outplanting considerations: No outplantings are proposed for the stabilization of *L. tenuifolia*, but if outplantings were to be established, they should not be located in areas where unnatural hybridization might occur. With this in mind, outplanting lines have been drawn delineating the areas where outplantings of *L. tenuifolia* should not be established due the documented or potential occurrence of related species not naturally occurring with *L. tenuifolia*.

Threats: Feral goats and pigs constitute major threats to *L. tenuifolia*. Although many plants grow on steep cliffs where they cannot be reached by ungulates, many others are within their reach. Furthermore, the animals degrade the plants' habitat by hastening the spread of invasive weeds and by disturbing substrates above the cliffs, thereby increasing the size and frequency of landslides and rock falls, which directly affect even the inaccessible plants and their steep cliff habitat. Alien plants threaten *L. tenuifolia* by altering the species' habitat and competing with it for sunlight, moisture, nutrients, and growing space. Moreover, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires. *Lipochaeta tenuifolia* is one of the Makua target taxa most threatened by fire. By the 1970's, fires had already impacted portions of the Kaluakauila and Keawaula population units. Over the last two decades additional fires have burned into the Ohikilolo Mauka and Ohikilolo Makai population units, and have destroyed portions of the Kahanahaiki population unit (Lau pers. comm. 2000).

Table 16.52 Current Population Units of *Lipochaeta tenuifolia*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kahanahaiki	300	0	300
	Kaluakauila	113	0	113
	Kamaileunu and Waianae Kai	1285-1955	405-635	880-1320
	Keaau	33-43	33-43	0
	Keawaula	40	0	40
	Mt. Kaala NAR	250	0	250
	Ohikilolo	1	1	0
	Ohikilolo Makai	16	0	16
	Ohikilolo Mauka	2000	0	2000

Table 16.53 Site Characteristics for Population Units of *Lipochaeta tenuifolia* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kahanahaiki	High – Medium	Moderate to Vertical	Low to High	None
Kamaileunu and Waianae Kai	Low to High	Flat to Vertical	Low to High	None
Mt. Kaala NAR	Medium – Low	Moderate to Vertical	Low to Medium	None
Ohikilolo Makai	Low to High	Moderate to Vertical	Low to High	Small
Ohikilolo Mauka	Low to High	Moderate to Vertical	Low to Medium	Large

Table 16.54 Threats to population units of *Lipochaeta tenuifolia* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kahanahaiki	Medium	Medium	Medium	Unknown A	N/A	Unknown A	Unknown A	Very high	High	Medium	Low to Medium
Kamaileunu and Waianae Kai	Medium	High	High	Unknown A	N/A	Unknown A	Unknown A	Very high	High	High	Low to Medium
Mt. Kaala NAR	High	High	High	Unknown A	N/A	Unknown A	Unknown A	Low	Medium	Medium	Low to Medium
Ohikilolo Makai	Low	Low	Medium	Unknown A	N/A	Unknown A	Unknown A	Very high	High	Low	Low to Medium
Ohikilolo Mauka	Low	Low	High	Low Unknown A	N/A	Unknown A	Unknown A	Very high	High	Medium	Low to Medium

Map removed to protect location of rare species. Available upon request.

16.19 Taxon Summary: *Neraudia angulata*

Neraudia angulata var. *angulata*

Photographer: Hawaii Natural Heritage Program

Neraudia angulata var. *dentata*

Photographer: K. Kawelo and J. Lau

Scientific name: *Neraudia angulata* R. Cowan var. *angulata* and *Neraudia angulata* R. Cowan var. *dentata* Degener & R. Cowan
Hawaiian name: *Maaloa, oloa*
Family: Urticaceae (Nettle family)
Federal status: Listed endangered

Description and biology: *Neraudia angulata* is an upright shrub reaching up to 3 m (9.8 ft) in height. The leaves are alternately arranged, and measure 7-15 cm (2.7-5.9 in) long. The undersides of the leaves are usually obviously covered with hairs. The leaf margins are sometimes toothed. In some cases the teeth are large and numerous, giving the leaf margin a ragged appearance. The degree to which the leaf margins of a given plant are toothed can vary according to the time of year. The flowers of *N. angulata* are borne in axillary clusters. The mature fruit is small and seed-like, and is enclosed in a red fleshy calyx.

For a discussion of the differences between the two varieties of *N. angulata* see the taxonomic background section below.

According the literature on *N. angulata*, the species is dioecious (with male and female flowers on separate plants). However, cultivated plants have shown that this is not always so. Many plants can have both male and female flowers (Lau pers. comm. 2000). *Neraudia*s are wind-pollinated (Wagner *et al.* 1990). Flowering and fruiting occurs throughout the year. The red fleshy calyx surrounding the mature fruit suggests that fruit-eating birds disperse the species' seeds. The plants appear to live for fewer than 10 years (Lau pers. comm. 2000).

Known distribution: *Neraudia angulata* has been recorded throughout the Waianae Mountains from 370-701 m (1,200-2,300 ft) in elevation.

Population trends: It is difficult to gauge long term population trends with *N. angulata* because of the tendency of its populations to fluctuate (Lau pers. comm. 2000). It is clear, however, that the number of sites where this species grows is diminishing.

Current status: The total number of individuals of *N. angulata* is about 170, about 30 of which are within the Makua action area. The current populations units of *N. angulata* are listed in Table 16.55 and their sites are plotted on Map 16.29. The sites of the population units proposed for management for stability are characterized in Table 16.56 and threats to the plants at these sites are identified in Table 16.57.

Habitat: *Neraudia angulata* typically grows in dry forests and shrublands, and it occasionally extends into mesic forests and shrublands. Some of the plants occur on gulch slopes. Others are found growing on steep to nearly vertical cliffs, and on cliff ledges. The species can be found in the forest understory, as well as among shrubs and grasses in exposed, sunny situations.

Taxonomic background: *Neraudia* is an endemic Hawaiian genus with five species. There are two recognized varieties of *N. angulata*: var. *angulata* and var. *dentata*. Variety *dentata* is characterized by leaf undersides with hairs projecting out from the leaf surface. Variety *angulata*, on the other hand, has leaf undersides with hairs lying close to the leaf surface, resulting in a silvery sheen. Another character distinguishing the two varieties is the leaf margin. Variety *angulata* does not have toothed margins. With var. *dentata*, however, examination of a colony large enough to provide an adequate sample will show that some percentage of the plants in the colony have at least some of their leaves exhibiting toothed leaf margins.

The taxonomy of *N. angulata* is in need of further study. The two varieties reportedly can be found growing near one another, yet remain distinct entities (Cowan 1949). However, populations have been found that seem not to represent either strict var. *dentata* or strict var. *angulata* (Lau pers. comm. 2000).

Outplanting considerations: *Neraudia melastomifolia* is the other species of *Neraudia* occurring in the Waianae Mountains. It generally grows in habitats wetter than those of *N. angulata*. There is, however, at least a little overlap in the ranges of the two species, for instance in North Palawai Gulch in the southern Waianae Mountains. It is not known whether the two species hybridize with one another. *Neraudia melastomifolia* should be avoided when outplanting *N. angulata*, unless the outplanting is being established in one of the few areas where the ranges of the two *Neraudia*s naturally overlap.

In addition, any outplanting of *N. angulata* should proceed with caution with regard to other plants of *N. angulata*. The taxonomy of *N. angulata* is still not well understood, and much remains to be learned. All parts of the Waianae Mountains are potentially already occupied by one or more forms of *N. angulata*. When planning for outplantings of *N. angulata*, care must be taken to avoid unwittingly compromising the genetic integrity of the varieties, populations, and potential ecotypes currently included within *N. angulata*. Any outplanting of *N. angulata* should be conducted close to the source plants, and away from areas where plants with differing morphology or ecological preferences grow or potentially grow.

Threats: Fire poses a threat to many of the *N. angulata* population units. Fires have already destroyed or damaged portions of *N. angulata*'s habitat within the Makua action area, particularly in Kaluakauila Gulch and in Kahanahaiki. Other threats to *N. angulata* include feral goats and pigs, and alien plants. Also, *N. angulata*'s range extends into lands in the lower elevations of the Waianae Mountains, which were heavily grazed in the 1800's and early 1900's. Many of these lands are no longer grazed. On some other lands, however, cattle continue to threaten the species.

Table 16.55 Current Population Units of *Neraudia angulata*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Halona	15	0	15
	Kapuna	1	0	1
	Leeward Puu Kaua	3	0	3
	Makaha	70	0	70
	Makua	31	0	31
	Manawai	12	0	12
	Waianae Kai Makai	4	0	4
	Waianae Kai Mauka	46	0	46

Table 16.56 Site Characteristics for Population Units of *Neraudia angulata* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kapuna	Medium-Low	Moderate	High	None
Makaha	High- Medium	Moderate to Vertical	Low to High	None
Makua	Low to High	Moderate to Vertical	Low to High	Large
Manawai	Medium-Low	Moderate	High	None
Waianae Kai Mauka	High-Medium	Moderate to Steep	High	None

Table 16.57 Threats to Population Units of *Neraudia angulata* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kapuna	High	Medium	High	Unknown A	Unknown A	Unknown B	Unknown A	Very high	High	Low	Medium
Makaha	Medium	Medium	Medium	Unknown A	Unknown A	Unknown B	Unknown A	Very high	High	Low	Low, to Medium
Makua	Medium	Medium	Medium to High	Unknown A	Unknown A	Unknown B	Unknown A	Very high	Medium	Low	Low, to Medium
Manawai	High	High	High	Unknown A	Unknown A	Unknown B	Unknown A	High	Medium	Low	Medium
Waianae Kai Mauka	High	High	Medium	Unknown A	Unknown A	Unknown B	Unknown A	Very high	Medium	Low	Medium

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Map removed to protect location of rare species. Available upon request.

16.20 Taxon Summary: *Nototrichium humile*

Photographer: Hawaii Natural Heritage Program

Scientific name: *Nototrichium humile* Hillebr.
Hawaiian name: *Kului*
Family: Amaranthaceae (Amaranth family)
Federal status: Listed endangered

Description and biology: *Nototrichium humile* is a perennial basal-branching shrub with upright or arching branches. The plant is typically 1-2 m (3.3-6.6 ft) tall. Its leaves are ovate to oblong, measure 3-9 cm (1.2-3.5 in) long, and are green (unlike the other two species of *Nototrichium*, whose leaves are covered with silvery hairs). The spikes are slender, measure 3-14 cm (1.2-5.5 in) long, and hang down as they lengthen. The flowers are small and inconspicuous, and perfect (possessing both male and female reproductive parts). The fruits are not much larger than the flowers.

Flowering is generally heaviest in the spring and summer. It is not known if the plants are self-compatible. Pollination vectors for the species are unknown. The fruits mature a few weeks after flowering. The seeds have no obvious dispersal mechanisms. Based on observations of particular individuals of this species, the plants live for at least one or two decades (Lau pers. comm. 2000).

Known distribution: *Nototrichium humile* occurs in the Waianae Mountains of Oahu, where it found throughout the mountain range, on both the windward and leeward sides. The only record of the species beyond the Waianae Mountains is a specimen collected in the 1970s on the south slope of Haleakala, Maui. Recorded elevations for this species range from 60-700 m (200-2,300 ft).

Population trends: The population units of *N. humile* have not been well monitored. However, there have been no reports of obvious declines in numbers. The species often occurs on cliffs, and the individuals growing on the cliffs are protected to various degrees from cattle, feral ungulates, invasive alien weeds, and fire.

Current status: The status of *N. humile* on Maui is uncertain. There have been no reports of it on the island since it was first collected there. In the Waianae Mountains, the species is estimated to number 1,200-1,400 individuals, about 700-900 of which are in the Makua action area. The current population units of the species are listed in Table 16.58 and their sites are plotted on Maps 16.30 and 16.31. The sites of the population units proposed for management for stability are characterized in Table 16.59 and threats to the plants at these sites are identified in Table 16.60.

Habitat: *Nototrichium humile* can be found growing on gulch slopes or in gulch bottoms in the understory of dry forests dominated by trees such as *lama* (*Diospyros sandwicensis*) and/or *lonomea* (*Sapindus oahuensis)*, or in dry shrublands closer to the ridge tops. The species can also be found on open dry cliffs and cliff ledges sparsely vegetated with shrubs and grasses. Small groups of plants or isolated plants can sometimes be found as outliers in mesic habitats. In all situations, the species is usually found on more or less north facing slopes.

Taxonomic background: There are three species in the endemic Hawaiian genus *Nototrichium*. The two besides *N. humile* are *N. sandwicensis,* which occurs on all of the main Hawaiian Islands, and the newly described *N. divaricatum* of northwestern Kauai.

Outplanting considerations: *Nototrichium sandwicensis* is fairly common in parts of Kauai and Hawaii, but elsewhere in the Hawaiian Islands it is either rare or completely absent. It is extremely rare on Oahu, having been found only in a small area between the Dillingham Airfield and Kaena Point. The Oahu population may number under 100 individuals (Lau pers. comm. 2000), and is therefore of conservation concern. Moreover, although not currently considered a separate taxon, the Oahu population is morphologically distinctive among the populations of *N. sandwicensis* in Hawaii. As the Oahu plants are more ornamental than other forms, they constitute the bulk of the plants of the species grown in gardens, and utilized in landscaping (Lau pers. comm. 2000). It is unknown whether hybridization between *N. humile* and *N. sandwicensis* is possible. No *N. humile* outplantings are proposed. However, any future outplanting efforts of *N. humile* in the Waianae Mountains would best be conducted outside the range of *N. sandwicensis*, at least until the potential for hybridization between the two species in the wild is better studied. An outplanting line has been drawn through the northern part of the Waianae Range limiting potential reintroductions to areas south of the line.

Threats: *Nototrichium humile* is one of the more fire-endangered Makua target taxa because of its occurrence in the lower, drier reaches of the Waianae Mountains. Other major threats to *N. humile* include feral goats and pigs, cattle grazing, and alien plants. If the Maui plants still persist, a burgeoning axis deer population on the island represents an additional threat.

