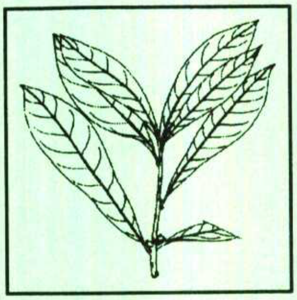
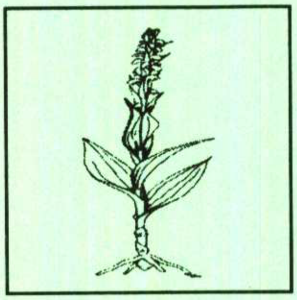
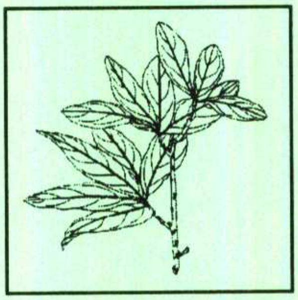
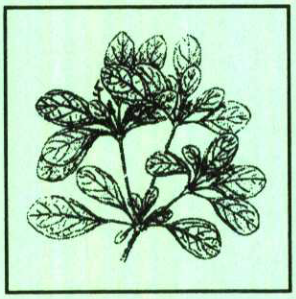
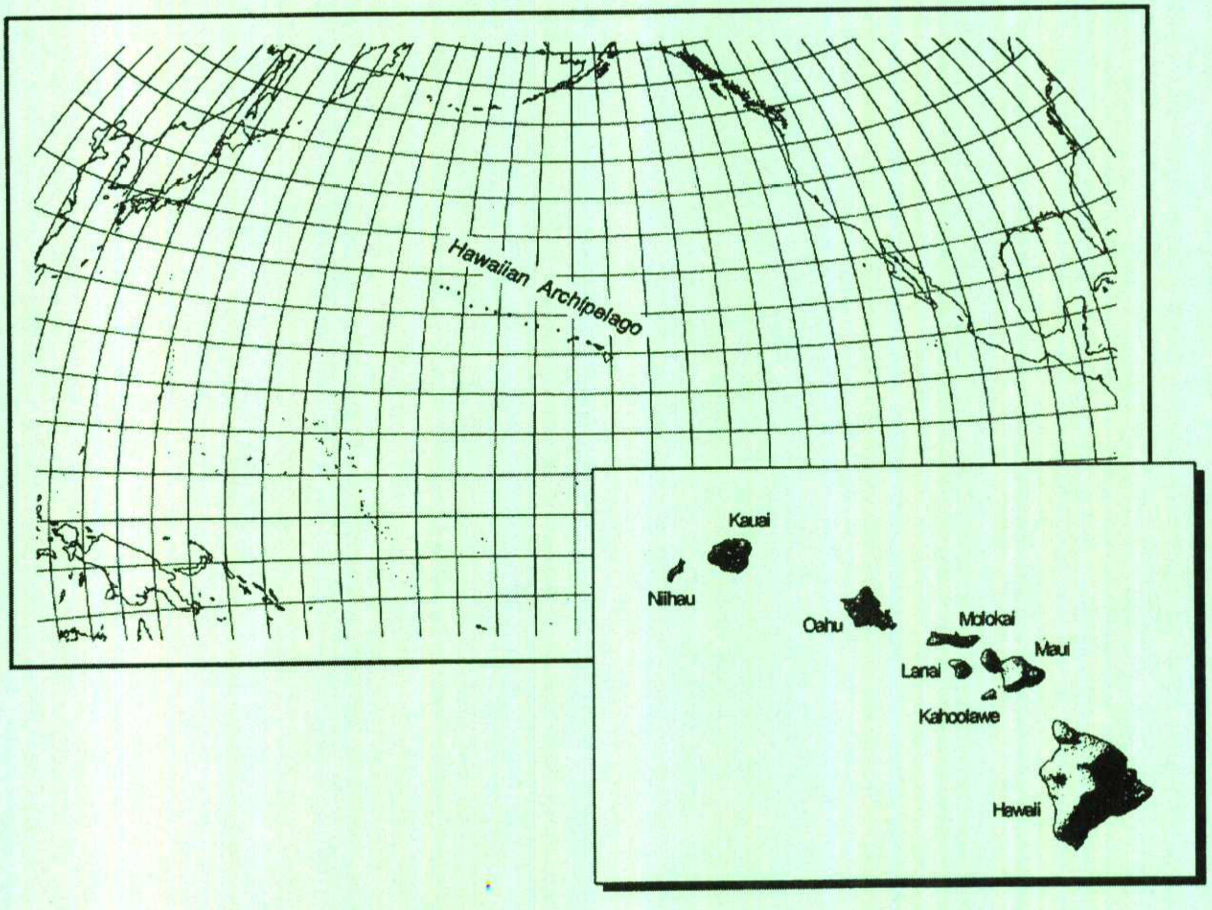
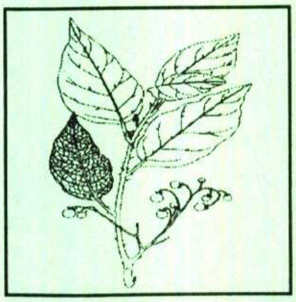
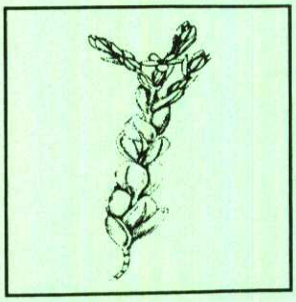
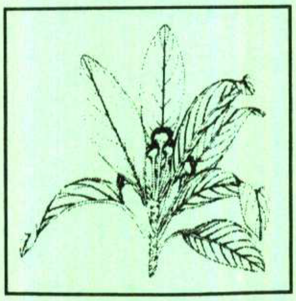
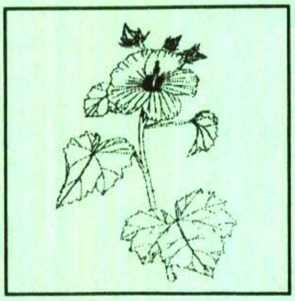
U.S. Fish & Wildlife Service

Recovery Plan for the Multi-Island Plants



RECOVERY PLAN FOR MULTI-ISLAND PLANTS

Published by

U.S. Fish and Wildlife Service

Portland, Oregon

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DISCLAIMER PAGE

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service, sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Costs indicated for task implementation and/or time for achievement of recovery are only *estimates* and are subject to change. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the U.S. Fish and Wildlife Service *only* after they have been signed by the Regional Director or Director as *approved.* Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

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EXECUTIVE SUMMARY

Current Species Status: Twenty-five plants addressed in this plan are federally listed as endangered, and one is federally listed as threatened. Numbers of known remaining populations and individuals are as follows:

TAXON	POPULATIONS	INDIVIDUALS
Achyranthes mutica	3	20-50
Adenophorus periens	13-18	1,295-1,330
Bonamia menziesii	31-44	several thousand
Cenchrus agrimonioides	7-8	fewer than 100
Centaurium sebaeoides	13	580-2,250
Cyanea grimesiana ssp. *grimesiana*	14	fewer than 50
Cyperus trachysanthos	8	517
Diellia erecta	6-7	34-36
Euphorbia haeleeleana	15	450-625
Flueggea neowawraea	34	124-195
Hibiscus brackenridgei	12	311-364
Isodendrion laurifolium	14	190-210
Isodendrion longifolium	19	fewer than 1,000
Mariscus pennatiformis	1-2	200
Neraudia sericea	3	50-100
Panicum niihauense	1	23
Phyllostegia parviflora	2	49
Plantago princeps	29	640-1,750
Platanthera holochila	5	fewer than 41
Sanicula purpurea	4-5	181-261
Schiedea hookeri	11	220-330
Schiedea nuttallii	6	4-100
Sesbania tomentosa	20-30	4,000-5,000
Solanum incompletum	2	40
Spermolepis hawaiiensis	12	2,000-6,000
Vigna o-wahuensis	8	fewer than 100

Distribution: The 26 Hawaiian plants have relatively wide, but scattered, distributions across the island chain. Their historical and current distributions average five islands for each taxon. All 26 plants are now found on 1 or more of the 8 main Hawaiian Islands; 2 of the plants are also found on 1 or more of 3 Northwestern Hawaiian Islands.

Habitat Requirements and Limiting Factors: The 26 plants grow in a wide range of vegetation communities (grasslands, shrublands, and forests), elevational zones (coastal to subalpine), and moisture regimes (dry to wet). They have been affected by or are currently threatened by the following, to differing degrees: habitat degradation and/or predation by pigs, goats, deer, sheep, and cattle; invasion and competition from naturalized, introduced vegetation; habitat loss from fires; erosion of substrate produced by hurricane, weathering, or human- or animal-caused disturbance; human impacts from military and recreational activities; alien insect infestations; predation by alien snails and slugs; and the potential for extinction from random naturally occurring events because of small population size and/or limited distribution.

Recovery Objectives: Delisting. Interim and downlisting objectives are provided to stabilize extremely rare plants and downlist the endangered plants to threatened status.

Recovery Criteria:

• Interim Objective

The interim objective is to stabilize all existing populations of Multi-island plants. To be considered stable, each taxon[1] must be managed to control threats (e.g., fencing, weeding, etc.) and be represented in an *ex situ*[2] collection. In addition, a minimum of three populations of each taxon should be documented on islands where they now occur or occurred historically. Each of these populations must be naturally reproducing and

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1 **Taxon**, plural **taxa**. A term used in biological classification (taxonomy), meaning a group of organisms at any rank (in this recovery plan, the ranks are variety, subspecies, and species).

2 ***Ex situ.*** Off-site, as in a botanical garden, as opposed to *in situ*, in a plant's native habitat.

increasing in number, with the following minimum numbers of mature individuals: 25 for long-lived perennials,

50 for short-lived perennials, and

100 for the annual taxa.

- Downlisting Objectives

For downlisting, a total of five to seven populations of each taxon should be documented on islands where they now occur or occurred historically. Each of these populations must be naturally reproducing, stable or increasing in number, and secure with the following minimum numbers of mature individuals per population:

100 for long-lived perennials,

300 for short-lived perennials, and

500 for the annual taxa.