Table 16.58 Current Population Units of *Nototrichium humile*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kahanahaiki	140	0	140
	Kaimuhole and Palikea Gulch	54	0	54
	Kaluakauila	200-400	0	200-400
	Keaau	21-31	0	21-31
	Kealia	3	0	3
	Keawapilau	10	0	10
	Keawaula	230	0	230
	Kolekole (East Side)	13	0	13
	Makaha	159	0	159
	Makua (East Rim)	1	0	1
	Makua (South Side)	120-140	0	120-140
	Nanakuli	5	0	5
	Puu Kaua (Leeward Side)	12	0	12
	Waianae Kai	200-320+	28	200-320+
Maui:	Lualailua	No data	0	No data

Table 16.59 Site Characteristics for Population Units of *Nototrichium humile* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kaimuhole and Palikea Gulch	Medium – Low	Moderate to Steep	High	None
Kaluakauila	High – Medium	Moderate to Vertical	Low to High	None
Makua (south side)	Medium – Low to High	Moderate to Vertical	Low to High	Large
Waianae Kai	Medium – Low to High	Moderate to Vertical	Low to High	None

Table 16.60 Threats to Population Units of *Nototrichium humile* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kaimuhole and Palikea Gulch	High	High	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	High	Medium	Medium to High
Kaluakauila	Low to High	N/A	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	High	Low	Low to Medium
Makua (south side)	Low to Medium	Low	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low to Medium
Waianae Kai	Low to High	Low to High	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low to Medium

Map removed to protect location of rare species. Available upon request.

Map removed to protect location of rare species. Available upon request.

16.21 Taxon Summary: *Phyllostegia kaalaensis*

Photographer: J. Jacobi

Scientific name: *Phyllostegia kaalaensis* St. John
Hawaiian name: None known
Family: Lamiaceae (Mint family)
Federal status: Listed endangered

Description and biology: *Phyllostegia kaalaensis* is a perennial herb with long stems extending out from the base of the plant. Its oppositely arranged leaves measure 5-13 cm (2.0-5.1 in) long. The inflorescences are borne at the stem tips. Each inflorescence consists of a single main stem with nodes each bearing 3-6 flowers. The flowers are tubular, white, and slightly fragrant. Each fruit consists of four segments connected at their bases. A segment consists of a single seed surrounded by a fleshy pulp. The fruits turn blackish upon ripening.

Flowering in *P. kaalaensis* has been reported from January to June (Nagata 1980). Insects, most likely moths, are presumed to pollinate the species' flowers. Little is known of the species' breeding system. The fleshy blackish fruits of the species are indicative of seed dispersal by fruit-eating birds.

The branches of *P. kaalaensis* often touch the ground and take root. A rooted stem becomes a separate plant when the stem connecting it to its maternal plant is severed. Reproduction in this species may be primarily through vegetative means, as most of the currently known plants are in dense patches far away from any other plants of the species. To date there have been no reports of seedlings or immature plants that obviously originated from a seed (Lau pers. comm. 2000). Given the species' tendency for vegetative reproduction, its clones have the potential for living indefinitely.

Known distribution: *Phyllostegia kaalaensis* is endemic to the Waianae Mountains. The species has been found throughout the mountain range from 490-760 m (1,610-2,500 ft).

Population trends: *Phyllostegia kaalaensis* colonies have been known only since the 1970's. Plants can no longer be found at a number of sites where the species had previously been recorded. Such sites include the branches of Ekahanui Gulch in the southern Waianaes, and several spots in Pahole Gulch in the northern Waianaes. The Waianae Kai colony has experienced a marked decrease in the size over the past decade. When first discovered in 1993, the colony contained about 30 plants. The count was down to eight plants when the plants were most recently observed in 1998.

Current status: The total number of known *P. kaalaensis* individuals is 32-37. Of these, 14-19 are located in the Makua action area. However, as mentioned above, the three largest population units each give the appearance of representing a single clone. If these population units truly represent single clones, the species' known, genetically unique individuals number seven or less.

The species' current population units are listed in Table 16.61 and their sites are plotted on Map 16.32. All sites are proposed for management for stability. The sites are characterized in Table 16.62 and threats to the plants at these sites are identified in Table 16.63.

Habitat: *Phyllostegia kaalaensis* is found in gulch bottoms and on gulch slopes in mesic to dry-mesic areas. It occurs most commonly in forests dominated by *lama* (*Diospyros sandwicensis*) and/or *lonomea* (*Sapindus oahuensis*), or in forests containing a mix of several tree species. The species grows either under the forest canopy, or in sunny openings.

Taxonomic background: *Phyllostegia kaalaensis*' closest relative is the common *P. glabra*, whose range includes the Waianae Mountains. *Phyllostegia kaalaensis* was accepted as representing a species distinct from *P. glabra* only within the past decade (Wagner *et al*. 1999). The two are distinguished not only by various morphological differences, but by different habitat requirements as well. *Phyllostegia kaalaensis* occurs in habitats drier than those of *P. glabra*. The two species are not known to grow near one another.

Outplanting considerations: *Phyllostegia kaalaensis*' geographical and ecological ranges broadly overlap those of several other species of *Phyllostegia* in the Waianae Mountains, including the endangered *P. mollis*, *P. parviflora*, and *P. hirsuta* (Lau pers. comm. 2000). Natural hybrid combinations have been identified among the Hawaiian *Phyllostegia*s (Wagner *et al*. 1990). Since hybridization seems to be a natural occurrence in *Phyllostegia*, the presence of the aforementioned endangered *Phyllostegia*s in a given gulch should not preclude the establishment of outplantings of *P. kaalaensis* in the gulch, as long as they are not conducted in the vicinity of any pre-existing wild populations of these endangered *Phyllostegia*s.

Given the ecological separation between *P. kaalaensis* and its close relative *P. glabra*, as long as outplanting sites for *P. kaalaensis* are established in the species' appropriate habitat, there should not be any *P. glabra* growing nearby.

Threats: Major threats to *P. kaalaensis* include feral pigs and goats. These ungulates degrade the species' habitat, and harm the plants by feeding on them, trampling them, or uprooting them while rooting for food. Alien plants threaten the species by altering the species' habitat and competing with it for sunlight, moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires. Since all of *P. kaalaensis*' population units are small and concentrated in tight patches, they are especially vulnerable to extirpation due to natural disasters.

As it is possible that the known plants represent a small number of genetically unique clones, inbreeding depression could potentially occur in *P. kaalaensis* populations. If indications of inbreeding depression are observed, controlled experiments on the consequences of mixing different stocks should be initiated.

Table 16.61 Current Population Units of *Phyllostegia kaalaensis.*
The numbers of individuals include mature and immature plants, and do not include seedlings. Populations proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kapuna	2	0	2
	Keawapilau	2	0	2
	Pahole	10-15	0	10-15
	Palikea Gulch	10	0	10
	Waianae Kai	8	0	8

Table 16.62 Site Characteristics for Population Units of *Phyllostegia kaalaensis* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kapuna	Medium- Low	Moderate	High	None
Keawapilau	Medium-Low	Flat	High	None
Pahole	Medium-Low	Flat to Moderate	High	Large
Palikea Gulch	High- Medium	Moderate	High	None

Table 16.63 Threats to Population Units of *Phyllostegia kaalaensis* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kapuna	High	Low	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	High	Medium
Keawapilau	High	Medium	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium
Pahole	Low	Low	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	High
Palikea Gulch	High	High	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Medium

Map removed to protect location of rare species. Available upon request.

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16.22 Taxon Summary: *Plantago princeps* var. *princeps*

Photographer: J. Obata

Scientific name: *Plantago princeps* Cham. & Schlechtend. var. *princeps*
Hawaiian name: *Ale*
Family: Plantaginaceae (Plantain family)
Federal status: Listed endangered

Description and biology: *Plantago princeps* var. *princeps* is a woody shrub, which is unusual for the genus. Most continental species in this genus are small herbs. The plant is either single stemmed or sparingly branched at the base, and attains a height of at least 1 m (3.3 ft) tall. The leaves are arranged in a cluster at the tip of each branch, are strap-shaped, and measure up to 20 cm (7.8 in) long. Each stem tip usually bears several erect, axillary inflorescences, each of which consists of a single stem bearing densely arranged flowers on its upper portion. The flowers and capsules are small and inconspicuous. The capsules each bear 3-4 black seeds measuring 1.5-2.1 mm (0.06-0.08 in) long.

Flowering and fruiting specimens have been collected throughout the year. The surface of the seed is covered by a mucilaginous membrane (Wagner *et al.* 1990), which is theorized to cause the seeds to stick to animals (Carlquist 1974). With the complete absence of ground mammals in Hawaii prior to the arrival of the Polynesians, birds, including the many now extinct flightless species, would have been the primary dispersal agents of Hawaiian *Plantago*s. Little is known about the target taxon's breeding system and pollination. The longevity of individuals of this taxon is unknown, but since the plant is a small shrub, its longevity is presumed to be less than 10 years, and it is therefore a short-lived taxon for the purposes of the Implementation Plan.

Known distribution: *Plantago princeps* var. *princeps* has been recorded from three general areas on the island of Oahu. Most of the currently known plants are scattered at locations throughout the Waianae Mountains, on both the leeward and windward sides of the mountain range. There are also historical records of it from the southeastern Koolau Mountains in the valleys of Kalihi, Nuuanu, and Manoa. It has not been observed in that region for over half a century. The taxon was discovered for the first time in the central Koolau Mountains in 2001, when plants were found at Waiawa. These plants are located just a short distance to the lee of the Koolau summit ridge. Recorded elevations for the plant range from 480-792 m (1,580-2,600 ft).

Population trends: When *P. princeps* var. *princeps* was rediscovered in 1987 in the Waianae Range, it had not been seen in over half a century in the Koolaus, and not since the 1800's in the Waianaes. Since all currently known colonies of the taxon were discovered relatively recently, the taxon's population trends are not well documented. The colony of plants discovered in 1987 in the North Branch of North Palawai Gulch is the only colony for which a trend has been observed. When found in 1987, the colony contained approximately 20 plants, but only five have been seen in the last five years. In this case, the taxon's rapid decline can be attributed to competition from daisy fleabane (*Erigeron karvinskianus*), a highly invasive alien plant.

Current status: The known population units of *P. princeps* var. *princeps* in the Waianae Mountains total approximately 200 plants. About 26 individuals are found within the Makua action area. The Waiawa population unit in the Koolau Mountains consists of two mature plants and about 40 immature ones. The species' current population units are listed in Table 16.64 and their sites are plotted on Maps 16.33 and 16.34. All are proposed for management for stability. Their sites are characterized in Table 16.65 and threats to the plants at these sites are identified in Table 16.66.

Habitat: *Plantago princeps* var. *princeps* occurs in two extremely different types of habitat. In the Waianae Mountains the plants are found in the mesic vegetation on cliff faces, cliff ledges, and at the bases of cliffs. The majority of these plants are accessible only with the help of ropes. Their cliff habitat is vegetated with native grasses, sedges, herbs, and shrubs. The historic southeastern Koolau Range plants also grew in mesic cliff habitats. In contrast, the Waiawa plants are situated in a rainforest area close to the Koolau summit ridge, which receives more precipitation than anywhere else on the island. The plants were observed to be growing on a streamside embankment (Perlman pers. comm. 2000).

Taxonomic background: *Plantago princeps* is endemic to the Hawaiian Islands. The species is divided into four varieties: var. *anomala* of Kauai; var. *laxiflora* of Molokai, Maui, and Hawaii; var. *longibracteata* of Kauai and the Koolau Mountains of Oahu; and var. *princeps* of both mountain ranges on Oahu. All of the varieties except var. *longibracteata* are sizable woody shrubs. In contrast, var. *longibracteata* is a small herb.

When the Waianae Range plants were rediscovered in 1987, the specimens collected were identified as var. *anomala*. Only the southeastern Koolau Range plants were considered to represent var. *princeps* (Wagner *et al.* 1990). The Waianae Range plants were subsequently reclassified as var. *princeps* (Wagner *et al.* 1999).

Outplanting considerations: *Plantago princeps* var. *princeps* is the only native *Plantago* in the Waianae Mountains. The situation is more complex in the Koolau Mountains, where in addition to var. *princeps*, there is another variety of *P. princeps* recorded, namely var. *longibracteata*. This variety is known from historical specimens collected on the windward side of the Koolaus in the Kaluanui area between Punaluu Valley and Hauula. It has been recorded on wet cliffs and alongside waterfalls. Additionally, there is a second native species in the Koolaus, *P. pachyphylla*, which is common in the Koolau summit areas. On Kauai, *P. princeps* var. *longibracteata* and *P. pachyphylla* form a hybrid population at the Waialeale summit (Bruegmann pers. comm. 2000). It is not yet known whether the ranges of *P. pachyphylla* or *P. princeps* var. *longibracteata* overlap that of *P. princeps* var. *princeps* in the Koolau rainforests, and whether any hybridization occurs or could potentially occur. No outplantings are currently proposed in the Koolaus, but if they are deemed necessary in the future, further study should be conducted on the distribution of *Plantago* taxa in the Koolau Range, and their potential for hybridization.

Given the extreme differences between the habitats of the Waianae Range and Waiawa plants, it would not be prudent to mix the two stocks at a single outplanting site.

Threats: The primary threats to *P. princeps* var. *princeps* of the Waianae Mountains include feral pigs and goats. Only a few goats are present in the Koolau Mountains, and none are in the rainforests of the mountain range. Pigs, however, are common in parts of the Koolaus and they likely threaten the Waiawa population unit. Various alien plant species threaten *P. princeps* var. *princeps* by altering its habitat and competing with it for sunlight, moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires. The alien weed threats are worse in the mesic Waianae sites than in the wet Waiawa site in the Koolaus.