Each population should persist at this level for a minimum of 5 consecutive years before downlisting is considered.

- Delisting Objectives

For delisting, a total of 8 to 10 populations of each taxon should be documented on islands where they now occur or occurred historically. Each of these populations must be naturally reproducing, stable or increasing in number, and secure from threats, with the following minimum numbers of mature individuals per population:

100 for long-lived perennials,

300 for short-lived perennials, and

500 for the annual taxa.

Each population should persist at this level for a minimum of five consecutive years.

Actions Needed:

1. Protect habitat and control threats.
2. Expand existing wild populations.
3. Conduct essential research.
4. Develop and maintain monitoring plans.
5. Reestablish wild populations within the historic range.
6. Validate and revise recovery criteria.

Total Estimated Cost of Recovery (in thousands of dollars):

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	Total
1999	1093	0	352	0	0	0	1445
2000	1361	0	352	0	0	0	1713
2001	2290	0	352	0	0	0	2642
2002	2371	13	352	62	0	0	2788
2003	2361	13	352	62	0	0	2798
2004	2094	0	79	62	15	67	2317
2005	2094	0	79	62	15	67	2317
2006	2094	0	79	62	0	0	2235
2007	2094	0	79	62	0	0	2235
2008	2094	0	79	62	0	0	2235
2009	2094	0	79	62	0	0	2235
2010	2094	0	79	62	0	0	2235
2011	2094	0	79	62	0	0	2235
2012	2094	0	79	62	0	0	2235
2013	2094	0	79	62	0	0	2235
Totals	**30416**	**26**	**2550**	**744**	**30**	**134**	**33900**

Some costs are yet to be determined.

Date of Recovery: Downlisting and/or delisting may be considered in 2010, if recovery objectives have been met.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

A. Brief Overview

This recovery plan deals with 26 Hawaiian plant taxa that are, or were, widely distributed across the island chain. *Centaurium sebaeoides* (awiwi) was listed as endangered on October 29, 1991 (54 FR 55770–55786). *Adenophorus periens* (pendant kihi fern), *Bonamia menziesii* (no common name [NCN]), *Diellia erecta* (NCN), *Flueggea neowawraea* (mehamehame), *Hibiscus brackenridgei* (mao hau hele), *Mariscus pennatiformis* (NCN), *Neraudia sericea* (maaloa), *Plantago princeps* (ale), *Sesbania tomentosa* (ohai), *Solanum incompletum* (thorny popolo), *Spermolepis hawaiiensis* (NCN), and *Vigna o-wahuensis* (Oahu vigna) were listed as endangered on November 10, 1994 (59 FR 56333–56351). *Achyranthes mutica* (NCN), *Cenchrus agrimonioides* (kamanomano), *Cyanea grimesiana* ssp. *grimesiana* (haha), *Cyperus trachysanthos* (pu uka a), *Euphorbia haeleeleana* (NCN), *Isodendrion laurifolium* (aupaka), *Panicum niihauense* (lau ehu), *Phyllostegia parviflora* (NCN), *Platanthera holochila* (NCN), *Sanicula purpurea* (NCN), *Schiedea hookeri* (NCN), and *Schiedea nuttallii* (NCN) were listed as endangered, and *Isodendrion longifolium* (aupaka) was listed as threatened, on October 10, 1996 (61 FR 53108–53124).

These 26 taxa (hereafter referred to as the "Multi-island plants") are found on 1 or more of the following Hawaiian Islands: Laysan, Necker, Nihoa, Niihau, Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, and Hawaii. The current and former distributions of each taxon are described in the individual species accounts. Their habitats are summarized in Table 1 (page 7).

B. General Description of Habitat

Much of the information in the following four sections was taken directly from the listing packages for these taxa (USFWS 1991, 1994, 1996).[3]

The Hawaiian archipelago includes eight large volcanic islands (Niihau, Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, and Hawaii), as well as offshore islets, shoals, and atolls set on submerged volcanic remnants at the northwest end of the chain (the Northwestern Hawaiian Islands; Figures 1 and 2). The archipelago covers a land area of about 16,600 square kilometers (6,400 square miles), extending roughly between latitude 18°50' to 28°15' North and longitude 154°40' to 178°70' West, and ranging in elevation from sea level to 4,200 meters (13,800 feet) (Dept. of Geography 1983). The regional geological setting is a mid-oceanic volcanic island archipelago set in a roughly northwest-to-southeast line, with younger islands to the southeast. The youngest island, Hawaii, is volcanically active. The older islands are increasingly eroded, so that the basaltic portions of many of the northwestern-most islands (such as Laysan, Midway, and Kure) are entirely submerged, and coralline atolls and shoals are often all that remain above sea level (Macdonald *et al.* 1986). The topography of the Hawaiian Islands is extremely diverse. On the youngest islands, Hawaii and Maui, gently sloping unweathered shield volcanoes with very poor soil development are juxtaposed with older, heavily weathered valleys with steep walls, well-developed streams, and gently sloped flood plains. The older islands to the northwest (i.e., Niihau, Kauai, Oahu, and Molokai) are generally more weathered. On a typical older island, sea cliffs and large amphitheater-headed[4] valleys on the windward (northeast) side contrast with erosionally younger, dissected slopes on the leeward (southwest) side (Dept. of Geography 1983).

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3 Acronyms used in the references include USFWS–U.S. Fish and Wildlife Service; DOFAW–Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife; HINHP–Hawaii Natural Heritage Program; TNCH–The Nature Conservancy of Hawaii; HPCC–Hawaiian Plant Conservation Center.

4 An amphitheater-headed valley ends abruptly at cliffs or steep slopes, which at the bottom may form a concave slope reminiscent of a Greek or Roman theater.

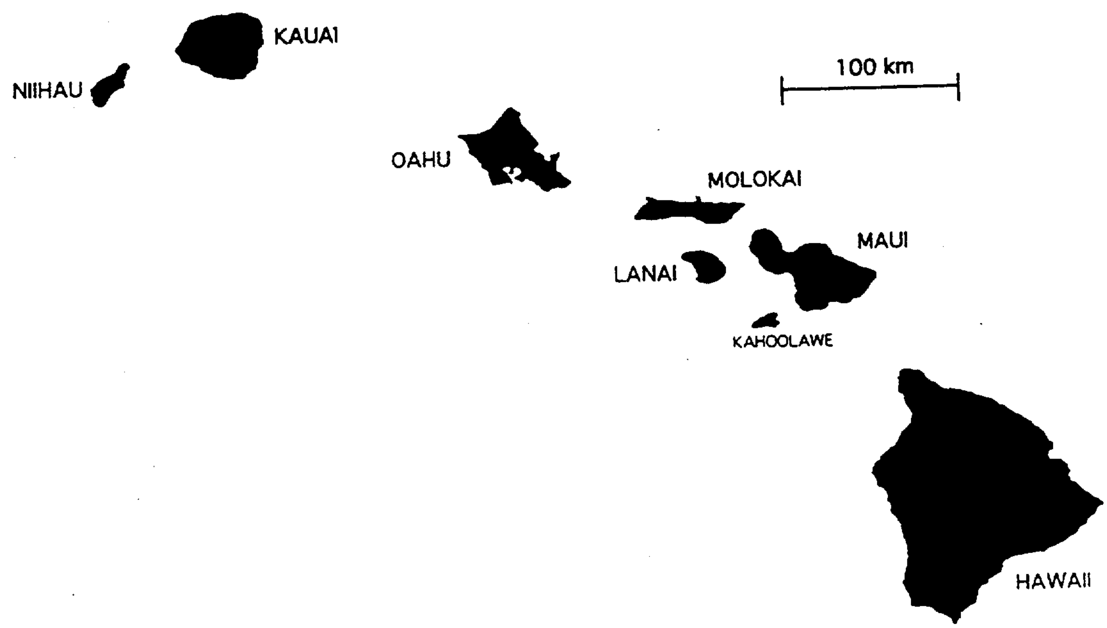

Figure 1. Map of the Main Hawaiian Islands.