Table 16.64 Current Population Units of *Plantago princeps* var. *princeps*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Ekahanui	23	0	23
	Halona	50 – 100	0	50 – 100
	North Branch of North Palawai	7	0	7
	North Mohiakea	30	0	30
	Ohikilolo	14	0	14
	Pahole	12	0	12
	South Branch of North Palawai	25	0	25
	Waiawa (Koolaus)	42	0	42

Table 16.65 Site Characteristics for Population Units of *Plantago princeps* var. *princeps* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Ekahanui	High- Medium	Moderate to Vertical	Low to High	None
Halona	High- Medium	Vertical	Low	None
North Mohiakea	High	Vertical	Low	None
Ohikilolo	High-Medium	Steep to Vertical	Low to Medium	Large
South Branch of North Palawai	Medium-Low	Steep	Medium	None
Waiawa (Koolaus)	High	Steep	Low	None

Table 16.66 Threats to Population Units of *Plantago princeps* var. *princeps* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Ekahanui	Low to High	Low	High	Unknown A	Unknown A	Unknown A	Unknown A	High	Medium	Low	Medium
Halona	Low to High	Low	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low
North Mohiakea	Low	N/A	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low
Ohikilolo	Low	Low	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low
South Branch of North Palawai	High	N/A	High	Unknown A	Unknown A	Unknown A	Unknown A	High	Medium	Low	Medium
Waiawa (Koolaus)	High	N/A	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Low	Low	Low	Low

Map removed to protect location of rare species. Available upon request.

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Map removed to protect location of rare species. Available upon request.

16.23 Taxon Summary: *Pritchardia kaalae*

Photographer: Hawaii Natural Heritage Program

Scientific name: *Pritchardia kaalae* Rock
Hawaiian name: *Loulu*
Family: Arecaceae (Palm family)
Federal status: Listed endangered

Description and biology: *Pritchardia kaalae* is a fan palm reaching up to 10 m (33 ft) tall (Lau pers. comm. 2000). It is a tree with a single erect trunk surmounted by a cluster of fronds. The species' inflorescences are very long, nearly reaching the frond tips to often extending well beyond the fronds. The flowers are borne in one or more bunches on the inflorescence. The fruits of *P. kaalae* are globose, and measure about 2 cm (0.8 in) in diameter.

*Pritchardia*s usually, if not always, bear perfect (possessing male and female reproductive parts) flowers. *Pritchardia kaalae* is most likely self-compatible, as cultivated trees of other species of *Pritchardia* produce viable seeds even when far away from any other *Pritchardia*s. Not much is known about the pollination of Hawaiian *Pritchardia*s. However, with respect to palms in general, it had been traditionally believed that all are wind pollinated. Recent research, however, indicates otherwise. Uhl and Dransfield (1987) predict that "most palms will be shown to be insect pollinated, or that both wind and insects are involved."

The large fruits of some Hawaiian *Pritchardia*s have been cited as examples of gigantism in plants of Oceanic islands (Carlquist 1974). The fruits of *P. kaalae*, however, are much smaller than the larger-fruited *Pritchardia*s, and appear to be small enough to have been consumed and dispersed by the larger of the now extinct flightless birds that occurred in Hawaii prior to human settlement.

The longevity of individuals of this species has not been documented, although they undoubtedly live for many decades.

Known distribution: *Pritchardia kaalae* has been found only in the northern Waianae Mountains. The great majority of the trees are on either Ohikilolo Ridge or on the northern side of Kaala from East Makaleha Valley to Manuwai Gulch. The few known trees beyond the major concentrations are in the bottom of Makaha Valley and on the ridge between Waianae Kai and Schofield Barracks Military Reservation. The recorded range in elevation for this species is from 460-945 m (1,500-3,100 ft).

In some parts of Hawaii, the current distribution of *Pritchardia* is apparently at least partially determined or influenced by the planting of trees by native Hawaiians (Hodel 1980). This is especially evident in the Kona region of Hawaii Island where there are no sites where *P. affinis* can be considered truly wild. All of the currently known older trees are in areas that were densely populated at the time of western contact. In the case of *P. kaalae*, however, there does not seem to be any evidence of native Hawaiian influences in the distribution of the species (Lau pers. comm. 2000).

Population trends: The number of mature trees of this species has been slowly decreasing as the older trees die off with very few immature plants to take their place.

Current status: The total number of individuals of *P. kaalae* is slightly more than 300 plants. A little more than half of these are on Ohikilolo Ridge in the Makua action area. The current populations units are listed in Table 16.67 and their sites are plotted on Map 16.35. The sites of the population units proposed for management for stability are characterized in Table 16.68 and threats to the plants at these sites are identified in Table 16.69.

Habitat: *Pritchardia kaalae* is found in the mesic zone on moderately steep slopes to very steep cliffs. Many of the trees in the lower elevations are in forests dominated by *lama* (*Diospyros sandwicensis*) and/or *ohia* (*Metrosideros* spp.). The highest trees are in the upper wetter zone of the mesic forest, which is often dominated by *lehua ahihi* (a species of *ohia*, *Metrosideros tremuloides*). The steeper, more open cliffs where this species grows are vegetated largely with shrubs, grasses and sedges, and small trees.

Taxonomic background: *Pritchardia* is a genus restricted to the tropical Pacific islands and the Hawaiian Islands including about 25 species, about 20 of which are endemic to the Hawaiian Islands. The taxonomy of the Hawaiian species of *Pritchardia* are taxonomically difficult because characteristics used to distinguish the species appear to be highly plastic (Read and Hodel 1990). *Pritchardia kaalae*'s extremely long inflorescences sets the species apart from all other Hawaiian *Pritchardia* species except one.

The Waianae Mountains to the south of *P. kaalae* territory in the northern part of the mountain range are devoid of *Pritchardia*s of any kind, with the exception of a *Pritchardia* colony south of Pohakea Pass in North Palawai Gulch. There are only two mature trees and one juvenile in the colony. These plants are the only members of what is considered to be an undescribed species most closely related to *P. martii*, the sole species of *Pritchardia* in the Koolau Mountains (Gemmill 1996).

Outplanting considerations: Outplantings of *P. kaalae* should not be established in the southern Waianae Mountains since *P. kaalae*'s recorded range is limited to the northern Waianae Mountains, and since there is a second extremely rare undescribed species of *Pritchardia* in the southern Waianaes. An outplanting line was drawn through the central portion of the mountain range limiting potential reintroduction sites to areas north of the line.

Threats: Recent studies of fossil pollen and charcoal deposits on Oahu indicate that when the Polynesians first settled in Hawaii *Pritchardia* constituted a major element of the vegetation of the lowlands of Oahu, including the island’s dry leeward lowlands adjoining the Waianae Mountains. The arrival of the Pacific rat (*Rattus exulans*) on Oahu via the canoes of early Polynesian voyagers appears to have brought about a collapse of these *Pritchardia* populations due to fruit predation by the rats (Athens pers. comm. 2000). The *Pritchardia*s growing in this largely vanished lowland vegetation have not been identified, but it is quite possible that *P. kaalae* formerly extended into the lowlands and was included in the lowland *Pritchardia* populations decimated by the rats. In any case, it can be surmised that the advent of the Pacific rat diminished *P. kaalae*’s range and numbers to some extent. Western contact brought about the introduction of additional species of rats to Hawaii that potentially feed on *Pritchardia* fruits. The rate of recruitment in *P. kaalae* populations continues to be negatively affected due to fruit predation by rats, as evidenced by significant increases in recruitment rates when rats are controlled in *P. kaalae* groves (Rohrer pers. comm. 2000).

Other major threats to *P. kaalae* include feral pigs and goats, which degrade the plants’ habitat and harm them through feeding on the plants, trampling them, or uprooting them. Alien plants also threaten the species by altering its habitat and competing with it for sunlight, moisture, nutrients, and growing space.

The non-Hawaiian *P. thurstonii* and *P. pacifica* are commonly grown as ornamentals in Hawaii. It is not known if they pose a threat to the genetic integrity of the Hawaiian *Pritchardia*s through hybridization. Hawaiian *Pritchardia*s from islands other than Oahu are also occasionally planted as ornamentals on Oahu. In contrast, the Oahu species have almost never been utilized for this purpose (Lau pers. comm. 2000). The potential for genetic contamination of the native *Pritchardia*s of Oahu by the planted Hawaiian *Pritchardia*s from other islands remains to be investigated.

Collection of *Pritchardia* fruits by commercial palm growers or their collectors has been a problem with some of the rarer Hawaiian *Pritchardia*s. For instance, an immature plant of the extremely rare *P. viscosa* is known to have been illegally collected from the wild (Perlman pers. comm. 2000), and harvesting of fallen fruits has become evident at the only remaining grove of *P. schattaueri* (Perry pers. comm. 2000). It is not known to what level palm collectors are affecting *P. kaalae*.

The most worrisome of any potential threat to the Hawaiian *Pritchardia*s is lethal yellowing, a palm disease that is slowly making its way through the tropical and subtropical zones of the world. It is most well known for its devastating effects on coconut trees, but Hawaiian *Pritchardia*s planted in Florida as ornamentals have also proven to be extremely susceptible to the disease. The disease is fatal; there is currently no cure for it once a susceptible individual is infected with the disease. Lethal yellowing is caused by a “mycoplasma-like-organism” (Murakami 1999). The organism is transmitted by a sap-sucking plant hopper, *Myndus crudus*. Symptoms include the yellowing of the palm's fronds prior to its death. The disease is particularly frustrating because infected plants have an incubation period of from six months to two years before symptoms appear. The disease originated in islands in the Caribbean Sea, and is now known from many Caribbean islands, Florida and Texas in the United States of America, Central America, West Africa, and Tanzania in East Africa. The insect transmitter of the disease has not yet been found in Hawaii, so Hawaii is safe from this disease for now (Murakami 1999).

Table 16.67 Current Population Units of *Pritchardia kaalae*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Makaha	1	0	1
	Makaleha to Manawai	141	0	141
	Ohikilolo	165	0	165
	Waianae Kai	9	0	9

Table 16.68 Site Characteristics for Population Units of *Pritchardia kaalae* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Makaleha to Manawai	High-Medium	Moderate to Vertical	Low to High	None
Ohikilolo	High- Medium	Moderate to Vertical	Low to Medium	Large

Table 16.69 Threats to Population Units of *Pritchardia kaalae* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Makaleha to Manawai	Low to High	High	High	Unknown B	N/A	Unknown A	Unknown A	Low	Medium	High	Low to Medium
Ohikilolo	Low	Low	High	High	N/A	Unknown A	Unknown A	Very high	Medium	High	Low

Map removed to protect location of rare species. Available upon request.

16.24 Taxon Summary: *Sanicula mariversa*

Photographer: J. Lau

Scientific name: *Sanicula mariversa* Nagata & Gon
Hawaiian name: None known
Family: Apiaceae (Parsley family)
Federal status: Listed endangered

Description and biology: *Sanicula mariversa* is a perennial herb with its leaves, stems, and flowering and fruiting stalks above the ground. The plant has a thick underground storage root. The basal leaves are three to five-lobed, and measure up to 23 cm (9 in) across. Flowers and fruits are borne in masses on stems up to 0.7 m (27 in) in height. Some of the yellow flowers are perfect (possessing male and female reproductive parts) and others are staminate (possessing only male reproductive parts). The fruits are 4-6 mm (ca. 0.2 in) long, and are covered with hooked bristles.

The leaves and stems of *S. mariversa* die back to the storage root usually in May. The plants are dormant through the warm and dry summer months until new growth emerges at the onset of the wet season. This appearance of new growth takes place usually in October or November. The species flowers from February through May, and their fruits mature in April and May (Kawelo pers. comm. 2000).

The massed yellow flowers of this species suggest pollination by insects. The fruit’s bristles indicate that the fruits are capable of dispersal by birds. The age at which wild plants mature is not known. However, with respect to a cohort of four year old plants currently under cultivation, a few are flowering and fruiting for the first time, but the majority still have not flowered (Kawelo pers. comm. 2000). The longevity of individuals of the species is unknown, but since the plant is a small herb, its longevity is presumed to be less than 10 years, and it is therefore a short-lived taxon for the purposes of the Implementation Plan.

Known distribution: *Sanicula mariversa* is endemic to the Waianae Mountains. It was not discovered until the late1970's when it was found on Ohikilolo Ridge. There is also a sizeable colony in Keaau Valley, on the ridge separating Keaau Valley from Makaha Valley. It has also been reported at Puu Kanehoa, which is south of Kolekole Pass. An immature plant was seen there sometime in the 1970's (Obata pers. comm. 2000). The species is also known to occur on Kamaileunu Ridge, which includes the peak of Puu Kawiwi.

Population trends: Population trends of *S. mariversa* populations have not been detected due to the paucity of data. Fewer than 25 years have passed since the species was discovered, and for most of those years the Ohikilolo and Keaau population units were seldom visited. Furthermore, the plants cannot be observed when dormant. Over the last few years the Ohikilolo and Keaau population units have been monitored annually. There have been considerable differences from year to year in the number of plants reported (Kawelo pers. comm. 2000). It is not known whether the recorded differences reflect actual fluctuations in population numbers.

Current status: Approximately 300 individuals of *S. mariversa* are known, all but two of which are on Ohikilolo Ridge or in Keaau Valley. Both of these sites are within the Makua action area. The two plants outside the action area were recently found at Puu Kawiwi on Kamaileunu Ridge. The species' current population units are listed in Table 16.70 and their sites are plotted on Map 16.36. All of the sites are proposed for management for stability. The sites are characterized in Table 16.71 and threats to the plants at these sites are identified in Table 16.72.

Habitat: *Sanicula mariversa* is found at mesic sites, usually on north-facing slopes just off the ridge tops. Most of the known plants grow in deep soil. However, the two plants recently found at Puu Kawiwi were observed to be growing in the cracks of a nearly vertical rock face (Perlman pers. comm. 2000).