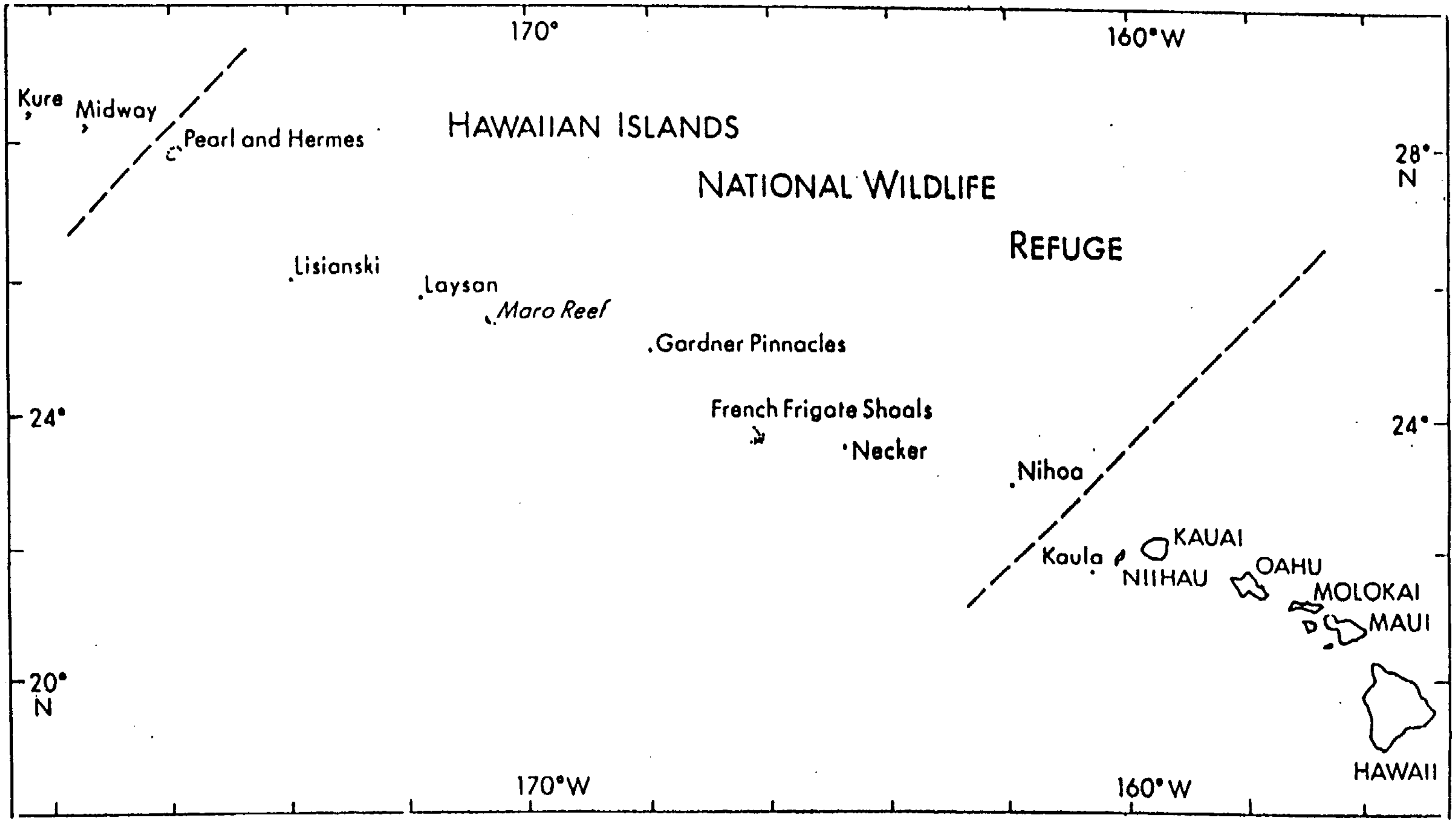

Figure 2. Map of the Northwestern Hawaiian Islands. Dashed lines show boundaries of the Hawaiian Islands National Wildlife Refuge.

The native-dominated vegetation of the Hawaiian Islands varies greatly according to elevation, moisture regime, and substrate. The most recent classification of Hawaiian natural communities recognizes nearly 100 native vegetation types (Gagné and Cuddihy 1990). Within these types are numerous island-specific or region-specific associations, comprising an extremely rich array of vegetation types within a very limited geographic area. Major vegetation formations include forests, woodlands, shrublands, grasslands, herblands, and pioneer associations on lava and cinder substrates.

Hawaii has lowland, montane, and subalpine forest types, extending from sea level to above 3,000 meters (9,800 feet) in elevation. Coastal and lowland forests are generally dry or mesic, rarely wet, and may be open- or closed-canopied. The stature of lowland forests is generally under 10 meters (30 feet). Seventeen taxa included in this recovery plan (*Achyranthes mutica, Bonamia menziesii, Cenchrus agrimonioides, Cyanea grimesiana* ssp. *grimesiana, Diellia erecta, Euphorbia haeleeleana, Flueggea neowawraea, Hibiscus brackenridgei, Isodendrion laurifolium, Isodendrion longifolium, Mariscus pennatiformis, Neraudia sericea, Phyllostegia parviflora, Schiedea hookeri, Schiedea nuttallii, Solanum incompletum*, and *Spermolepis hawaiiensis*) have been reported from lowland dry or mesic forest habitat while five taxa (*Adenophorus periens, Bonamia menziesii, Isodendrion laurifolium, Isodendrion longifolium*, and *Phyllostegia parvifolia)* have been reported from lowland wet forest habitat. Montane forests, occupying elevations between 500 and 2,000 meters (1,640 and 6,560 feet), are dry to mesic on the leeward slopes of the islands of Kauai, Maui, and Hawaii. On those islands, as well as Oahu, Molokai, and Lanai, mesic to wet montane forests occur on the windward slopes and summits. The dry and mesic forests may be open- to closed-canopied, and may exceed 20 meters (65 feet) in stature. Of the species in this recovery plan, two (*Plantago princeps* and *Solanum incompletum*) have been reported from montane mesic and dry forest habitats. Montane wet forests are usually dominated by several species of native trees and tree ferns. Three species (*Plantago princeps, Platanthera holochila*, and *Sanicula purpurea*) have been reported from montane wet forest habitat. Montane bogs, found on Kauai, Molokai, Maui, and Hawaii, occur primarily on flat or gently sloping terrain with impervious substrates at elevations between 1,130 and 1,700 meters (3,710 and 5,580 feet). The vegetation of most of these bogs consists of an irregular, hummocky cushion of sedges, with *Metrosideros* (ohia) usually a codominant. Two of the taxa, *Platanthera holochila* and *Sanicula purpurea*, have been reported from montane bog habitats. At high montane and subalpine elevations, at and above 1,700 meters (5,580 feet) elevation, are subalpine forests, usually open-canopied and forming a mosaic with surrounding grasslands and shrublands. Subalpine forests are known only from Haleakala on East Maui and from Hualalai, Mauna Kea, and Mauna Loa on Hawaii. *Solanum incompletum* has been reported from subalpine forest.

Hawaiian shrublands are also found from coastal to alpine elevations. The majority of Hawaiian shrubland types are in dry and mesic settings, or on cliffs and slopes too steep to support trees. Wet montane shrublands are typically dominated by ohia. Taxa reported from native shrublands include *Hibiscus brackenridgei*, *Neraudia sericea*, *Panicum niihauense*, *Sanicula purpurea*, *Sesbania tomentosa*, *Spermolepis hawaiiensis*, and *Vigna o-wahuensis*.

Hawaiian grassland types are found from coastal to subalpine settings. Coastal and lowland grasslands are known from the Northwestern Hawaiian Islands, Kauai, Oahu, Molokai, Lanai, Maui, and Hawaii. *Mariscus pennatiformis*, *Sesbania tomentosa*, and *Vigna o-wahuensis* have been reported from native grasslands.

Coastal strand vegetation is found throughout the Hawaiian Islands and four taxa included in this recovery plan, *Cenchrus agrimonioides* var. *laysanensis*, *Centaurium sebaeoides*, *Mariscus pennatiformis*, and *Panicum niihauense* have been reported from dry coastal strand vegetation. *Cyperus trachysanthos* has been reported from dry to wet sites on coastal cliffs or talus slopes, as well as from flat, coastal areas.

Table 1. Summary of Multi-island plants habitat types and associated plant species.

SOC - Species of Concern - may require special management in the future but is not presently a candidate for listing. Current and/or former habitats of the Multi-island plants overlap with a majority of other native and alien plant species found in Hawaii, including most other endangered, threatened, and rare species. Associated species listed below are limited to those that best characterize the immediate area of current Multi-island plants habitat.

Habitat Type: **Coastal Dry Shrubland**	Multi-island Recovery Plan Species	Associated Native Species	Associated Alien Species
elevation: below 300 meters (below 980 feet) rainfall: less than 500 millimeters (less than 20 inches) per year	*Centaurium sebaeoides* *Mariscus pennatiformis* *Sesbania tomentosa*	*Bidens* sp. (kookoolau) *Eragrostis variabilis* (kawelu) *Sida fallax* (ilima) *Scaevola sericea* (naupaka) *Heteropogon contortus* (pili) *Ipomoea pes-caprae* (beach morning glory) *Lipochaeta* sp. (nehe) *Myoporum sandwicense* (naio) *Sporobolus virginicus* (akiaki) *Chamaesyce celastroides* var. *kaenana* (endangered)	*Melinus minutiflora* (molasses grass) *Leucaena leucocephala* (koa haole) *Prosopis pallida* (kiawe) *Cenchrus ciliaris* (buffelgrass) *Cynodon dactylon* (Bermuda grass)

Habitat Type: **Lowland Dry & Mesic Grassland & Shrubland**	Multi-island Recovery Plan Species	Associated Native Species	Associated Alien Species
elevation: 30–2,000 meters (98–6,560 feet) rainfall: 100–2,000 millimeters (4–79 inches) per year	*Hibiscus brackenridgei* *Mariscus pennatiformis* *Neraudia sericea* *Panicum niihauense* *Spermolepis hawaiiensis* *Vigna o-wahuensis*	*Chenopodium oahuense* (aheahea) *Cyperus laevigatus* (makaloa) *Eragrostis variabilis* (kawelu) *Heteropogon contortus* (pili) *Ipomoea* sp. *Scaevola sericea* (naupaka) *Sida fallax* (ilima) *Vitex* sp. (kolokolo kahakai)	*Melinus minutiflora* (molasses grass) *Pennisetum setaceum* (fountain grass) *Leucaena leucocephala* (koa haole) *Prosopis pallida* (kiawe) *Cenchrus ciliaris* (buffelgrass)

Habitat Type: **Lowland Dry Forest**	Multi-island Recovery Plan Species	Associated Native Species	Associated Alien Species
elevation: 300–1,500 meters (984–4,920 feet) rainfall: 500–2,000 millimeters (19–79 inches) per year	*Achyranthes mutica* *Bonamia menziesii* *Cenchrus agrimonioides* *Euphorbia haeleeleana* *Flueggea neowawraea* *Hibiscus brackenridgei* *Schiedea hookeri*	*Canthium odoratum* (alahee) *Diospyros sandwicensis* (lama) *Dodonaea viscosa* (aalii) *Erythrina sandwicensis* (wiliwili) *Myoporum sandwicense* (naio) *Nestegis sandwicensis* (olopua) *Osteomeles anthyllidifolia* (ulei) *Sapindus oahuensis* (lonomea) *Sophora chrysophylla* (mamane)	*Lantana camara* (lantana) *Leucaena leucocephala* (koa haole) *Melinis minutiflora* (molasses grass) *Pennisetum clandestinum* (Kikuyu grass) *Pennisetum setaceum* (fountain grass) *Psidium guajava* (guava) *Schinus terebinthifolius* (Christmas berry)