On Ohikilolo Ridge and in Keaau Valley, most *S. mariversa* plants are growing at sites now dominated by the annual, non-native grasses fescue (*Vulpia* sp.) and bromegrass (*Bromus* sp.). The remnants of the native vegetation at these sites, together with the composition of similar, but more intact locations in the Waianae Mountains, indicate that the native vegetation was originally a mix of native sedges, grasses, herbs, ferns, and shrubs, with a good percentage of the ground covered by lichens and mosses (Lau pers. comm. 2000). At one of the sites on Ohikilolo Ridge the plants are growing where *ohia* (*Metrosideros* spp.) shrubland grades into open slopes.

Taxonomic background: *Sanicula mariversa* is the only *Sanicula* recorded in the Waianae Mountains. It is one of the four species of *Sanicula* occurring in Hawaii, all of which are endemic to Hawaii.

Outplanting considerations: There are no hybridization concerns with respect to the outplanting of *S. mariversa* in the Waianae Mountains since no other species of *Sanicula* occur in the mountain range.

Threats: Feral goats seriously threaten *S. mariversa*, even though they apparently do not browse on it very much (Kawelo pers. comm. 2000). They threaten the species by denuding the slopes where the plants grow, and by disturbing the substrate, thereby accelerating the process of erosion. Erosion scars grow progressively larger, and in addition to eroding out individual plants, the scars destroy the deep-soiled slopes, which constitute *S. mariversa*'s prime habitat supporting the highest densities of the species. An erosion scar had been eating into a slope containing most of the plants on Ohikilolo Ridge until erosion control measures were initiated within the last five years. Goats have been practically eliminated from the Makua side of Ohikilolo Ridge where the Ohikilolo population unit is located, but a large number of goats continue to impact the population unit in Keaau.

Alien shrubs and trees, and the taller and denser of the alien grasses constitute serious threats to *S. mariversa*. The short alien grass dominating the sites at Ohikilolo Ridge and Keaau does not seem to be extremely detrimental to the species. Removing the grass may cause more harm than good, unless it can somehow be replaced with native groundcover.

Human disturbance impacts *S. mariversa* plants at the Keaau site. A trail runs directly through the densest part of the population unit. Several of the plants are right alongside the trail, and are at risk of being trampled by hunters and hikers. On Ohikilolo Ridge, some of the plants are within 2 m (6.6 ft) of the ridge top fence and the trail running alongside the fence (Rohrer pers. comm. 2000). Fence maintenance and human traffic could possibly harm these plants.

Table 16.70 Current Population Units of *Sanicula mariversa*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kamaileunu	26	0	26
	Keaau	141	0	141
	Ohikilolo	143	0	143
	Puu Kawiwi	2	0	2

Table 16.71 Site Characteristics for Population Units of *Sanicula mariversa* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kamaileunu	Medium-Low	Steep to Vertical	Low to Medium	None
Keaau	Medium-Low	Flat to Steep	Low	None
Ohikilolo	Medium-Low	Moderate to Vertical	Low	Large
Puu Kawiwi	Medium-Low	Vertical	Low	None

Table 16.72 Threats to Population Units of *Sanicula mariversa* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kamaileunu	Low	High	High	Unknown A	N/A	Unknown A	Unknown A	Very high	Medium	Medium	Low to High
Keaau	Low	High	Medium	Unknown A	N/A	Unknown A	Unknown A	Very high	Medium	High	Medium
Ohikilolo	Low	Medium	Medium	Unknown A	N/A	Unknown A	Unknown A	Very high	Medium	High	High
Puu Kawiwi	Low	High	High	Unknown A	N/A	Unknown A	Unknown A	Very high	Medium	Low	Low

Map removed to protect location of rare species. Available upon request.

16.25 Taxon Summary: *Schiedea kaalae*

Photographer: J. Lau

Scientific name: *Schiedea kaalae* Wawra
Hawaiian name: None known
Family: Caryophyllaceae (Pink family)
Federal status: Listed endangered

Description and biology: *Schiedea kaalae* is a perennial herb with short stems usually trailing on the ground. Each of the main stems ends in a rosette of leaves. The leaves are 14-24 cm (5.5-9.4 in) long. The flowers are borne on open panicles measuring up to 40 cm (15.6 in) or rarely up to 60 cm (23.4 in) long. The flowers are perfect (possessing both male and female reproductive parts). The tiny seeds are contained in capsules measuring about 4 mm (0.16 in) long.

Schiedea kaalae is known to be capable of self-pollination through the study of plants in cultivation (Weller pers. comm. 2000). It is probably either insect pollinated or largely self-pollinating (Wagner *et al.* 1995). The species has been observed in flower from March through June (Nagata 1980). Its dispersal agents are unknown. The longevity of individuals of this species is unknown, but since the plant is an herb, its longevity is presumed to be less than 10 years, and it is therefore a short-lived taxon for the purposes of the Implementation Plan.

Known distribution: *Schiedea kaalae* is endemic to both mountain ranges of Oahu. In the Waianae Mountains it has been documented from the windward side of the northern and southern portions of the mountain range. In the Koolaus it has been found on the windward side of the north-central part of the mountain range, ranging from Punaluu in the south to the Hauula area in the north. The species occurs at elevations of 210-790 m (700-2,600 ft).

Population trends: The number of plants of *S. kaalae* has been steadily decreasing. The Makaua population unit, for instance, has over the last 15 years decreased from about 30 known plants to only two known plants today, probably as a result of a large increase in the number of pigs in the gulch over that time period.

Current status: *Schiedea kaalae* is still found in both the Waianae and Koolau Mountains. Fewer than 25 wild plants are known to be extant. About 18 plants are known in the Waianaes and about six plants are known in the Koolaus. However, in the Koolau Mountains there remains much potential habitat for the species that has never been botanically surveyed. Within the Makua action area there are three known plants, all of which are in Pahole Gulch, which adjoins the Makua Military Reservation. The species' current population units are listed in Table 16.73 and their sites are plotted on Maps 16.37 and 16.38. The sites of the population units proposed for management for stability are characterized in Table 16.74 and threats to the plants at these sites are identified in Table 16.75.

Habitat: *Schiedea kaalae* in the Waianae Mountains is consistently found growing in the understory of diverse mesic forests, usually in gulch bottoms or low to mid-gulch slopes. The plants are usually found growing in soil or a mix of soil and rocks. They are often found on slopes whose groundcover is sparse. Occasionally they are seen growing in cracks in rock embankments.

In the Koolau Mountains, *S. kaalae* has been found in habitats that range from mesic to fairly wet. The species occurs there in gulch bottoms and on lower gulch slopes. Some plants grow on gentle to moderate slopes, while others are found growing on steep rock embankments and nearly vertical cliffs. Some Koolau *S. kaalae* sites are constantly wet from seeping water.

Taxonomic background: The endemic Hawaiian genera *Schiedea* and *Alsinidendron* constitute a complex of species descended from a single colonizing ancestor (Wagner *et al.* 1995). *Schiedea kaalae* belongs to a subgroup of the genus *Schiedea* that includes *S. nuttallii* and *S. pentandra*.

Outplanting considerations: In many cases, *S. kaalae* is located in the same drainages as its relatives *S. nuttallii*, *S. pentandra*, *S. hookeri*, and *Alsinidendron obovatum*. In such cases *S. kaalae* is usually found in parts of the drainages that are drier than where these related taxa are growing. Hybridization between *Schiedea* species has been documented in the wild, and hybridization is not uncommon when *Schiedea* species are grown together in cultivation. In order to avoid inadvertently causing unnatural hybridization, *S. kaalae* should not be outplanted near any related species with which it does not naturally occur.

Plants from the Koolau and Waianae Mountain Ranges should not be mixed in reintroductions. Since many miles of unsuitable habitat separate the Waianae Range and Koolau Range populations, it is presumed that genetic communication between the two populations was rare under natural conditions. Additionally, since the Waianae and Koolau *S. kaalae* habitats are rather different, it may be especially important when reintroducing this species to utilize stock originating from the same mountain range where the reintroduction is attempted. Such stock is likely to be better adapted to the environmental conditions of the reintroduction site than stock from the other mountain range.

There is a large gap between the recorded locations for *S. kaalae* in the northern Waianaes and recorded locations in the southern Waianaes. As it is possible that the northern and southern plants are genetically distinct because of the gap, the northern and southern stocks should be preserved separately. Outplanting lines have been drawn limiting the outplanting of the northern and southern stocks to their respective ends of the mountain range.

Threats: Major threats to *S. kaalae* include feral pigs, which degrade the species' habitat, and harm the plants by feeding on them, trampling them, or uprooting them while rooting for food. Alien plants threaten the species by altering the species' habitat and competing with it for sunlight, moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires.

Seedlings and immature plants are seldom seen, especially in populations in the Waianae Mountains (Lau pers. comm. 2000). This may be the result of seedling predation by introduced slugs and snails (Weller pers. comm. 2000). Experiments have been conducted using barriers to prevent mollusks from gaining access to the areas around mature plants of the *S. kaalae* relative, *Alsinidendron obovatum*. The installation of these barriers has resulted in the appearance of numerous seedlings within the barriers, whereas the areas under neighboring plants not so protected have shown no such regeneration (Rohrer pers. comm. 2000).

Low levels of genetic diversity in *S. kaalae* populations may not be detrimental to the species, as plants from populations that appear to have undergone repeated self-fertilization are vigorous in cultivation, and are among the most vigorously growing of *Schiedea*s under greenhouse conditions (Weller pers. comm. 2000). However, if there are indications that the species' naturally-occurring or reintroduced populations are being affected by inbreeding depression, controlled experiments on the ramifications of mixing different stocks should be conducted.

Table 16.73 Current Population Units of *Schiedea kaalae*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Huliwai	1-2	0	1-2
	Maakua (Koolaus)	4	0	4
	Makaua (Koolaus)	2	0	2
	North Branch of South Ekahanui	3	0	3
	North Kaluaa	2	0	2
	North Palawai	1	0	1
	Pahole	3	0	3
	South Branch of South Ekahanui	7	0	7

Table 16.74 Site Characteristics for Population Units of *Schiedea kaalae* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
North Branch of South Ekahanui	Medium – Low	Moderate	High	None
North Kaluaa	Medium – Low	Moderate	High	None
Pahole	Medium – Low	Steep	High	Large
South Branch of South Ekahanui	High – Medium	Moderate	High	None, Small, Large

Table 16.75 Threats to Population Units of *Schiedea kaalae* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
North Branch of South Ekahanui	High	N/A	High	Unknown A	Unknown A	Unknown B	Unknown A	High	Medium	Medium	Medium
North Kaluaa	High	N/A	High	Unknown A	Unknown A	Unknown B	Unknown A	Very high	Medium	Low	Medium
Pahole	Low	N/A	High	Unknown A	Unknown A	Unknown B	Unknown A	Very high	Medium	Low	Medium
South Branch of South Ekahanui	Low to High	N/A	Medium	Unknown A	Unknown A	Unknown B	Unknown A	High	Medium	Medium	Medium

Map removed to protect location of rare species. Available upon request.

Map removed to protect location of rare species. Available upon request.

16.26 Taxon Summary: *Schiedea nuttallii*

Photographer: J. Obata

Scientific name: *Schiedea nuttallii* Hook.
Hawaiian name: None known
Family: Caryophyllaceae (Pink family)
Federal status: Listed endangered

Description and biology: *Schiedea nuttallii* is an erect shrub reaching up to 1.5 m (4.9 ft) tall. The lower portions of its stems are woody. The leaves are oppositely arranged, measure 5-13 cm (2.0-5.1 in) long, and are often purple-tinged. The flowers are borne in inflorescences 20-25 cm (7.8-9.8 in) long. The flowers are small, inconspicuous, and perfect (possessing both male and female reproductive parts). The tiny seeds are contained within capsules 2.5-3.5 mm (0.1-0.14 in) long.

Schiedea nuttallii belongs to a subgroup of *Schiedea* species that are probably either insect-pollinated or largely self-pollinating (Wagner *et al.* 1995). Dispersal agents for the subspecies of *S. nuttallii* that includes the Waianae Range plants is unknown. The longevity of individuals of the subspecies is also unknown, but since the plant is a small, semi-woody shrub, its longevity is presumed to be less than 10 years, and it is therefore a short-lived taxon for the purposes of the Implementation Plan.

Known distribution: The subspecies that includes the Waianae Range plants has been recorded from the islands of Oahu and Maui, and possibly Molokai (see the Taxonomic Background section below for a discussion of *S. nuttallii*'s taxonomic status). On Oahu, it has been recorded throughout the Waianae Mountains and at the southeastern end of the Koolau Mountains. The Maui record is based on a historical collection from Maui without specific locality data (Weller pers. comm. 2000).

In the Waianae Mountains, the subspecies has been found from 549-732 m (1,800-2,400 ft). Elevations for the Maui and Koolau Range plants were not recorded.

Population trends: No populations of this subspecies have been carefully tracked over a period of many years. Nevertheless, it is clearly declining. Several of the Waianae Range colonies known in the 1970's and 1980's have apparently been extirpated.

Current status: The subspecies of *S. nuttallii* that includes the Oahu and Maui plants is known to persist only in the northern Waianae Mountains, where about 50 plants are known. All of them are in the Makua action area. Plants in the southern part of the Waianae Mountains have not been seen since the late 1970's.

The taxon's current population units are listed in Table 16.76 and their sites are plotted on Map 16.39. All of the population units are proposed for management for stability. Their sites are characterized in Table 16.77 and threats to the plants at these sites are identified in Table 16.78.

Habitat: The taxon usually grows in the understory of mesic forests dominated by *koa* (*Acacia koa*) and *ohia* (*Metrosideros polymorpha*), and is usually found on north-facing gulch slopes.

Taxonomic background: The genus *Schiedea* is an endemic Hawaiian genus. The genera *Schiedea* and *Alsinidendron* constitute a complex of related species descended from a single colonizing ancestor. *Schiedea nuttallii* belongs to a subgroup of the genus *Schiedea* that includes *S. kaalae* and *S. pentandra* (Wagner *et al.* 1995).

In the last comprehensive treatment of the genus *Schiedea*, published in 1990 (Wagner *et al.* 1990), *S. nuttallii* was considered to be comprised of plants from Oahu and Kauai. The taxonomy of the subgroup of *Schiedea*s that includes *S. nuttallii* is undergoing a major revision, which will soon be published (Weller pers. comm. 2002). Plants on Kauai formerly considered to be *S. nuttallii* will be split off into two separate species endemic to Kauai. A historical specimen collected on Maui, which was not formerly included in *S. nuttallii*, will be placed in the species. The species will be comprised of two subspecies, with the Oahu and Maui plants constituting subsp. *nuttallii*. Plants discovered in 1998 in the Waikolu Drainage on Molokai will represent a new subspecies. The subspecific assignment of the few historical specimens of *S. nuttallii* from Molokai is yet to be determined. The subspecies of the Waianae Mountains grows in mesic forests, and bears flowers that open fully, while the subspecies represented by the recently discovered Molokai plants was found alongside a stream in rainforest, and is characterized by flowers that do not open.

Outplanting considerations: In the Waianae Mountains, *S. nuttallii* is often located in the same drainages as its close relatives *S. kaalae* and *S. pentandra*, and the more distantly related *Alsinidendron obovatum*. Hybridization between *Schiedea* species has been documented in the wild, and *Schiedea* species grown together in cultivation occasionally hybridize (Weller pers. comm. 2000). In order to avoid inadvertently causing unnatural hybridization, *S. nuttallii* should not be outplanted near any related species with which it does not naturally occur.

Threats: The major threats to *S. nuttallii* in the Waianae Mountains include feral pigs, which degrade the species' habitat, and harm the plants by feeding on them, trampling them, or uprooting them while rooting for food. Alien plants threaten the species by altering the taxon's habitat and competing with it for sunlight, moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires.

Seedlings are observed in populations of *S. nuttallii* in the Waianae Mountains, but the recruitment rates in these populations are likely being lowered due to seedling predation by introduced slugs and snails (Weller pers. comm. 2000). Experiments have been conducted using barriers to prevent mollusks from gaining access to the areas around mature plants of a species related to *S. nuttallii,* namely *Alsinidendron obovatum*. The installation of these barriers has resulted in the appearance of numerous seedlings within the barriers, whereas the areas under neighboring plants not so protected have shown no such regeneration (Rohrer pers. comm. 2000).

Table 16.76 Current Population Units of *Schiedea nuttallii.* The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kahanahaiki	33	0	33
	Kapuna – Keawapilau Ridge	3	0	3
	Pahole	14-15	0	14-15

Table 16.77 Site Characteristics for Population Units of *Schiedea nuttallii* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kahanahaiki	High-Medium	Moderate	High	Large
Kapuna – Keawapilau Ridge	High-Medium	Moderate	High	None
Pahole	Low to High-Medium	Moderate to Steep	High	Large

Table 16.78 Threats to Population Units of *Schiedea nuttallii* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kahanahaiki	Low	Low	Medium	Unknown A	Unknown A	Unknown B	Unknown A	Very high	Medium	Low	Medium
Kapuna – Keawapilau Ridge	High	Medium	Medium	Unknown A	Unknown A	Unknown B	Unknown A	Very high	Medium	Medium	Medium
Pahole	Low	Low	Medium	Unknown A	Unknown A	Unknown B	Unknown A	Very high	Medium	Medium	Medium

Map removed to protect location of rare species. Available upon request.

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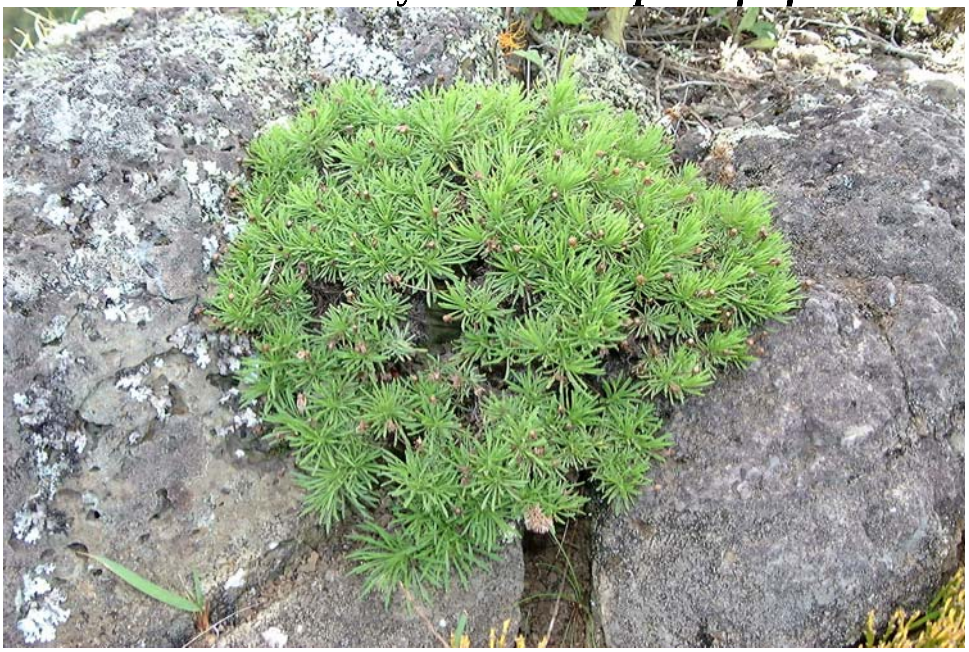
16.27 Taxon Summary: *Tetramolopium filiforme*



Photographer: J. Jacobi

Scientific name: *Tetramolopium filiforme* Sherff var. *filiforme* and *T. filiforme* Sherff var. *polyphyllum* (Sherff) Lowrey
Hawaiian name: None known
Family: Asteraceae (Sunflower family)
Federal status: Listed endangered

Description and biology: *Tetramolopium filiforme* is a dwarf shrub 5-15 cm (2-6 in) tall, and is often mounded in shape. The narrow leaves are clustered at the branch tips, and measure 1-2 cm (0.4-0.8 in) long. The flower heads are purplish-white, and are held up above the foliage on long slender stalks. The ray florets are female, and their rays are white to pale lavender. The disk florets are functionally male, and are colored maroon or rarely yellow. The achenes (a type of dry, seed-like fruit) measure 2-2.7 mm (*ca.* 0.1 in) long, bear sparse short glandular hairs or are hairless, and are tipped with bristles almost as long as the achenes.

Flowering usually occurs in the late winter and spring (Lowrey 1986). The plants are capable of self-pollination (Lowrey 1986). *Tetramolopium filiforme* is likely insect-pollinated, as are most conspicuous-flowered species in the sunflower family.

Tetramolopium filiforme is presumed to be wind-dispersed, as bristle-bearing achenes are characteristic of the wind-dispersed members of the sunflower family. The species may additionally be bird-dispersed, as the bristles can cause the achenes to stick to birds' feathers (Lowrey 1995). Another characteristic of *Tetramolopium* achenes indicating dispersal by birds are sticky glandular hairs on the achenes, which would contribute to their adherence to feathers. With *T. filiforme*, however, this feature is either not well developed, or completely absent (Lowrey 1986).

Tetramolopium filiforme reproduces by seed. By their second year, greenhouse plants show signs of old age. They live until they are about three years old (Lowrey 1986). Wild plants appear to be able to live to an age of 5-10 years (Lau pers. comm. 2000).

Known distribution: *Tetramolopium filiforme* is narrowly endemic to the northern leeward Waianae Mountains. Outside of its center of abundance on Ohikilolo Ridge on the Makua Military Reservation it is found only in small outlying populations, which are located from Kahanahaiki in the north to Kamaileunu Ridge and Puhawai in the south. These plants occurring beyond Ohikilolo Ridge all represent var. *filiforme*. Only on Ohikilolo Ridge do both varieties occur. Variety *polyphyllum* is found only at the higher and wetter portion of Ohikilolo Ridge. The plants on the low, dry, seaward end of the ridge are all morphologically typical var. *filiforme*. As one ascends the ridge into higher wetter habitats, plants showing var. *polyphyllum* traits begin to show up growing together with var. *filiforme*-looking plants. At the highest portion of the ridge, the majority of the plants show var. *polyphyllum* traits to some degree. However, it appears that nowhere along the ridge do all the plants represent var. *polyphyllum*.

The species ranges from 340-900 m (1,100-3,000 ft) in elevation. The low elevation plants of the species, as well as the plants at the highest elevation at Puhawai, are of var. *filiforme* morphology.

Population trends: Feral goats have brought the number of plants on Ohikilolo Ridge down significantly over the last few decades. In the 1970s there were many plants growing along the crest of the ridge (Obata pers. comm. 2000). Due to the subsequent increase in the number of goats on the ridge in the 1980s and 1990s, the species is no longer abundant on the accessible portions of the ridge top. That the species has not declined more steeply than it has, and still numbers in the thousands, is due to the large number of plants found on cliff faces inaccessible to goats.

Current status: *Tetramolopium filiforme* is conservatively estimated to number at least 5,000 mature plants on Ohikilolo Ridge, in addition to many immature ones. The other populations are miniscule in comparison. At Kahanahaiki, there are about 50 plants. There were an estimated 25 plants in the Keaau colony at last report in 1990. Only 12 plants were found when recently counted at the Puhawai site. A single plant was known in Waianae Kai, but it was no longer there when the site was visited in 2001. All known plants of the species are located within the Makua Action Area, with the exception of the 12 plants at Puhawai.

The species' current population units are listed in Table 16.79 and their sites are plotted on Map 16.40. All sites are proposed for management for stability. The sites are characterized in Table 16.80 and threats to the plants at these sites are identified in Table 16.81.

Habitat: *Tetramolopium filiforme* is growing in a dry habitat at the seaward extreme of the Ohikilolo population unit. The higher, more inland plants are in dry-mesic and mesic habitats. In general, the species grows on exposed rocky ridges and on sparsely vegetated, nearly vertical cliffs, and are often rooted in cracks in the rock.

Taxonomic background: The genus *Tetramolopium* has an unusual disjunct distribution. There are species in Hawaii and New Guinea, in addition to a single species on Mitiaro, a small island in the Cook Islands in the South Pacific. Of the approximately 36 species in the genus, 11 are Hawaiian. The genus is divided into three sections: section *Alpinum*, section *Tetramolopium*, and section *Sandwicense*. Although *T. filiforme* is best placed in the section *Tetramolopium*, the species also possesses characteristics that are otherwise unique to the section *Sandwicense*. This combination of characteristics of two sections of the genus in *T. filiforme* is hypothesized to be the result of a hybridization event in the distant past between two different species of *Tetramolopium*. One parental species is thought to be an undetermined member of the section *Tetramolopium*. The other parental species is thought to be *T. lepidotum*, which is a member of the section *Sandwicense*, and is the only member of the genus recorded from the Waianae Mountains besides *T. filiforme* (Lowrey 1986, Okada *et al.*1997). This hypothesis is supported by the results of molecular genetic analysis (Okada *et al.*1997).

The two varieties of *T. filiforme* are differentiated primarily by their leaf characteristics, particularly the leaf shape and the presence or absence of teeth along the leaf margin. Variety *filiforme* has extremely narrow, linear leaves with no teeth along the leaf margins, whereas var. *polyphyllum* has leaves that widen towards the leaf apex, and its leaf margins bear prominent teeth.

It had been thought that the two varieties on Ohikilolo Ridge are distinct, and are geographically separated (Lowrey 1986), but it has been observed over the last few years that the two morphological types are not clearly separated geographically (Lau pers. comm. 2000). In any given subpopulation along the higher portion of the ridge, plants are found that fit the description of one of the two varieties, as well as plants with characteristics intermediate between the two varieties. The taxonomy of *T. filiforme* on Ohikilolo Ridge needs to be clarified through further study.

Outplanting considerations: The Hawaiian *Tetramolopium*s are all highly interfertile with one another. In greenhouse experiments, all of the Hawaiian species except the two not available at the time were crossed in all combinations, producing first, second, and third generation hybrid progeny (Lowrey 1986). In the wild, the various Hawaiian species appear to be maintained as separate entities through either geographical or ecological separation.

As mentioned above, the other species of *Tetramolopium* recorded from the Waianae Mountains is *T. lepidotum*. It has been recorded from most parts of the mountain range not occupied by *T. filiforme*. Its habitat requirements are similar to *T. filiforme*'s. Its numbers have always been much lower than *T. filiforme*'s numbers. Its two currently known populations contain a total of fewer than 200 plants. The species has been documented at locations not far removed from *T. filiforme*'s range. A specimen was collected at the head of Makua Valley near the valley rim in 1932, not very far from *T. filiforme* locations on Ohikilolo Ridge; and a small colony is known on the eastern side of Waianae Kai, not far from the Waianae Kai *T. filiforme* site. It is possible that other colonies of *T. lepidotum* occur near the edges of *T. filiforme*'s range. In order to minimize the chance of inadvertently causing the genetic swamping of any unrecorded populations of *T. lepidotum,* an out-planting line for *T. filiforme* has been drawn. The line cuts across the ridges of Ohikilolo and Kamaileunu next to the furthest inland recorded *T. filiforme* sites, and away from *T. lepidotum* sites and areas that potentially harbor unrecorded plants of *T. lepidotum*. The southeastern end of the outplanting line includes the Puhawai population unit of *T. filiforme* within the area considered acceptable for outplanting *T. filiforme*.

There are also concerns about outplanting var. *polyphyllum* into areas beyond its known range on Ohikilolo Ridge into areas where only strict var. *filiforme* is known to occur, such as the ridge of Kamaileunu where the Waianae Kai plant was located. Such outplantings should not be conducted pending further taxonomic and ecological study of the two recognized varieties.