Habitat Type: **Lowland Mesic Forest**	Multi-island Recovery Plan Species	Associated Native Species	Associated Alien Species
elevation: 30–1,600 meters (98–5,249 feet) rainfall: 1,200–3,800 millimeters (47–150 inches) per year	*Bonamia menziesii* *Cenchrus agrimonioides* *Cyanea grimesiana* ssp. *grimesiana* *Diellia erecta* *Euphorbia haeleeleana* *Flueggea neowawraea* *Hibiscus brackenridgei* *Isodendrion laurifolium* *Isodendrion longifolium* *Mariscus pennatiformis* *Neraudia sericea* *Phyllostegia parviflora* *Schiedea hookeri* *Schiedea nuttallii* *Solanum incompletum* *Spermolepis hawaiiensis*	*Metrosideros polymorpha* (ohia) *Acacia koa* (koa) *Antidesma pulvinatum* (hame) *Bobea* sp. (ahakea) *Xylosma* sp. (maua) *Canthium odoratum* (alahee) *Diospyros sandwicensis* (lama) *Pisonia* sp. (papala kepau) *Pouteria* sp. (alaa) *Myoporum sandwicense* (naio) *Dicranopteris linearis* (uluhe) *Erythrina sandwicensis* (wiliwili) *Exocarpus luteolus* (heau) *Psychotria* sp. (kopiko) *Styphelia tameiameiae* (pukiawe) *Syzygium sandwicensis* (ohia ha) *Wikstroemia* sp. (akia)	*Aleurites moluccana* (kukui) *Pennisetum setaceum* (fountain grass) *Blechnum occidentale* *Clidemia hirta* (Koster's curse) *Leucaena leucocephala* (koa haole) *Lantana camara* (lantana) *Melinus minutiflora* (molasses grass) *Psidium cattleianum* (strawberry guava) *Senecio mikanioides* (German ivy) *Schinus terebinthifolius* (Christmas berry)

Habitat Type: **Lowland Wet Forest**	Multi-island Recovery Plan Species	Associated Native Species	Associated Alien Species
elevation: 100–1,200 meters (328–3,937 feet) rainfall: < 1,500– >5,000 millimeters (<59– > 197 inches) per year	*Adenophorus periens* *Bonamia menziesii* *Isodendrion laurifolium* *Isodendrion longifolium* *Phyllostegia parviflora*	*Metrosideros polymorpha* (ohia) *Cibotium glaucum* (hapuu) *Broussaisia arguta* (kanawao keokeo) *Cheirodendron trigynum* (olapa) *Cyanea* sp. (haha) *Dicranopteris linearis* (uluhe) *Freycinetia arborea* (ieie) *Myrsine* sp. (kolea) *Perrottetia sandwicensis* (olomea) *Pittosporum* sp. (hoawa) *Psychotria hawaiiensis* (kopiko) *Cyrtandra* sp. (haiwale)	*Ageratina adenophora* (Maui pamakani) *Clidemia hirta* (Koster's curse) *Paspalum conjugatum* (Hilo grass) *Psidium cattleianum* (strawberry guava) *Rubus rosifolius* (thimbleberry)

Habitat Type: **Montane Mesic & Dry Forest**	Multi-island Recovery Plan Species	Associated Native Species	Associated Alien Species
elevation: 500–2,000 meters (1,640–6,560 feet) rainfall: 300–1,900 millimeters (12–75 inches) per year	*Plantago princeps* *Solanum incompletum*	*Acacia koa* (koa) *Bobea elatior* (ahakea lau nui) *Cyanea acuminata* (haha) *Dicranopteris linearis* (uluhe) *Hibiscus arnottianus* (kokio keokeo) *Labordia tinifolia* (kamakahala) *Machaerina angustifolia* (uki) *Metrosideros polymorpha* (ohia) *Microsorum spectrum* *Myrsine fosbergii* (kolea)–SOC *Pisonia umbellifera* (papala kepau) *Psychotria* sp. (kopiko) *Touchardia latifolia* (olona) *Sophora chrysophylla* (mamane)	*Aleurites moluccana* (kukui) *Clidemia hirta* (Koster's curse) *Psidium cattleianum* (strawberry guava)

Habitat Type: **Montane Wet Forest & Bog**	Multi-island Recovery Plan Species	Associated Native Species	Associated Alien Species
elevation: 1,200–2,200 meters (3,937–7,218 feet) rainfall: more than 2,500 millimeters (100 inches) per year	*Plantago princeps* *Platanthera holochila* *Sanicula purpurea*	*Antidesma platyphyllum* (hame) *Bidens sandvicensis* (kookoolau) *Broussaisia arguta* (kanawao) *Cheirodendron trygynum* (olapa) *Cibotium* sp. (hapuu) *Coprosma ernodeoides* (kukaenene) *Cyanea acuminata* (haha) *Cyrtandra* sp. (haiwale) *Dicranopteris linearis* (uluhe) *Dubautia laxa* (naenae pua melemele) *Hibiscus arnottianus* (kokio keokeo) *Lagenifera* sp. *Labordia tinifolia* (kamakahala) *Machaerina angustifolia* (uki) *Metrosideros polymorpha* (ohia) *Oreobolus furcatus* *Styphelia* sp. (pukiawe) *Vaccinium* spp. (ohelo) *Microsorum spectrum* *Myrsine fosbergii* (kolea)-SOC *Phyllanthus distichus* (pamakani mahu) *Psychotria* sp. (kopiko) *Piper methysticum* (awa) *Pisonia umbellifera* (papala kepau)	*Axonopus fissifolius* (narrow-leaved carpet grass)

Habitat Type: **Subalpine Forest**	Multi-island Recovery Plan Species	Associated Native Species	Associated Alien Species
elevation: 1,700–3,000 meters (5,578–9,843 feet) rainfall: variable	*Solanum incompletum*	*Myoporum sandwicense* (naio) *Acacia koa* (koa) *Sophora chrysophylla* (mamane) *Argyroxiphium sp.* (silversword)	*Senecio mikanioides* (German ivy) *Verbascum thapsus* (mullein)

C. Overall Reasons for Decline and Current Threats

Native vegetation on all of the main Hawaiian Islands has undergone extreme alteration because of past and present land management practices including ranching, deliberate alien animal and plant introductions, and agricultural development (Cuddihy and Stone 1990; Wagner *et al.* 1985). Most of the Northwestern Hawaiian Islands have undergone similar alteration, but to a lesser degree. The primary threats facing the 26 plant species included in this recovery plan include destruction and adverse modification of habitat by feral animals and competition with alien plants. Threats facing each of the Multi-island plants are summarized in Table 2.

Feral Ungulate Animals

Twenty-four of the 26 species in this recovery plan are threatened, to differing degrees, by introduced (alien) ungulate animals. Ungulates such as cattle (*Bos taurus*), goats (*Capra hircus*), pigs (*Sus scrofa*), sheep (*Ovis aries*), axis deer (*Axis axis*), black-tailed deer (*Odocoileus hemionus columbianus*), and mouflon (*Ovis musimon*) were introduced either by the early Polynesians or more recently by European settlers for food, recreational hunting, and/or commercial ranching activities. Over the 200 years following their introduction, their numbers increased and the adverse impacts of feral ungulates on native vegetation have become increasingly apparent. Beyond the direct effect of trampling and grazing native plants, feral ungulates have contributed significantly to the heavy erosion still taking place on most of the main Hawaiian Islands. The following taxa's low numbers make them especially vulnerable to disturbances: *Achyranthes mutica, Cenchrus agrimonioides, Cyanea grimesiana* ssp. *grimesiana*, *Diellia erecta*, *Mariscus pennatiformis*, *Neraudia sericea*, *Panicum niihauense*, *Phyllostegia parviflora*, *Platanthera holochila*, *Schiedea nuttallii*, *Solanum incompletum*, and *Vigna o-wahuensis*. Such disturbances could also promote erosion and greater ingression of alien plant species.

Table 2. Summary of threats to the Multi-island plants.

SPECIES	Alien animal activity												
	Pigs	Goats	Sheep/ Mouflon	Deer	Cattle	Rodents	Slugs/ Snails	Alien plants	Fire	Human impacts	Insects	Substrate loss	Limited numbers*
Achyranthes mutica		X			X			X					X[1,2]
Adenophorus periens	X	X						X	X				
Bonamia menziesii	X	X		X	X			X	X	X	P		
Cenchrus agrimonioides	X	P			P			X	P	P			X[1,2]
Centaurium sebaeoides		X			X			X	X	X			
Cyanea grimesiana ssp. *grimesiana*	X	X		X		P	P	X	X	P		X	X[1]
Cyperus trachysanthos								X	X	X			X[2]
Diellia erecta	X	X			X			X					X[1,2]
Euphorbia haeleeleana	X	X		X		X		X	X	P			
Flueggea neowawraea	X	X		X	X	P		X	X	X	X		
Hibiscus brackenridgei	X	X	X	X	X	P		X	X	X			
Isodendrion laurifolium	X	X		X				X		P			
Isodendrion longifolium	X	X						X	P	P			

Table 2. (Continued).

SPECIES	Alien animal activity: Pigs	Goats	Sheep/ Mouflon	Deer	Cattle	Rodents	Slugs/ Snails	Alien plants	Fire	Human impacts	Insects	Substrate Loss	Limited numbers*
Mariscus pennatiformis	X	X						X	X				X[2]
Neraudia sericea	X	X			P			X	X				X[1,2]
Panicum niihauense								X		X			X[1,2]
Phyllostegia parviflora	X				P			X	P	P			X[1,2]
Plantago princeps	X	X						X					
Platanthera holochila	X				X		P	X		X			X[1,2]
Sanicula purpurea	X							X		X			X[2]
Schiedea hookeri	X	X					X	X	P	P			
Schiedea nuttallii	X	X		P			X	X	P	P	X	X	X[1,2]
Sesbania tomentosa		X		X	X	X		X	X	X	P		
Solanum incompletum			X					X	P	P			X[1,2]
Spermolepis hawaiiensis		X	X	X				X	X	P		X	
Vigna o-wahuensis	X			X				X	X				X[1,2]

KEY: X=Immediate and significant threat
P=Potential threat
*No more than 100 individuals and/or fewer than 10 populations

[1] No more than 100 individuals
[2] Fewer than 10 populations
[3] No more than 10 individuals

Evidence of predation on three of the taxa by ungulates (cattle, deer, goats) is documented on Kauai, Oahu, Lanai, and Maui. On Kauai, evidence of predation on *Isodendrion laurifolium* by deer has been documented (USFWS 1996a). On Oahu, after cattle were removed, plants of *Bonamia menziesii* at Lualualei grow over native vegetation and drape well below the browse line (USFWS 1996a). On Lanai, axis deer are known to feed on this species, especially at Kanepuu. Depredation of *Hibiscus brackenridgei* ssp. *brackenridgei* by goats has been observed on Lanai and Maui. Goats eat the branch tips and strip the bark of the plants (USFWS 1996b). While there is no evidence of predation on the other 23 species, none of them are known to be unpalatable to cattle, deer, or goats. Predation is therefore a probable threat to species growing at sites where those animals have been reported (*Achyranthes mutica*, *Adenophorus periens*, *Cenchrus agrimonioides*, *Centaurium sebaeoides*, *Cyanea grimesiana* ssp. *grimesiana*, *Diellia erecta*, *Euphorbia haeleeleana*, *Flueggea neowawraea*, *Isodendrion longifolium*, *Neraudia sericea*, *Phyllostegia parviflora*, *Plantago princeps*, *Platanthera holochila*, *Sanicula purpurea*, *Schiedea hookeri*, *Schiedea nuttallii*, *Sesbania tomentosa*, *Solanum incompletum*, *Spermolepis hawaiiensis*, and *Vigna o-wahuensis*).

Insects

Black twig borer (*Xylosandrus compactus*) has been cited as an immediate threat to all extant populations of *Flueggea neowawraea* (USFWS 1996b). The black twig borer burrows into the branches and introduces a pathogenic fungus, most likely the ambrosia fungus (*Fusarium solani*), pruning the host severely and often killing branches or whole plants (Howarth 1985; James Nakatani, Hawaii State Board of Agriculture, *in litt.* 1996). All known plants of *Flueggea neowawraea* suffer slight to severe defoliation and reduced vigor due to infestations of this alien insect. The black twig borer is a pest of a number of threatened and endangered plants, and a serious pest of a number of economically important plants in Hawaii (J. Nakatani, *in litt.* 1996). Several parasitoids have been introduced to control the beetle, though none of them have become established. Further research on biological control of the beetle will need to proceed cautiously because a number of rare native scolytids in Hawaii are closely related to the black twig borer (Patrick Conant, Hawaii Department of Agriculture, personal communication 1997; J. Nakatani, *in litt.* 1996). An alien beetle (*Physomerus grossipes*), which has recently become established on Oahu, is a potential significant threat to *Bonamia menziesii* (David Orr, Waimea Arboretum Foundation, personal communication 1999).

Snails and Slugs

Little is known about the predation of certain rare Hawaiian plants by alien snails (such as the giant African snail [*Achatina fulica*]) and slugs (such as the leopard slug [*Milax gagates*]). Field botanists have observed indiscriminate slug predation on plant parts of members of the Campanulaceae (bellflower) family (USFWS 1996c). The effect of these alien predators on the decline of *Cyanea grimesiana* ssp. *grimesiana* (a member of the bellflower family) and related species is unclear, although they may pose a threat by feeding on the stems and fruit, thereby reducing the vigor of the plants and limiting regeneration (USFWS 1996c). *Schiedea* seedlings, occurring in mesic or wet sites, are apparently consumed by introduced slugs and snails. These have been observed feeding on *Schiedea membranacea*, a mesic forest species that occurs on Kauai. In contrast to mesic-forest species, *Schiedea* occurring in dry areas produce abundant seedlings following winter rains, presumably because the dry areas have fewer introduced consumers (Stephen Weller, University of California, Irvine, personal communication 1997).

Rodents

Two rat species, the black rat (*Rattus rattus*) and the Polynesian rat (*Rattus exulans*), and to a lesser extent other introduced rodents, eat large, fleshy fruits and strip the bark of some native plants, including plants in the bellflower family (USFWS 1996a). The largest population of *Euphorbia haeleeleana* on Oahu is seriously threatened by rat predation (USFWS 1996a). It is possible that rats eat the fruits of *Cyanea grimesiana* ssp. *grimesiana*, which produces fleshy fruit and stems and grows in areas where rats occur (USFWS 1996a). Seed predation by rats and mice (*Mus musculus*) threatens *Sesbania tomentosa* on Oahu. When rat and mice controls were initiated in 1994 and 1995, respectively, there were dramatic increases in seedling germination and survival (Dave Hopper, USFWS *in litt.* 1996; Bill Garnett, DOFAW, personal communication 1995).

Alien Plants

All 26 Multi-island plants are threatened by competition with 1 or more alien plant species. The most significant of these aliens appear to be *Schinus terebinthifolius* (Christmas berry), *Psidium cattleianum* (strawberry guava), *Melinus minutiflora* (molasses grass), *Pennisetum setaceum* (fountain grass), *Clidemia hirta* (Koster's curse), *Lantana camara* (lantana), *Leucaena leucocephala* (koa haole), *Rubus rosifolius* (thimbleberry), *Grevillea robusta* (silk oak), *Paspalum conjugatum* (Hilo grass), *Psidium guajava* (common guava), *Ageratina adenophora* (Maui pamakani), and *Ageratina riparia* (Hamakua pamakani) (USFWS 1995, 1996a,b). Other alien plants also pose significant threats to populations of the plants in this plan.

Christmas berry, introduced to Hawaii before 1911, is a fast-growing tree or shrub invading most mesic to wet lowland areas of the major Hawaiian Islands (Wagner *et al.* 1990). Christmas berry is distributed mainly by feral pigs and fruit-eating birds and forms dense thickets that shade out and displace other plants (Cuddihy and Stone 1990; Smith 1985; Stone 1985). This fast-growing species is found in lowland areas of the major Hawaiian Islands and is currently expanding its range. It is a major component of the mesic forests of the Waianae and Koolau Mountains of Oahu. It negatively affects over half the populations of *Bonamia menziesii*, 1 of the populations of *Plantago princeps* var. *princeps*, two-thirds of the *Cenchrus agrimonioides* populations, one-third of the *Isodendrion laurifolium* populations, 1 of 2 known populations of *Phyllostegia parviflora*, 6 of 11 populations of *Schiedea hookeri*, and all populations of *Flueggea neowawraea* that occur on Oahu. In addition, Christmas berry also affects 1 population of *Diellia erecta* in the Halawa Valley on Molokai and 1 population of *Bonamia menziesii* on Lanai. On Maui, Christmas berry is spreading into Iao Valley and on the south slope of East Maui (Haleakala Volcano). It is one of the primary alien plant threats to one or more populations of *Bonamia menziesii*, *Diellia erecta*, and *Plantago princeps* var. *laxiflora* that exist there (USFWS 1996b). On the island of Hawaii, Christmas berry continues to threaten at least two populations of

Diellia erecta and *Flueggea neowawraea* in the regions of Manuka and Honomalino in the South Kona District (USFWS 1996b).

In Hawaii, three insects have been released by the Hawaii Department of Agriculture to control the non-native Christmas berry: *Bruchus atronotatus,* a beetle, was released in 1932, and *Crasimorpha infuscata* and *Episimus utilis,* both moths, were released in 1954. In addition, a thrip and a sawfly have been introduced to control this non-native tree in dry forests of Florida (Biocontrol of Forest Pests Steering Committee, *in litt.* 1997). However, success has been limited in all cases (Myron Isherwood, Hawaii Department of Agriculture, personal communication 1998). Currently, researchers are searching in its native Brazil for additional potential biological control agents for Christmas berry.

Strawberry guava, an invasive shrub or small tree native to tropical America, has become naturalized on all of the main Hawaiian Islands, forming dense stands that exclude other plant species in disturbed areas (Cuddihy and Stone 1990). This alien plant grows primarily in mesic and wet habitats and provides food for several alien animal species, including feral pigs and game birds, which disperse the plant's seeds through the forest (Smith 1985; Wagner *et al.* 1985). Strawberry guava is considered one of the greatest alien plant threats to Hawaii's rain forests. On the island of Kauai, it is known to directly threaten four populations of *Isodendrion longifolium* and at least one population each of *Adenophorus periens*, *Bonamia menziesii*, *Euphorbia haeleeleana*, and *Isodendrion laurifolium* (Hawaii Natural Heritage Program [HINHP] 1995; Lorence and Flynn 1991, 1993; USFWS 1996a,b; Joel Lau, The Nature Conservancy of Hawaii [TNCH], personal communication 1992). Strawberry guava is a major invader of forests in the Waianae and Koolau Mountains of Oahu, where it often forms single-species stands. It poses an immediate threat to 2 populations each of *Cenchrus agrimonioides* and *Isodendrion laurifolium*, 6 populations of *Bonamia menziesii*, 10 populations of *Flueggea neowawraea*, and 1 population each of *Cyanea grimesiana* ssp. *grimesiana*, *Euphorbia haeleeleana*, *Isodendrion longifolium*, *Plantago princeps* var. *princeps*, and *Schiedea hookeri* on that island (HINHP 1995; USFWS 1996a,b; J. Lau, personal communication 1992). On Molokai, the habitat of the Halawa Valley population of *Diellia erecta* is currently being invaded by strawberry guava

(HINHP 1995; USFWS 1996b). On Lanai, this invasive plant threatens one of that island's populations of *Cyanea grimesiana* ssp. *grimesiana* (HINHP 1995; USFWS 1996a). On Maui, strawberry guava is beginning to invade the habitat of one population each of *Bonamia menziesii* and *Plantago princeps* var. *laxiflora* on West Maui and at least one population each of *Diellia erecta* and *Plantago princeps* var. *laxiflora* on East Maui (USFWS 1996b). It is also a major threat to the habitat of *Adenophorus periens* in the Kahaualea Natural Area Reserve on the island of Hawaii (HINHP 1995). To date, no biocontrol agents have been released against strawberry guava in Hawaii, though two species of insects are in quarantine and are currently undergoing host-screening (C.W. Smith, formerly with the Cooperative Park Studies Unit [CPSU], in *litt.* 1998).