Threats: Feral goats and pigs threaten *T. filiforme*, for although many of the plants grow on steep cliffs where they cannot be reached by the ungulates; many others are within their reach and are vulnerable. Furthermore, the animals degrade the plants' habitat by hastening the spread of invasive weeds. They also disturb substrates above the cliffs, thereby increasing the size and frequency of landslides and rock falls on the cliff faces. These disturbances directly affect even the plants inaccessible to the ungulates.

Alien plants threaten *T. filiforme* by altering the species' habitat and competing with it for moisture, nutrients, and growing space. Also, the spread of highly flammable alien grasses increases the incidence and destructiveness of wildfires. *Tetramolopium filiforme* is one of the Makua target taxa most threatened by fire. Over the last two decades fires have burned into the lower reaches of the Ohikilolo Ridge population unit, and have almost reached the Kahanahaiki colony.

Infestations of at least two species of non-native scale insects have been observed on *T. filiforme* (Lau pers. comm. 2000). Elsewhere in the Waianae Mountains, scale insects have been observed on *T. lepidotum* being tended by ants. When tended by ants, scale infestations can become very serious. No evidence of scale insects being tended by ants have yet been reported on *T. filiforme* plants, but *T. filiforme* populations should be monitored for it.

Table 16.79 Current Population Units of *Tetramolopium filiforme*. The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Name	Total Number of Individuals	No Management Proposed	Management Proposed
Oahu:	Kahanahaiki	50	0	50
	Keaau	25	0	25
	Ohikilolo Makai	2500+	0	2500+
	Ohikilolo Mauka (both varieties)	2500+	0	2500+
	Puhawai	12	0	12
	Waianae Kai	0*	0	0*

* The known plant has died. However, viable seeds may still exist in a seed bank at the site.

Table 16.80 Site Characteristics for Population Units of *Tetramolopium filiforme* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Keaau	Medium-Low	Steep to Vertical	Low to Medium	None
Kahanahaiki	High-Medium	Vertical	Low	None
Ohikilolo Makai	Medium-Low to High-Medium	Moderate to Vertical	Low to Medium	Large
Ohikilolo Mauka (both varieties)	Medium-Low to High- Medium	Moderate to Vertical	Low to Medium	None, Large
Puhawai	High-Medium	Flat to Vertical	Low to Medium	None

Table 16.81 Threats to Population Units of *Tetramolopium filiforme* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Keaau	Low	Low to High	Medium to High	N/A	N/A	Unknown A	Unknown B	Very high	High	Low	Low to High
Kahanahaiki	Low	Low	Low	N/A	N/A	Unknown A	Unknown B	Very high	High	Low	Low
Ohikilolo Makai	Low	Low to Medium	Low to High	N/A	N/A	Unknown A	Low	Very high	Medium to High	Low to Medium	Low to High
Ohikilolo Mauka (both varieties)	Low	Low to Hgh	Low to High	N/A	N/A	Unknown A	Low	Very high	Medium	Low to Medium	Low to High
Puhawai	Low	N/A	Medium	N/A	N/A	Unknown A	Unknown B	Low	Medium	Low	Low to Medium

Map removed to protect location of rare species. Available upon request.

16.28 Taxon Summary: *Viola chamissoniana* subsp. *chamissoniana*

Photographer: Hawaii Natural Heritage Program

Scientific name: *Viola chamissoniana* Ging. subsp. *chamissoniana*
Common name: *Olopu, pamakani*
Family: Violaceae (Violet family)
Federal status: Listed endangered

Description and biology: *Viola chamissoniana* subsp. *chamissoniana* is a woody shrub. This is unusual in the genus *Viola*, as most non-Hawaiian species are small herbs. The taxon is basal-branching with branches measuring 20-60 cm (8-23 in) long. Some populations, especially the ones on steep cliffs, have plants with lax, reclining or drooping branches. Other populations consist of plants with erect branches forming upright shrubs. At the end of each stem is a cluster of roughly triangular leaves measuring about 2-4 cm (0.8-1.6 in) long. The taxon's flowers are large, white, and held above the leaves. Due to the conspicuousness of the flowers, flowering plants are easily recognized from a distance. The seeds are borne in capsules that open as they dry. The seeds are egg-shaped, dark brown to almost black, and measure about 2 mm (0.1 in) long.

Little is known about the taxon's breeding system. Its pollinators are as yet unrecorded. However, its large white fragrant flowers held above its leaves suggest it is moth pollinated. Dispersal agents for this taxon are unknown. The longevity of individuals of the taxon is also unknown, but since the taxon is a small, woody plant, its longevity is presumed to be less than 10 years, and it is therefore a short-lived taxon for the purposes of the Implementation Plan.

Known distribution: *Viola chamissoniana* subsp. *chamissoniana* is known only from the Waianae Mountains. It has been recorded throughout the mountain range on both the windward and leeward sides, and it has been found from 700-1,000 m (2,300-3,040 ft).

Population trends: This taxon's population trends have not been well documented since all of the known populations were discovered only within the last two decades. However, since many members of this taxon grow on the steep cliffs inaccessible to feral ungulates, it is likely that the taxon has not declined in numbers as steeply as most of the Makua target taxa that are not cliff dwelling. It is also possible that the taxon was originally more common off the cliffs than it is nowadays, and has been able to survive only on the steeper cliffs inaccessible to feral ungulates.

Current status: There are six known population units of *V. chamissoniana* subsp. *chamissoniana*, totaling almost 400 individuals. About 250 of these are within the Makua action area. The taxon's current population units are listed in Table 16.82 and their sites are plotted on Map 16.41. All of the sites are proposed for management for stability. The sites are characterized in Table 16.83 and threats to the plants at these sites are identified in Table 16.84.

Habitat: *Viola chamissoniana* subsp. *chamissoniana* occurs in mesic habitats. At the majority of the taxon's sites the plants grow on cliffs and cliff ledges that are usually north facing. Typically, few plants at these sites are reachable without the aid of ropes. These cliffs are sparsely to moderately vegetated with native shrubs, grasses, and sedges. The steep north-facing cliffs in the Waianaes are among the mountain range’s most native and undisturbed of its mesic habitats. Although the taxon is usually found growing on cliffs, there are sites where the plants are growing on gentle slopes in native shrubland.

Taxonomic background: There are seven species of *Viola* native to Hawaii; all are Hawaiian endemics. *Viola chamissoniana* consists of two subspecies other than subsp. *chamissoniana*: subsp. *tracheliifolia*, which is endemic to Kauai, Oahu, Molokai, and Maui; and subsp. *robusta*, which is endemic to Molokai. These two subspecies are not considered rare. Subspecies *chamissoniana* differs from the two subspecies primarily in its large white flowers held above its leaves, whereas the other subspecies have relatively inconspicuous flowers borne amongst their leaves.

Outplanting considerations: The only other native *Viola* occurring in the Waianae Mountains is the common *V. chamissoniana* subsp. *tracheliifolia*, which like subsp. *chamissoniana*, occurs throughout the mountain range. Subspecies *tracheliifolia* is generally found growing in the forest understory, while subsp. *chamissoniana* is most often growing in open, exposed habitats. Several sites are known where the two subspecies grow side by side. Hybridization between the two has not been reported in the wild, and the potential for it to occur is not known. Since subsp. *chamissoniana* occurs naturally in close proximity to the non-endangered subsp. *tracheliifolia*, hybridization concerns are minimal. In any case, at any site with appropriate habitat for subsp. *chamissoniana*, it may be impossible to avoid planting adjacent to subsp. *tracheliifolia*.

Threats: Invasive alien plants gravely threaten *V. chamissoniana* subsp. *chamissoniana* by altering the taxon's habitat and competing with it for moisture, nutrients, and growing space. Feral goats and pigs also threaten it, for although many individuals of the target taxon grow on steep cliffs where they cannot be reached by the ungulates; many others are within their reach and are thus susceptible to predation. Furthermore, the animals degrade the plants’ habitat by hastening the spread of invasive weeds. They also disturb the substrate above the cliffs, thereby increasing the size and frequency of landslides and rock falls on the cliff faces. These disturbances directly affect even the plants inaccessible to the ungulates.

Table 16.82 Current Population Units of *Viola chamissoniana* subsp. *chamissoniana.* The numbers of individuals include mature and immature plants, and do not include seedlings. Population units proposed for management are shaded.

Island	Population Unit Name	Total Number of Individuals	No Management Proposal	Management Proposed
Oahu:	Halona	3	0	3
	Kamaileunu	38	0	38
	Makaha	50	0	50
	Ohikilolo	250	0	250
	Puu Hapapa	13	0	13
	Puu Kumakalii	20	0	20

Table 16.83 Site Characteristics for Population Units of *Viola chamissoniana* subsp. *chamissoniana* Proposed for Management for Stability.

Population Unit:	Site Characteristics:			
	Habitat Quality	Terrain	Accessibility	Existing Fence
Kamaileunu	Medium- Low to High-Medium	Vertical	Low	None
Makaha	Medium-Low to High-Medium	Vertical	Low	None
Ohikilolo	Medium-Low to High	Steep to Vertical	Low to Medium	None, Large
Puu Hapapa	Medium- Low	Steep to Vertical	Low to Medium	None
Puu Kumakalii	Medium- Low	Moderate	High	None

Table 16.84 Threats to Population Units of *Viola chamissoniana* subsp. *chamissoniana* Proposed for Management for Stability.

Population Unit:	Threats:										
	Pigs	Goats	Weeds	Rats	Black Twig Borer	Slugs and Snails	Other Arthro-pods	Fire Ignition	Fire Fuels	Erosion	Human Distur-bance
Kamaileunu	Low	Low to High	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low
Makaha	Low	Low to High	High	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low
Ohikilolo	Low	Low to High	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Very high	Medium	Low	Low to Medium
Puu Hapapa	N/A	Medium	Medium	Unknown A	Unknown A	Unknown A	Unknown A	Medium	Medium	Low	Medium
Puu Kumakalii	Medium	N/A	Medium	Unknown A	Unknown A	Unknown A	Unknown A	High	Medium	Low	Medium

Map removed to protect location of rare species. Available upon request.

17.0 Bibliography

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18.0 Glossary of Terms

Action area (AA): All areas affected directly or indirectly by the federal action and not merely the immediate area involved in the action. In this case, the action area includes the lands in and around Makua Military Reservation (MMR) at risk from fire caused by military activities based on vegetation types, fire history, natural and human-made barriers, and a consensus of where fires could be stopped by State, Federal, and Army fire fighting resources. The AA includes all of MMR, as well as adjacent lands considered at risk of damage or destruction from activities originating within MMR, including the entire Kuaokala Forest Reserve, all of Pahole Natural Area Reserve, most of West Makaleha Gulch, the northern side of Makaha Valley, and the northern side of Keaau Valley.

Adaptive management: Management designed to change with conditions and information, using results of monitoring and other information to refine the design, scope, or implementation of management actions or the monitoring program for an area or a taxon.

Alien: (same as **exotic, introduced, or non-native**) A taxon that is not native, *i.e.*, one introduced accidentally or purposefully by man. In Hawaii, these include Polynesian introductions (such as kukui, coconut, pig, and rat) and all post-Cook introductions (such as guava, Christmas berry, mosquitoes, pigs, goats, cattle, deer, and sheep). See **endemic, native.**

Army: U.S. Army

Augmentation: Outplanting or addition of individuals of a taxon in habitat that is known to currently contain individuals of that taxon. The purpose of augmentation is to bolster the numbers and/or genetic variability of an existing population of plants or animals. For the purposes of the Implementation Plan, an augmentation consists of the addition of a taxon less than 1000 m from known wild individuals of that taxon (or less than 500 m if a barrier to gene flow such as a major ridge or habitat discontinuity exists). See **outplanting**, **reintroduction**.

BA: See **biological assessment.**

BACT: See **best available control technology.**

BO: See **biological opinion.**

BTB: See **black twig borer.**

Basalt: A dark, dense volcanic rock commonly occurring in Hawaiian lava flows.

Baseline PU management: A minimal level of management initially applied to all all population units (PUs), designed to maintain baseline population levels (no net loss of individuals). This level of management includes: monitoring of populations, ungulate management as needed around individuals, management as needed of aggressive weeds around individuals, control as needed of other immediate threats (*e.g.*, rodents, slugs, human disturbance), collection for genetic storage, and collection for propagules. See **full PU management, partial PU management.**

Baseline survey: The first complete set of data collected for a monitoring program. This initial survey should be conducted prior to the initiation of management actions (*e.g.*, threat control, taxon reintroduction, *etc.*) in an area.

Best available control technology (**BACT**)**:** Techniques that provide the most effective and efficient means of controlling specific management problems.

Biological assessment (BA): The document prepared by a federal agency describing its proposed action and the action's potential effect on federally listed taxa.

Biological opinion (BO): The document prepared by the USFWS that reviews the BA and provides the Service's opinion on whether the action will jeopardize federally listed taxa or adversely modify critical habitat.

Biota: All plants and animals of a given area. A general term for living things.

Biotic: Pertaining to plants and animals and characteristics related to their presence.

Black twig borer (BTB): *Xylosandrus compactus*, an alien beetle that tunnels galleries through the twigs of many tree and shrub taxa, and can potentially kill off a large percentage of a plant’s twigs. The borers may also kill the trunks and main branches of tree saplings and full-grown shrubs.

C: See **candidate species.**

CCRT: Center for Conservation Research and Training.

CPC: Center for Plant Conservation.

Candidate species (C): Plant or animal taxa considered by the USFWS for possible addition to the List of Endangered and Threatened Species. See **federal status.**

Canopy: The tallest layer of vegetation in a community. In a forest, the canopy is made up of the tallest and most numerous trees. In a shrubland, the canopy is the tallest shrub layer. Closed canopies are those where the foliage interlocks to form a continuous layer over the underlying vegetation or ground. Open canopies are those where there are gaps in the foliage, and more light may reach the lower vegetation layers or ground.