First introduced to the Hawaiian Islands as cattle fodder, **molasses grass** was later planted for erosion control (Cuddihy and Stone 1990). This alien grass quickly spread to dry and mesic forests previously disturbed by ungulates. Molasses grass produces a dense mat which may smother plants (Smith 1985), essentially preventing seedling growth and native plant reproduction (Cuddihy and Stone 1990). Because it burns readily and often grows at the border of forests, molasses grass tends to carry fire into areas with woody native plants (Cuddihy and Stone 1990; Smith 1985). It is able to spread prolifically after a fire and effectively competes with less fire-adapted native plant species, ultimately creating a stand of alien grass where forest once stood. Molasses grass is becoming a major threat to 10 taxa on 4 islands. In the Waianae Mountains of Oahu, three populations of *Bonamia menziesii*, two populations of *Schiedea hookeri*, and one population each of *Cenchrus agrimonioides*, *Euphorbia haeleeleana*, and *Plantago princeps* var. *princeps* are immediately threatened by this grass (USFWS 1996a). On Molokai, at least one population each of *Diellia erecta*, *Plantago princeps* var. *laxiflora*, and *Neraudia sericea* and all populations of *Vigna o-wahuensis* on the island are also negatively affected. Molasses grass is quickly spreading throughout the dry regions of West Maui, threatening two populations of *Diellia erecta* there. On Hawaii Island, a population of *Sesbania tomentosa* in the Hawaii Volcanoes National Park is located in an area invaded by molasses grass (USFWS 1996b). This plant has never been targeted for biological control (M. Isherwood, personal communication 1998).

Fountain grass, like molasses grass, has greatly increased the risk of fire in some regions, especially on the dry slopes of Hualalai, Kilauea, and Mauna Loa volcanoes on the island of Hawaii. The effects of fountain grass invasion are similar to those discussed above for molasses grass. Fountain grass threatens the native vegetation on the leeward slopes of Hualalai in a region where at least one population of *Hibiscus brackenridgei* ssp. *brackenridgei* and Hawaii Island populations of *Bonamia menziesii* and *Vigna o-wahuensis* (HINHP 1995; USFWS 1996b) occur.

Koster's curse, a noxious shrub native to tropical America, is found in mesic to wet forests on at least six islands in Hawaii (Almeda 1990; Hawaii Department of Agriculture 1981; Smith 1992). This noxious shrub forms a dense understory, shading out other plants and hindering plant regeneration (Cuddihy and Stone 1990). First reported on Oahu in 1941, it had spread through much of the Koolau Mountains by the early 1960's, and into the Waianae Mountains by 1970 (Cuddihy and Stone 1990). It poses a serious threat to one population of *Isodendrion laurifolium* and two populations of *Plantago princeps* var. *longibracteata* in the Koolau Mountains. In the Waianae Mountains, Koster's curse poses a serious threat to two populations of *Cyanea grimesiana* ssp. *grimesiana*, one population of *Isodendrion longifolium*, the largest population of *Phyllostegia parviflora*, and one of the largest populations of *Schiedea hookeri* (USFWS 1996a). Koster's curse is widespread in Honouliuli and threatens two populations of *Flueggea neowawraea* that occur in that area of the Waianae Mountains.

This prolific alien plant has recently spread to five other islands, including Kauai, where there are at least five small infestations totaling about 40 hectares (100 acres) (Cuddihy and Stone 1990); one of these poses an immediate threat to one population of *Adenophorus periens* and two populations of *Isodendrion longifolium* in Waioli Valley (USFWS 1996a,b; J. Lau, personal communication 1992). Koster's curse threatens one of the two populations of *Cyanea grimesiana* ssp. *grimesiana* on Molokai (USFWS 1996a).

Perhaps the most promising biological control agent against Koster's curse is the *Colleotrichum* fungus *Gloeosporioides* f. sp. *clidemiae* which is being released by the Division of Forestry and Wildlife in collaboration with Dr. Eduardo Trujillo, a plant pathologist at the University of Hawaii. This fungus was first released in 1986 on Aiea

Loop Trail, and has been subsequently released on all islands. It has an observable negative impact on Koster's curse, although no quantitative data are available.

Other biological control agents released by the Hawaii Department of Agriculture include *Antiblemma acclinalis.* This noctuid moth from Trinidad and Tobago was released in 1995 and is currently established in the vicinity of the Aiea Loop Trail, Palolo Valley, and possibly Kalihi Valley. Further releases are planned on Army-managed land on Oahu. This moth was released on Kauai but did not become established. Another biological control agent, *Lius poseidon* (buprestid beetle), was initially released on Oahu, Maui, Kauai, and Hawaii in 1988. This beetle is currently established near the Aiea Loop Trail, and some leaf feeding has been observed, but damage is not significant. The fruit and flower-feeding insect, *Mompha trithalama,* was released in 1995–1996 but only a few recoveries were made in the Makiki area. *Carposina bullata* was introduced in 1985 and 1986, but it proved to be difficult to rear in captivity. The pyralid moth, *Ategumia matutinalis*, introduced in 1969 from Trinidad, is well established on Oahu, but damage to *Clidemia* foliage is insignificant (M. Isherwood, personal communication 1998). *Liothrips urichi*, introduced from Fiji in 1953, is well established and doing an excellent job in open areas, but has not been effective in the forest understory. This insect is considered to be a successful biological control agent because it feeds on terminal growth (M. Isherwood, personal communication 1998).

Lantana, a horticultural derivative of species native to tropical America, is an aggressive, thicket-forming shrub that produces chemicals that inhibit the growth of other plant species. This species can now be found on all of the main islands in mesic forests, dry shrublands, and other dry, disturbed habitats (Cuddihy and Stone 1990; Smith 1985; Wagner *et al.* 1990). On Kauai, lantana poses a threat to two populations of *Euphorbia haeleeleana* and one population of *Isodendrion laurifolium* within the Kuia Natural Area Reserve, three other populations each of *Euphorbia haeleeleana* and *Isodendrion laurifolium*, and one population of *Isodendrion longifolium*. Lantana is a major component of the vegetation at Paaiki Valley and Waimea Canyon and is rapidly becoming established in Pohakuao. It poses a threat to populations of *Flueggea neowawraea* in those areas (HINHP 1995; USFWS 1996b). In the Waianae Mountains of Oahu, one population each of *Cenchrus agrimonioides* and *Cyanea grimesiana* ssp. *grimesiana* and three populations of *Schiedea hookeri* are immediately threatened by this shrub (Lorence and Flynn 1993; USFWS 1996a). One population of *Bonamia menziesii* on Lanai and one on Maui are also negatively affected by this invasive plant (HINHP 1995; USFWS 1996b).

Twenty-six insects have been introduced by the Hawaii Department of Agriculture from 1902 though 1951 for the biological control of lantana. Fifteen of these insects became established on one or more islands. Although lantana infestations are still prevalent in some localities on each island, they are not as significant as they were prior to the introduction of the biocontrol agents (M. Isherwood, personal communication 1998). A fungus, *Septoria lantana*, was released and established on Kauai in 1997 by the Division of Forestry and Wildlife in cooperation with Dr. Trujillo of the University of Hawaii. It is too early to determine its impact (M. Isherwood, personal communication 1998).

Koa haole, a naturalized shrub, is sometimes the dominant species in low elevation, dry, disturbed areas on all of the main Hawaiian Islands (Geesink *et al.* 1990). This alien species threatens to degrade the habitat of eight of the species in this plan. Koa haole is one of the major weeds found at Polihale on the island of Kauai, growing in the vicinity of a population of *Sesbania tomentosa* and the only known population of *Panicum niihauense* (HINHP 1995; USFWS 1996b; J. Lau, personal communication 1992). On Oahu, the Kaena Point, Diamond Head, and Makapuu populations of *Cyperus trachysanthos* are threatened by alien grasses and possibly by koa haole (USFWS 1996a; J. Lau, personal communication 1994). In the Waianae Mountains, koa haole is one of the primary weed threats to half of the *Bonamia menziesii* populations and all of the *Hibiscus brackenridgei* ssp. *mokuleianus* populations found in the area (HINHP 1995; USFWS 1996b; J. Lau, personal communication 1992). Most of the Molokai populations of *Sesbania tomentosa* and one Kahoolawe population of *Vigna o-wahuensis* are also negatively affected by koa haole (HINHP 1995; USFWS 1996b; J. Lau, personal communication 1992). On Maui, koa haole poses a threat to *Hibiscus brackenridgei* ssp. *brackenridgei* and *Spermolepis hawaiiensis* in the Lihau section of the West Maui Natural Area Reserve, and is probably also a threat to *Hibiscus brackenridgei* ssp. *brackenridgei* and *Sesbania tomentosa* elsewhere on West Maui

(HINHP 1995; USFWS 1996b; J. Lau, personal communication 1992). This species has never been targeted for biological control (M. Isherwood, personal communication 1998).

Thimbleberry, native to Asia, is naturalized in disturbed mesic to wet forest on all of the main Hawaiian Islands (Cuddihy and Stone 1990). On Kauai, this shrub poses a threat to the largest population of *Euphorbia haeleeleana*, two populations of *Isodendrion laurifolium*, and five populations of *Isodendrion longifolium* (Lorence and Flynn 1993; USFWS 1996a). One of the two populations of *Cyanea grimesiana* ssp. *grimesiana* on Lanai is threatened by thimbleberry (USFWS 1996a).

Silk oak, native to Queensland and New South Wales, Australia, was extensively planted in Hawaii for timber and is now naturalized on most of the main Hawaiian Islands (Smith 1985; Wagner *et al.* 1990). On Kauai, this alien tree threatens *Euphorbia haeleeleana* in Hipalau Valley. In the Waianae Mountains of Oahu, silk oak negatively affects one population each of *Cenchrus agrimonioides*, *Euphorbia haeleeleana*, *Isodendrion laurifolium*, *Schiedea hookeri*, and *Schiedea nuttallii* (USFWS 1996a). This species has not been targeted for biological control (M. Isherwood, personal communication 1998).

Hilo grass is naturalized in moist to wet disturbed areas on all of the main Hawaiian Islands except Niihau and Kahoolawe, and produces a dense ground cover. On Kauai, this perennial grass threatens the Wahiawa Mountains and Waioli Valley populations of *Isodendrion longifolium* (Lorence and Flynn 1991, 1993; USFWS 1996a). In the Waianae Mountains of Oahu, Hilo grass threatens one population of *Cenchrus agrimonioides* and the largest population of *Schiedea hookeri* (USFWS 1996a). No biological control agents have been released for this species (M. Isherwood, personal communication 1998).

Common guava, a shrub or small tree native to the New World tropics, is naturalized on all of the main islands, except perhaps Niihau and Kahoolawe (Wagner *et al.* 1990). Common guava is a serious weed that invades disturbed sites, forming dense thickets in dry and mesic and wet forests (Smith 1985; Wagner *et al.* 1990). On Kauai, common guava poses a threat to a population of *Isodendrion longifolium* in Waioli Valley (Lorence and Flynn 1993). In the Waianae Mountains of Oahu, this alien plant threatens the largest populations of *Schiedea hookeri* and *Schiedea nuttallii*, while on the island of Hawaii, common guava threatens at least one population of *Achyranthes mutica*, and *Flueggea neowawraea* at Manuka (D. Paul, *in litt.* 1998; USFWS 1996a). No biological control agents have been released for this species (M. Isherwood, personal communication 1998).

Maui pamakani and **Hamakua pamakani**, both native to tropical America, have naturalized in dry areas to wet forest on Oahu, Molokai, Lanai, Maui, and Hawaii (Wagner *et al.* 1990). These two noxious weeds form dense mats with other alien plants and prevent regeneration of native plants (Anderson *et al.* 1992). In the Waianae Mountains of Oahu, two populations of *Schiedea hookeri* are threatened by both Maui pamakani and Hamakua pamakani, and the largest population of *Phyllostegia parviflora* is threatened by Maui pamakani (USFWS 1996a). On Hawaii, one population of *Achyranthes mutica* is threatened by Hamakua pamakani (USFWS 1996b).

The most successful biological control agent used for suppression of Hamakua pamakani infestations is the fungus *Entyloma ageratinae*. It was introduced from Jamaica in 1974 by Dr. Trujillo of the University of Hawaii. After its release in 1975, it quickly became established on Oahu and Hawaii. This fungus significantly reduced Hamakua pamakani infestations on rangelands on the island of Hawaii.

In addition to the fungus, the Hawaii Department of Agriculture released three insects for control of this weed. A tephritid fly, *Xanthaciura connexionus*, was introduced from Mexico in 1955, but it did not become established. In 1973, another tephritid, *Procedidochares alani*, was introduced from Mexico. This species, known in Hawaii as the Hamakua pamakani gall fly, became established on Oahu and Hawaii and has contributed to the suppression of infestations of the weed, particularly in drier habitats that are not favorable for the fungus. The Hamakua pamakani plume moth, *Oidaematophorus beneficus*, was also introduced from Mexico in 1973. This pterophorid moth is established in wetter habitats on Hawaii, but it is difficult to determine its effectiveness as it thrives in the same wet habitat as the *Entyloma* fungus (M. Isherwood, personal communication 1998).

The eupatorium gall fly, *Procecidochares utilis*, was introduced from Mexico in 1944 for control of Maui pamakani, known in other parts of the world as crofton weed and formerly identified as *Eupatorium adenophorum*. This tephritid became established on Maui, where the weed was known to have been introduced and where it was most prevalent, and has been credited with nearly complete suppression of Maui pamakani infestations in the islands (M. Isherwood, personal communication 1998).

Kiawe (*Prosopis pallida*), a deciduous thorny tree that can grow to 20 meters (65 feet) in height, overshadows other plants and competes with associated vegetation for available water and space. Introduced to Honolulu in the early 19th century, it spread rapidly throughout the drier parts of the Hawaiian Islands (Geesink *et al.* 1990). At Polihale on the island of Kauai, it is the primary alien plant threat to *Sesbania tomentosa* and to the only known population of *Panicum niihauense*. Two Molokai populations of *Sesbania tomentosa* compete with kiawe for water and space on Moomomi's beaches. The primary alien plant threat to *Vigna o-wahuensis* on the island of Kahoolawe is kiawe (HINHP 1995).

Australian red cedar (*Toona ciliata*) is a fast-growing tree that was probably introduced to Hawaii for lumber. It is now found in many of Hawaii's extensively planted lowland forests and has become naturalized in mesic to wet forests (Wagner *et al.* 1990). Today, this tree is a definite threat to at least one population of *Bonamia menziesii* and most of the plants of *Flueggea neowawraea* in the Waianae Mountains of Oahu (J. Lau, personal communication 1992).

Buffelgrass (*Cenchrus ciliaris*) forms continuous cover in dry habitats and provides excellent fuel for fire, from which it recovers quickly. Its seeds are easily dispersed by wind (Smith 1985). Buffelgrass threatens the habitat of two populations of *Sesbania tomentosa* on Molokai, and at least one population of *Vigna o-wahuensis* on Kahoolawe (J. Lau, personal communication 1992).

Prickly Florida blackberry (*Rubus argutus*) was introduced to the Hawaiian Islands in the late 1800's (Haselwood and Motter 1976). The fruits are easily spread by birds to open areas where this plant can form dense, impenetrable thickets (Smith 1985). The Kauai population of *Adenophorus periens* that is located at the boundary of the Hono O Na Pali Natural Area Reserve and Na Pali Coast State Park is threatened by this noxious weed (J. Lau, personal communication 1992). On Oahu, prickly Florida blackberry threatens the largest population of *Cenchrus agrimonioides* (USFWS 1996a).

The Hawaii Department of Agriculture has released five insect biological control agents for prickly Florida blackberry. The blackberry skeletonizer, *Schreckensteinia festaliella*, was introduced from California in 1963. This heliodinid moth is established on Hawaii, Maui, and Kauai. After recent releases on Oahu's Mt. Kaala, it is now established at that site. Although feeding damage to terminal shoots is very noticeable in some localities, prickly Florida blackberry continues to outgrow the damage because soil moisture is always adequate in the habitat where it grows. A tortrioid moth, *Croesia zimmermani,* was introduced from Mexico in 1963. This species is established on Hawaii, Maui, and Kauai. Typically, it is a leaf-eater and has caused extensive damage to terminal shoots. However, as with the blackberry skeletonizer, the vigorous growth of the blackberry overcomes foliar damage. An aegerid moth, *Bembecia marginata*, was introduced from Oregon in 1963, but failed to become established. The blackberry sawfly, *Priophorus morio*, was introduced from Oregon in 1966. This tenthredinid is established on Kauai and Oahu (Mt. Kaala), but population densities are very low and damage to blackberry is negligible. A chrysomelid beetle, *Chlamisus gibbosa*, was introduced from Missouri in 1967 and 1968, but never became established (M. Isherwood, personal communication 1998).

A recent introduction to the Hawaiian Islands, **yellow Himalayan raspberry** (*Rubus nivens*), is rapidly becoming a major weed pest in wet forests, pastures, and other open areas on the island of Hawaii. It forms large thorny thickets and displaces native plants. It can invade the understory of wet forests and fill a niche presently unoccupied by any other major wet forest weed in Hawaii. This alien plant has spread very rapidly in recent years. One population of *Adenophorus periens* grows in Olaa Tract within the Hawaii Volcanoes National Park in a region where yellow Himalayan raspberry is found in increasing numbers (J. Lau, personal communication 1992).

A vine in the passionflower family, **banana poka** (*Passiflora mollissima*), was introduced to the islands in the 1920's, probably as an ornamental. This vine is extremely detrimental to certain wet forest habitats of Kauai, Maui, and Hawaii. Heavy growth of this vine can damage or kill native trees by overloading branches, causing breakage, or by forming a dense canopy cover, intercepting sunlight and shading out native plants below. An infestation of this vine is located at Olaa Tract on Hawaii Island, the site of one population of *Adenophorus periens* (J. Lau, personal communication 1992).

Two moths have been released by the Hawaii Department of Agriculture to control banana poka: *Pyrausta perelgans*, a bud-feeder, and *Cyanotricha necyria*, a defoliator.

In addition, two other moths and two flies are currently being tested in quarantine (P. Conant, personal communication 1999).

Kikuyu grass (*Pennisetum clandestinum*), an aggressive, perennial grass introduced to Hawaii as a pasture grass, withstands trampling and grazing and is naturalized on four Hawaiian Islands in dry to mesic forest. It produces thick mats which choke out other plants and prevent their seedlings from establishing and has been declared a noxious weed by the U.S. Department of Agriculture (7 CFR 360) (O'Connor 1990; Smith 1985). Kikuyu grass is a threat to one population of *Achyranthes mutica* (USFWS 1996b).

A number of other alien plant species pose a significant threat to populations of the Multi-island plants. **Narrow-leaved carpet grass** (*Axonopus fissifolius*) (possibly the same as common carpetgrass, *A. affinis*) is native to subtropical North America and the New World tropics. Introduced to Hawaii in 1912, narrow-leaved carpet grass has become common in wet pastures, disturbed wet forest, and bogs on Kauai, Oahu, Lanai, Maui, and Hawaii. Narrow-leaved carpet grass is a threat to one population of *Sanicula purpurea* on Oahu (O'Connor 1990; USFWS 1996a). **Hairy horseweed** (*Conyza bonariensis*) is nearly cosmopolitan in distribution, although it is perhaps native to South America. It was naturalized in Hawaii before 1871 and is a common weed in urban and non-urban areas throughout Hawaii, generally in dry habitats. It threatens one population of *Achyranthes mutica* (USFWS 1996b; Wagner *et al.* 1990). **Bermuda grass** (*Cynodon dactylon*) is a major threat to at least one population of *Sesbania tomentosa* at Moomomi on Molokai. **Panini** (*Opuntia ficus-indica*), a prickly-pear cactus, was introduced to Hawaii before 1809 from Mexico and has become naturalized in dry, disturbed habitats on Kauai, Oahu, Maui, Kahoolawe, and Hawaii. Panini threatens one population of *Achyranthes mutica* (USFWS 1996a; Wagner *et al.* 1990). **German ivy** (*Senecio mikanioides*), a noxious, wind-dispersed vine that forms localized mats of vegetation, is a threat to 1 of 2 known populations of *Solanum incompletum* on the island of Hawaii (USFWS 1996b). This *Solanum incompletum* population is fenced and protected from ungulates, but it is not protected from German ivy. **Java plum** (*Syzygium cumini*), a large evergreen tree, is an aggressive invader of undisturbed forests (Smith 1985). It threatens to shade out the only known populations of *Hibiscus brackenridgei* ssp. *mokuleianus* on Oahu (USFWS 1996b). **Pride of India** (*Melia* *azedarach*), a fast-growing deciduous tree that forms deep shade, grows in open dry habitats. A major infestation of this large tree in Waimea Canyon on Kauai poses an immediate threat to individuals of *Flueggea neowawraea* (USFWS 1996b).