Coastal: One of five elevation zones used to classify Hawaiian natural communities. The Hawaiian coastal zone extends from the ocean up to the lowland zone. There is a coastal zone on all of the main islands. See **elevation zones.**

Codominant: In a natural community, a condition in which two or more plant taxa constitute at least 50% of the existing vegetation cover in a given area. By HINHP definition, codominant taxa each must make up 25% or more of the total vegetation cover. See **dominant, ecosystem, natural community.**

DLNR: Department of Land and Natural Resources.

DOFAW: Division of Forestry and Wildlife.

Degraded: Physically altered in such a way as to decrease the habitat quality for native species, or invaded by alien species.

Disturbance corridors: Disturbed areas, such as roads, trails, fencelines, or transects that are routes of regular or occasional travel and are at high risk of being invaded by weeds introduced from vehicles, boots, packs, *etc.*, as a result of human use of that pathway.

Dominant: In a vegetated community, the plant species contributing the most cover in a given area. Dominant species may also be the most numerous in a natural community. By HINHP definition, a dominant species must make up 25% or more of the total vegetation cover. See **codominant, ecosystem, natural community.**

Dry: A moisture category describing habitat in areas with less than 50 inches annual rainfall, or subject to seasonal drought, or bearing generally dry prevailing soil conditions. See **mesic, wet.**

E: See **endangered species.**

ESRI: See **Environmental Systems Research Institute.**

ESU: See **evolutionarily significant unit**s.

Ecosystem: An assemblage of animals and plants and its interaction with the environment. See **codominant, dominant, natural community.**

Element: According to HINHP, a plant, animal, or natural community (*i.e.*, collectively, the elements of natural diversity).

Elevation zones: Broad regions defined by elevation range and used to classify natural communities. There are five elevation zones defined by the Hawaiian natural community classification: coastal, lowland, montane, subalpine, and alpine. Those zones included as habitat in MUs within the IP (coastal, lowland, and montane) are defined separately.

Endangered species (E): A taxon officially recognized by Federal or State officials to be in immediate danger of extinction throughout all or a significant portion of its range due to natural or man-made factors. See **federal status.**

Endemic: Naturally restricted to a locality. Most of Hawaii's native plants and animals are endemic (restricted) to the Hawaiian Islands. Many are restricted to a single island, mountain range, or even gulch. See **alien, endemism, native.**

Endemism: The extent to which the taxa of a region are unique to that region. See **endemic.**

Environmental Systems Research Institute (ESRI): A geographic information systems software developer who produces ArcView, ArcInfo, ArcIMS, *etc*.

Evolutionarily significant units (ESU): Used in the Implementation Plan in reference to genetically differentiated units of *Achatinella mustelina* populations throughout the species' range in the Waianae Mountains.

Ex situ*:** Away from the wild population site. For example, *ex situ* cultivation involves growing the taxon in a greenhouse at a different location from the wild site. See ***in situ, inter situ.

Exotic: (same as **alien**, **introduced**, and **non-native**) A taxon that is not native, *i.e.*, one introduced accidentally or purposefully by man. In Hawaii, these include Polynesian introductions (such as kukui, coconut, pig, rat, and jungle fowl) and many post-Cook introductions (such as guava, Christmas berry, mosquitoes, pigs, goats, cattle, deer, and sheep). See **endemic, native.**

Federal Status: Official U.S. Fish and Wildlife Service categories for plant and animal taxa according to the Federal Register (USFWS 1999):

Listed Endangered (LE)	=	formally listed as endangered.
Listed Threatened (LT)	=	formally listed as threatened.
Proposed Endangered (PE)	=	proposed to be formally listed as endangered.
Proposed Threatened (PT)	=	proposed to be formally listed as threatened.
Candidate (C)	=	for which substantial information on biological vulnerability and threat(s) support proposals to list them as endangered or threatened.
Species of Concern (SOC)	=	Taxa which appear to be declining in range or numbers, but for which adequate information, in the way of status, threats, and decline in range is not available to proceed with listing.

Feral: Formerly domesticated animals reverted to wild state or living in wild habitat.

Feral ungulate activity: Detectable damage or sign of feral ungulates including: scat, browsing, trails, trampling, wallows, and rooting.

Field survey: Field work designed to provide general information on the distribution, abundance, or status of taxa, populations, communities, or habitats within an area. In many cases a field survey is used to develop a catalog of the taxa and habitats within a specific area, but may not provide much detailed information on status and abundance of the taxa.

Full PU management: Actions needed to achieve stabilization**:** this level of management includes: monitoring of populations, ungulate management over the entire management unit (MU) or MU subunits surrounding the population unit (PU), management of aggressive weeds within a 10 m radius of individuals, control as needed of other threats (*e.g.*, rodents, slugs, human disturbance) as needed to encourage recruitment, collection for genetic storage and for propagules, and augmentation, as needed, based on monitoring results. See **baseline PU management, partial PU management.**

GIS: See **geographic information system.**

GPS: See **global positioning system.**

Genetic storage: Storage of living tissue (*e.g.*, seeds or vegetative material) for the purpose of acquiring and maintaining samples of genetic material of a taxon which could be reintroduced into a wild or managed population of this taxon in the future. For plants, such storage techniques can vary from cold/dry storage of seeds, lab maintenance of living tissue culture, or holding in cultivation at *inter situ* sites.

Geographic information system (GIS): A computerized mapping system coupled with a database that is used to input, store, manage, manipulate, update, analyze, and display geographic data in digital form. A GIS consists of information in two forms, both graphic and non-graphic. Graphic data are the digital “map layers” or drawing files that represent actual features on the earth such as trees, roads, or parking lots. Typically such data are represented as points, lines, or polygons, respectively. The non-graphic data are the information or attributes that describe those features such as the species name, surface type, or number of acres. A GIS can store and utilize georeferenced remotely sensed images as well, such as aerial photographs and satellite images.

Global positioning system (**GPS):** Consists of up to 24 NAVSTAR satellites that orbit the Earth (in six different planes) at about 12,000 miles altitude providing precise positioning information (x, y, z coordinates) to users on the ground and in the air. It is a free service, owned and operated by the Department of Defense, which operates 24 hours a day and is usable in all weather. Handheld GPS devices can be taken in the field to map locations and corresponding attribute data for export and use in a GIS. GPS can also be used to navigate back to previously mapped locations.

HINHP: Hawaii Natural Heritage Program.

HPPRCC: See **Hawaii and Pacific plants recovery coordinating committee**.

HRPRG: See **Hawaii rare plant restoration group.**

Hawaii and Pacific plants recovery coordinating committee (HPPRCC): A team of botanists brought together by the USFWS to advise that agency on issues relating to the status and recovery of plants in both Hawaii and the Pacific Islands.

Hawaii rare plant restoration group (HRPRG): An informal multi-agency group that collaborates in tracking the status of extremely rare Hawaiian plant taxa, and recommends management strategies.

IP: See **Implementation Plan.**

IT: See **Implementation Team.**

ITAM: Integrated Training Area Management.

Implementation Plan (IP): The written action plan for stabilization of the target taxa identified as at risk from Army training. The Makua IP includes taxon-level management and maintenance of native habitat (ecosystem and regional management).

Implementation Team (IT): A multi-agency committee providing the natural resource/biological expertise and landowner representation necessary to effectively plan and assess the stabilization of the target taxa.

In situ**:** At the site of a wild population. For example, *in situ* management involves taking action to manage a taxon at the site where the wild population exists. See ***inter situ, ex situ***.

Intact: Maintaining at least 60 percent cover in native species.

Inter situ**:** At a site separate from wild populations, but near enough in either location or habitat range that conditions are similar to those in the wild. For example, *inter situ* cultivation of a taxon might involve establishing plantings in a place at a similar elevation and moisture setting as a wild population, but with the benefits of relatively easy access to management practices that would be difficult to exercise at remote settings. *Inter situ* populations may be used as living collections and as a means of producing propagules that may be used in a taxon reintroduction or augmentation program. See ***in situ, ex situ*****.**

Introduced: (same as **alien, exotic, or non-native**) A taxon that is not native, *i.e.*, one introduced accidentally or purposefully by man. In Hawaii, these include Polynesian introductions (such as kukui, coconut, pig, rat, and jungle fowl) and many post-Cook introductions (such as guava, Christmas berry, mosquitoes, pigs, goats, cattle, deer, and sheep). See **endemic, native.**

Invertebrates: Animals without backbones, including such groups as insects, spiders, shrimps, and snails. Some Hawaiian invertebrates are rare and endangered.

In vitro**:** Under controlled, laboratory conditions (literally "in glass," alluding to cultures of living tissues in glassware such as vials and petri plates).

Lowland: One of five elevation zones used to classify Hawaiian natural communities. The Hawaiian lowland zone lies above the coastal zone, up to about 1000 meters (roughly 3000 feet) elevation. There is a lowland zone on all of the main islands. See **elevation zones.**

Lyon: University of Hawaii at Manoa’s Harold L. Lyon Arboretum micropropagation and seed storage laboratories and greenhouse facilities.

MMR: Makua Military Reservation.

MU: See **management unit**.

MVP: See **minimum viable population.**

Manage as a propagule source: To apply active management for the persistence of target individuals at a site, but not necessarily toward stabilization of the target population in the stricter sense. Such management includes small-scale protection from threats in the immediate vicinity of target individual(s), until such time as the individual(s) mature and produce sufficient propagules (*e.g.*, seeds) for recommended outplanting actions. See **manage for genetic storage collection**.

Manage for genetic storage collection: Collection of living material from a designated population unit for the express purpose of acquiring and maintaining adequate samples of genetic material of a taxon. Baseline management is necessary until sufficient material for genetic storage is collected. See **manage as a propagule source**.

Manage for stability: One of the population management categories that is used to deal actively with threats to an existing population of a Makua target taxon over the long term, at a broader habitat level, typically within a fenced MU. The intent is to remove limiting factors to individuals in the population so that their numbers remain at stable levels (defined by the Implementation Team and/or the U.S. Fish and Wildlife Service), or increase to achieve stable levels.

Management goal: A general statement describing what should be accomplished if the management program is successful. It addresses questions such as whether the number of individuals in a native taxon population should be increased or maintained at a certain level, or whether invasive alien species should be controlled or eliminated.

Management objective: A clearly articulated description of a measurable standard, desirable state, threshold value, amount of change, or trend to achieve for a particular plant population or habitat characteristic. Management objectives should include reference to several characteristics, including 1) identification of the taxon or habitat variable to monitor, 2) what sites to monitor, 3) the specific attributes to monitor (*e.g.*, plant density, cover, frequency, *etc*.), 4) what the management needs to accomplish or achieve, 5) the degree of change or state that needs to be achieved, and 6) the timeframe for measuring and achieving the change or desired state.

Management unit (MU): An area designated by the IT for active protective management with the express goal of stabilization of populations of target taxa within the unit. The MU is designed to contain enough area of suitable habitat for stabilization of target taxa over the long term. Typically, an MU lies within a fenced unit within which threats are removed or controlled and regeneration of native habitat and target taxa is actively encouraged.

Matrix species: Species that are dominant components of a plant community, including major tree, understory, and ground cover species that provide the basic vegetative structure of a habitat.

Mesic: An area receiving 50 to 75 inches of annual rainfall, or otherwise provided with sufficient water to result in moist soil conditions. See **dry, wet.**

Microsite: Specific location of an individual planted or wild plant which includes a unique set of environmental characteristics (both biotic and abiotic) that may influence the growth or survival of the plant.

Mid-credit line: A line that separates the higher fire risk (lower credit) area from the lower fire risk (higher credit) area in Makua Military Reservation (MMR). The mid-credit boundary line follows the valley rims of Keaau and Makua valleys, and then cuts through the head of Kahanahaiki valley. It then reaches the Nike site access road, and follows the road to the boundary of the action area. The major areas included within the mid-credit boundary line include Pahole and Kapuna gulches (which are considered at lower fire risk because of their mesic habitat), and the forest patch alongside the crest of Ohikilolo ridge at the junction of Makua, Makaha, and Keaau valleys. The Ohikilolo forest patch is buffered from fire by the dense forests above the grasslands in the bottom of Makua Valley, and the sparsely vegetated cliffs above the forest. These buffers, along with the mesic character of the highest parts of the southern rim of Makua (Ohikilolo Ridge), are considered to provide sufficient protection for the forest patch to warrant its inclusion in the higher credit (lower fire risk) region. No portions of Keaau valley and the areas west of the head of Kahanahaiki Valley are included in the higher credit (lower fire risk) region, as these areas are considered relatively vulnerable to fires originating in MMR.

Minimum viable population (MVP): A theoretical population size at which one can presume maintenance of normal population genetic structure and flow. MVP therefore cannot be assessed for severely depressed populations, or for populations where not enough is known about genetic structure or gene flow. MVP cannot be adequately assessed for the Makua target taxa. The Implementation Team uses general guidelines from the Center for Plant Conservation and the Hawaii and Pacific Plant Recovery Coordinating Committee, and other sources to determine target population sizes in lieu of using the MVP.

Mollusk: Invertebrates in the phylum Mollusca. Common representatives are snails, mussels, clams, oysters, squids, and octopuses.

Monitoring: The collection of data on characteristics of a population, a taxon, or a habitat (*e.g.*, survival, growth, phenology, abundance, distribution, population structure, species composition or diversity, *etc.*) to evaluate change in those variables over time. The results of monitoring [are] used to assess progress toward a predetermined management goal (*e.g.*, taxon distribution, population stability, community diversity), to evaluate the efficiency or success of a management action (*e.g.*, decrease or elimination of alien species impacts), or to identify new problems that may threaten the successful completion of a management objective.

Monitoring method: A technique used to gather information on the characteristics of a variable as part of a program to monitor natural resources or alien species impacts.

Monitoring objective: An objective that relates specifically to assessing selected taxon, community, or ecosystem attributes as a means of measuring success or failure in meeting specific management objectives. Monitoring objectives specify sampling information such as target levels of precision, power, acceptable error, and the magnitude of change you are trying to detect.

Monitoring protocol: A collection of monitoring methods that are used together to collect information on the taxa, populations, communities, habitats, or alien species impacts of an area. Elements of a monitoring protocol generally share a common monitoring framework and data are collected as part of a single monitoring effort.

Monotypic genus: A genus with only a single species.

Montane: One of five elevation zones used to classify Hawaiian natural communities. The Hawaiian montane zone lies above the lowland zone and runs from 1000 meters (roughly 3000 feet) to 2000 meters (roughly 6000 feet) elevation. There is a montane zone on Kauai, Oahu, Molokai, Maui, Lanai, and Hawaii. See **elevation zones.**

NARS: See **Natural Area Reserve System.**

NEPA: National Environmental Policy Act.

NPS: National Park Service.

NSSL: National Seed Storage Laboratory.

NTBG: National Tropical Botanical Garden.

Native: Includes both indigenous and endemic taxa found naturally in an area, not introduced accidentally or purposefully by man. See **alien, endemic**.

Natural Areas Reserve System (NARS): A system of protected and managed natural areas managed by the Hawaii DLNR-DOFAW.

Natural community: A natural assemblage of biotic elements (*e.g.*, plants and animals) that occurs within certain elevation, moisture, and habitat conditions; sometimes used loosely to mean "ecosystem." However, "ecosystem" includes abiotic environmental factors, so that (natural community + environment) = ecosystem. See **codominant, dominant, ecosystem.**

Non-native: (same as **alien, exotic, or introduced**) A taxon that is not native, *i.e.*, one introduced accidentally or purposefully by man. In Hawaii, these include Polynesian introductions (such as kukui, coconut, pig, and rat) and many post-Cook introductions (such as guava, Christmas berry, mosquitoes, pigs, goats, cattle, deer, and sheep). See **endemic, native.**

Non-parametric statistical method: A technique that uses frequency, rates, ranked scores, or percentiles as the basis for analysis and does not assume that the population follows a normal distribution.

Non-recalcitrant: In terms of seed/propagule storage, taxa that store well under a typical regime of low humidity, temperature, and light. See **orthodox, recalcitrant.**

Occurrence: The Hawaii Natural Heritage Program definition for where a rare taxon exists.

Orthodox: In terms of seed storage, desiccation tolerant seeds, surviving drying to low moisture contents (*e.g.*, 3-5% of fresh weight) and subsequent storage at temperatures below freezing (*e.g.*, -20C). See **non-recalcitrant, recalcitrant.**

Outplanting: Placement of plants into the ground at a natural or semi-natural site. Outplantings include reintroductions, augmentations, and plantings at *inter situ* locations. See **augmentation, reintroduction**.

PCA: See **Principal Component Analysis.**

PU: See **population unit.**

Parameter: A quantity that describes or characterizes an attribute of a population. Examples of parameters include the population mean, variance, or standard deviation.

Parametric statistical method: Analytical technique that assumes the population from which a sample is taken can be properly described by a mean and standard deviation, and further assumes that the population follows a normal distribution.

Partial PU management: Actions needed to increase population levels toward stability criteria (typically toward >25 individuals in a population unit (PU)). This level of management includes: monitoring of populations, ungulate management over the entire area needed to stabilize the PU, management of aggressive weeds within a 10 m radius of individuals, control as needed of other threats (*e.g.*, rodents, slugs, human disturbance) as needed to encourage recruitment, collection for genetic storage and for propagules, and augmentation, as needed, based on monitoring results. See **baseline PU management, full PU management.**

Physiognomy: General descriptive term for habitat, including categories such as bog, grassland, shrubland, forest, desert, and cliff.

Pilot study: Data collection in a scientific manner to test sampling design, data collection and analysis procedures, and to estimate basic parameters of the variables sampled. The results of a pilot study are used to refine and possibly simplify the subsequent monitoring program, and to provide realistic estimates of the time and resources required to conduct the monitoring.

Plant community: A spatial group of individuals of different plant species that generally overlap in their distribution within an area and share many similar habitat characteristics.

Population target: A numerical goal for the number of reproductive individuals in a stable population unit. Population targets are set by the IT, based upon base population target recommendations from conservation literature. These are modified (typically upward) according to the specific biological characteristics of each target taxon.

Population unit (PU): A group of individuals of a taxon that are in close spatial proximity to each other (*i.e.,* less that 1000 m apart, as defined by the IT), and are therefore presumed to be genetically similar and capable of crossing for reproduction. The PU is used by the IT as a working surrogate term for true biological populations, which can not be readily defined because too little is known of the population biology of many of the endangered taxa in Hawaii. Generally, members of a PU share a common habitat and are equally subject to impacts from fire, alien species (*e.g.*, ungulates or weeds), as well as major climatic events, such as hurricanes that may affect that local habitat.

Power (statistical power): The ability of a statistical test to detect a real difference or change. See **power analysis**, **type I sampling error**, **type II sampling error**.

Power analysis: A test to determine the appropriate number of sample points needed to minimize the probability of making Type II error when interpreting the results of a statistical data analysis. The power of a statistical test is a function of the number of sample points, the variance of the resulting data, the alpha level of probability for the test (determined to minimize the chance of making a Type I error in interpreting the results), and the minimum difference or change you are willing to consider important from a biological and management perspective. In conducting a power analysis you can determine the number of sample points needed by supplying values for the population variance (estimated from a previous study or from a pilot study), the alpha probability for the test, and the minimum difference or change value you want to use. See **power**, **type I sampling error**, **type II sampling error**.

Principal Component Analysis (PCA): A multivariate data analysis technique.

Priority weed: An alien plant with known ability to disrupt the vegetation of native ecosystems. Control of such weeds is a high priority. For example, *Clidemia hirta* is a priority weed that has displaced native understory plants in much of Oahu's forests. See **weed.**

Pristine: Undisturbed by humans and completely lacking alien taxa; entirely native.

Propagule: Any living material from which additional individuals can be generated. For plants, propagules refer typically to seeds, spores, cuttings, or other living material. For animals, propagules might include eggs or clonal tissue. See **propagule source.**

Propagule source: A location bearing an individual or individuals of a taxon from which propagules will be collected for genetic storage or for propagation. See **propagule**.

Protected: Legally dedicated to the perpetuation of native resources and managed to mitigate or remove threats to those resources, if necessary. Areas lacking either legal protection or management are considered incompletely protected.

Puu: Hill or volcanic cone.

Quadrat: A unit area of a specific size in which data on one or more variables are collected. Quadrats are the basic sampling units for collecting data on frequency, cover, and density of plants or animals in a monitoring program.

RAPD: See **Random Amplified Polymorphic DNA.**

Random Amplified Polymorphic DNA (RAPD): Analysis technique used to determine genetic structure within and between taxa, populations, and/or individuals.

Rare: Imperiled or threatened by extinction due to low numbers. In Hawaii Natural Heritage Program terminology, a plant, animal, or natural community with 20 or fewer occurrences, all or most of which are immediately threatened by such factors as alien invasion, direct destruction, or loss of habitat is considered to be rare.

Recalcitrant: In terms of seed/propagule storage, difficult to store under the standard low-temperature (-20C), low humidity regimes. Such taxa typically do not dry well, and therefore contain too much water to freeze well. They do not maintain viability under standard storage conditions and therefore defy efforts at long-term storage. Sometimes, special non-standard methods can be developed for the storage of propagules of recalcitrant taxa. See **non-recalcitrant, orthodox.**

Recovery: The process by which the decline of an endangered or threatened taxon is arrested or reversed, and threats to its survival are neutralized, so that its long-term survival in nature can be ensured. Recovery includes the long-term maintenance of secure, self-sustaining wild populations of the taxon with the minimum necessary investment of resources. The USFWS definition of recovery for plants varies according to the taxon's life history and other factors, but fundamentally requires sufficient numbers of regenerating individuals in a minimum number of populations (typically 8 to 10) over a set amount of time. See **stability.**

Reintroduction: Establishing a taxon into habitat within its known or suspected natural range that no longer includes extant individuals of that taxon. The purpose of reintroduction is to reestablish a sustained or growing population in the original or potential natural range of a plant or animal. For the purposes of the Implementation Plan, a reintroduction consists of the addition of a taxon greater than 1000 m from known wild individuals of that taxon (or greater than 500 m if a barrier to gene flow such as a major ridge or habitat discontinuity exists). See **augmentation, outplanting**.

Resampling statistical methods: Analytical techniques that can be used to calculate confidence intervals or perform significance testing on standard population parameters (*e.g.*, population mean or standard deviation) without the requirement that the population follows a normal distribution. Resampling methods are computer-intensive procedures that include randomization, bootstrap, and Monte Carlo techniques. These methods compare population parameters or standard test statistics (*e.g.*, t- or f-statistic, difference in means, *etc.*) from the sampled populations with the same statistics or parameters when all of the data values are pooled, mixed, and reselected ("resampled") into the same number of sample populations as in the original sample, with or without replacement depending on the specific technique used. After resampling is repeated many (*e.g.*, 10,000) times then the value of the test statistic calculated from the original populations is compared with the test statistics from the resampled populations to determine if the original result is typical or very different from the pooled and resampled data. The resulting calculated probability is believed to be a close approximation of the exact probability for that test.

SBMR: Schofield Barracks Military Reservation.

SOC: Species of Concern.

SOW: Scope of Work.

SP: Stabilization plan.

spp.: Abbreviation for more than one species.

subsp.: See **subspecies.**

Sampling unit: The base unit comprising a sample for data collection and analysis. Sampling units may be plots, quadrats, transects, points, individual plants, *etc.*

Sampling: In a general sense, sampling is often used to describe the process of collecting data. The same term also refers to the process of identifying a subset of individuals. Sampling elements need to be chosen by a random selection process if they are to be used to infer characteristics of the population as a whole.

Sampling framework: The logistical and analytical basis upon which a monitoring program is designed. The sampling framework includes consideration of the number of data collection sites, how and where data collection sites are located, what information will be collected, and how the resulting data will be analyzed in order to assess meeting the management goals for an area.

Sampling objective: An objective that relates specifically to assessing selected taxa, community, or ecosystem attributes as a means of measuring success or failure in meeting specific management objectives. Sampling objectives specify what variables will be sampled, as well as the levels of statistical significance desired to determine if a change has or has not occurred or difference exists or not between sampling times or situations for comparison (Type I and II error levels), and the minimum amount of detected change that would be considered to be biologically significant.

Stability: A plant taxon is considered stable when it has three populations with a minimum of either 25 mature and reproducing individuals of long-lived perennials (>10 year life span), 50 mature and reproducing individuals of short-lived perennials (<10 year life span) or 100 mature and reproducing individuals of annual taxa per season (<1 year life span). In addition to numerical criteria, genetic storage must be in effect for the taxon and all major threats must be controlled. This definition was adopted by the USFWS based on HPPRCC recommendations. See **recovery**.

Statistical power: The probability that a particular statistical test will detect a change or difference of a given size, if such a change has in fact occurred.

Strategic fence: Fence sections designed not to enclose, but to prevent movement of feral animals up steep-sided ridges, typically connecting to natural obstacles such as cliffs.

Subspecies (subsp.): A taxonomically distinguishable geographic or ecological subdivision of a species. See **variety.**

Survey: Field work designed to provide information on the distribution, abundance, or status of selected taxa, populations, communities, or habitats within an area. A survey is similar to an inventory but it is usually more directed toward specific taxa, populations, or communities within a given habitat and usually results in more detailed information than that obtained from an inventory. In many cases a field survey is used to develop a catalog of the taxa and habitats within a specific area, but may not provide much detailed information on status and abundance of the taxon.

Target taxon: For the purposes of this plan, any of the 29 endangered taxa from the Makua action area that are the focus of proposed stabilization efforts.

TNCH: The Nature Conservancy of Hawaii.

Taxon (plural = taxa): A group of plants or animals making up one of the categories or formal units in taxonomic classification. In this report a taxon can be a species, subspecies, variety, or form. This distinction is important because certain species have endemic Hawaiian subspecies or varieties that are considered rare.

Type I sampling error: The conclusion of statistical analysis that a change has taken place between the sampled populations when no real change has occurred. A Type I error is also called a "false change error". The probability of making a Type I error is labeled the P-value (probability) or alpha value in a statistical test. Generally, an alpha level (probability value) less than 0.10 (*i.e.*, >10% chance of a false change error) is considered to be statistically significant. See **power, power analysis, type II sampling error.**

Type II sampling error: The conclusion of a statistical analysis that no change has taken place between the sampled populations when a real change has actually occurred. A Type II error is also called a "missed change error." The probability of making a Type II error is labeled the *beta* value in a statistical test. The probability of not making a Type II error is 1 minus the beta value, and is known as the ‘power’ of a statistical test. As much as possible, the power of a statistical test should be at least 0.80 (80%) or greater, reducing the chance of making a Type II (missed change) error to less than 0.20 or 20%. See **power, power analysis, type I sampling error.**

UH: University of Hawaii.

USFWS: United States Fish and Wildlife Service.

USGS: United States Geological Survey.

Ungulate: A subdivision of hoofed mammals including pigs, goats, cattle, sheep, mouflon, and deer.

Variety (var.)**:** A taxonomically distinguishable subdivision of a species or subspecies. See **subspecies.**

Vegetation type or unit: Generalized classification unit used to describe a plant community based on physiognomic characteristics (such as vegetation structure and life form) of the vegetation and/or dominant species composition. An example of a vegetation unit would be an ohia wet forest.

Vertebrate: An animal with a backbone; native terrestrial vertebrate species in Hawaii include fish, birds, a bat, and a seal.

Viable: Capable of persisting and reproducing under favorable conditions.

Weed: An undesirable plant. In native ecosystems all alien plants are weeds. See **priority weed.**

Wet: An area receiving more than 75 inches of annual rainfall, or situated near groundwater or surface water, such that availability of water is not a major limiting factor to plants or animals there. See **dry, mesic.**

19.0 List of Preparers and Participants in Preparing the Makua Implementation Plan

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