Fire

Fire threatens 13 Multi-island plants, and potentially threatens 6, that grow in dry to mesic grassland, shrubland, and forests on five islands. On Oahu, military training exercises on the Makua Military Reservation and the Schofield Barracks Military Reservation have resulted in unintentionally ignited fires. Such fires may threaten populations of *Bonamia menziesii*, *Cenchrus agrimonioides*, *Euphorbia haeleeleana*, *Flueggea neowawraea*, *Schiedea nuttallii*, and *Spermolepis hawaiiensis* that grow in dry and mesic forest on those installations (USFWS 1996a). Three populations of *Bonamia menziesii* and two populations of *Flueggea neowawraea* located adjacent to the Makua Military Reservation are also possibly threatened by unintentionally ignited fires (HINHP 1995; J. Lau, personal communication 1992). The area has had a history of fires, which may have burned through at least one population of *Bonamia menziesii*, and burned to within a few tens of meters of another (HINHP 1995; USFWS 1996b). Accidentally or maliciously set fires in residential areas near the Lualualei Naval Reservation and the Makua Military Reservation could easily spread, potentially threatening one population of *Cenchrus agrimonioides*, most of the island's individuals of *Euphorbia haeleeleana*, one population of *Isodendrion longifolium*, several populations of *Schiedea hookeri*, and one population of *Schiedea nuttallii* (USFWS 1996a). Fire is also a threat to the following populations: one population each of *Bonamia menziesii* and *Flueggea neowawraea* on Oahu, one population of *Bonamia menziesii* on Lanai, three populations of *Cyperus trachysanthos*, two populations of *Sesbania tomentosa* and one population of *Vigna o-wahuensis* on Molokai, all known populations of *Vigna o-wahuensis* on Kahoolawe, and at least one population each of *Bonamia menziesii*, *Hibiscus brackenridgei* ssp. *brackenridgei*, and *Sesbania tomentosa* on Hawaii Island (HINHP 1995; Steven Bergfeld, DOFAW, *in litt.* 1996; J. Lau, personal communication 1992). Also, volcanic activity threatens one population of *Adenophorus periens* on Hawaii Island.

Other Human Impacts

On the islands of Oahu and Hawaii, habitat disturbance caused by human activities may threaten rare plant populations that grow where military training exercises and ground maneuvers are occasionally conducted. However, because most of the taxa grow on moderate to steep slopes, ridges, and gulches, habitat disturbance is probably restricted to foot and helicopter traffic. Trampling by ground troops associated with training activities and construction, maintenance, and utilization of helicopter landing and drop-off sites could affect populations of 14 of the taxa that occur on land leased or owned by the Army (*Bonamia menziesii*, *Cenchrus agrimonioides*, *Cyanea grimesiana* ssp. *grimesiana*, *Cyperus trachysanthos, Euphorbia haeleeleana, Flueggea neowawraea, Isodendrion laurifolium*, *Phyllostegia parviflora, Plantago princeps, Sanicula purpurea*, *Schiedea hookeri*, *Schiedea nuttallii*, *Solanum incompletum,* and *Spermolepis hawaiiensis*) (USFWS 1994, 1996a).

Disturbance caused by off-road vehicles threatens two of the taxa: *Panicum niihauense* at Polihale State Park on Kauai and several locations of *Sesbania tomentosa* on Maui and Hawaii Island.

Substrate Loss

Erosion, landslides, and rockslides due to natural weathering result in the death of individual plants as well as habitat destruction. This especially affects the continued existence of taxa or populations found on cliffs and steep slopes that have limited numbers and/or narrow ranges such as the Oahu populations of *Cyanea grimesiana* ssp. *grimesiana* and the Pahole-Makua Ridge population of *Schiedea nuttallii* on Oahu (USFWS 1996a; Loyal Mehrhoff, USFWS, personal communication 1995).

Small Numbers

The small number of populations and of individual plants of 14 of these taxa (*Achyranthes mutica*, *Cenchrus agrimonioides, Cyanea grimesiana* ssp. *grimesiana*, *Cyperus trachysanthos, Diellia erecta*, *Mariscus pennatiformis*, *Neraudia sericea*, *Panicum niihauense*, *Phyllostegia parviflora*, *Platanthera holochila*, *Sanicula purpurea, Schiedea nuttallii*, *Solanum incompletum*, and *Vigna o-wahuensis*) increases the potential for extinction from random naturally occurring events.

The limited gene pool may depress reproductive vigor, or a single human-caused or natural environmental disturbance could destroy a significant percentage of the individuals or the only known extant population. For example, *Solanum incompletum* is known from only 2 populations of approximately 40 individuals on Hawaii Island, while *Panicum niihauense* is known from a single population of 23 plants, respectively. Thirteen of the taxa have 10 or fewer populations and 11 of the taxa are estimated to number fewer than 100 individuals.

The reproductive systems of both *Euphorbia haeleeleana* and *Flueggea neowawraea* further exacerbate the problem of limited numbers: because each tree bears only male or female flowers, it must be cross-pollinated from a different tree (Hayden 1990; Wagner *et al.* 1990). If only a few trees flower at the same time, or if flowering trees are too widely separated for pollination by insects, no seed will be set. The survival of small, isolated populations, which probably are already experiencing depressed reproductive vigor, is therefore further threatened.

D. Overall Conservation Efforts

Federal and State

One species (*Centaurium sebaeoides*) covered by this plan was added to the Federal list of endangered and threatened plants on October 29, 1991 (USFWS 1991), while 12 of the taxa were added on December 12, 1994 (USFWS 1994), and the remaining 13 were added on November 12, 1996 (USFWS 1996a).

When a species is listed as endangered or threatened under the Endangered Species Act, it is automatically added to the State of Hawaii's list of protected species (Hawaii Revised Statutes Chapter [HRS] 195D). Hawaii State law prohibits taking of endangered flora and encourages conservation by State government agencies. ("Take" as defined by Hawaii State law means "to harass, harm . . . , wound, kill . . . , or collect endangered or threatened . . . species . . . or to cut, collect, uproot, destroy, injure, or possess endangered or threatened . . . species of . . . land plants, or to attempt to engage in any such conduct" [HRS 195D]). The Endangered Species Act offers additional protection to these taxa since it is a violation of the Endangered Species Act for any person to remove, cut, dig up, or damage or destroy an endangered plant in an area not under Federal jurisdiction in knowing violation of any State law or regulation or in the course of any violation of a State criminal trespass law [Section 9(a)(2) of the Endangered Species Act].

Critical habitat was not designated for any of the Multi-island plant taxa because of the possible increased threat to the plants by vandalism, researchers, curiosity seekers, or collectors of rare plants due to the mandated publication of precise maps and descriptions of critical habitat in local newspapers (USFWS 1991, 1994, 1996a).

Those taxa growing on lands managed by the National Park Service and U.S. Fish and Wildlife Service, and some lands managed by the Department of Defense and the State (land ownership is summarized in Appendix D) have benefitted from ongoing management programs, which include alien species control, fire control, research, and species-specific management.

Some of the plant taxa in this plan are located on the Schofield Barracks, the Makua Military Reservation, and the Pohakuloa Training Area under the jurisdiction of the U.S. Army. Army Environmental staff employed by the Research Corporation of the University of Hawaii have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report" (Report). The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (Barry Totten, U.S. Army, Schofield Barracks, *in litt.* 1998). Upon implementation, actions outlined in the Report may enhance conservation of the Multi-island plants found on their lands.

At the Lualualei Naval Reservation, *Bonamia menziesii* and one population of *Flueggea neowawraea* have been fenced, and there is an on-going weed removal program for these fenced areas (Joel Moribe, U.S. Navy, personal communication 1997). Three populations of *Schiedea hookeri* are in unfenced, natural management areas, which are areas set aside for conservation.

The State of Hawaii and the U.S. Fish and Wildlife Service provide funding to the National Tropical Botanical Garden, Lyon Arboretum, Pahole Mid-elevation Nursery, and the Volcano Rare Plant Facility which store and propagate Multi-island plants and many other endangered and threatened plant species. The State of Hawaii also maintains propagation and outplanting programs for many rare Hawaiian taxa, including *Flueggea neowawraea, Hibiscus brackenridgei, Sesbania tomentosa* and *Vigna o-*

wahuensis, and protective exclosures (areas fenced to exclude grazing animals) for *Hibiscus brackenridgei* and *Sesbania tomentosa*.

Private

A long-range management plan for the Honouliuli Preserve prescribes actions for alien plant management, ungulate control, fire control, rare species recovery, and native habitat restoration (TNCH 1997). It is expected that these actions will benefit Multi-island plants within the Preserve, including *Cenchrus agrimonioides*, *Cyanea grimesiana* ssp. *grimesiana*, *Phyllostegia parviflora*, *Plantago princeps*, *Schiedea hookeri*, and *Schiedea nuttallii*. The Nature Conservancy of Hawaii is also considering constructing a fence near South Ekahanui Gulch on the Preserve to protect a population of *Plantago princeps* that occurs near the cliffs (Joan Yoshioka, TNCH, personal communication 1999). In addition, two of the Multi-island plant taxa have been outplanted on the preserve, *Hibiscus brackenridgei* ssp. *mokuleianus* and *Schiedea hookeri*. These outplantings were made within fenced exclosures where there is on-going weed, slug, and rodent control.

The Nature Conservancy of Hawaii has implemented a fuel reduction treatment strategy for the Kanepuu Preserve on Lanai that includes mowing, at least yearly, the seven distinct fenced units (Coleen Cory, TNCH, personal communication 1999). In addition, the Kanepuu Preserve fire protection plan is updated each year and incorporates the participation of local, State, and private agencies (Alenka Remec, TNCH, personal communication 1999). It is expected that these actions may enhance conservation of the Multi-island plants found there. In addition, fenced exclosures protect *Bonamia menziesii* and *Hibiscus brackenridgei* found on the Preserve.

During the past year, a fenced exclosure was constructed around the population of *Platanthera holochila* found on the Nature Conservancy of Hawaii's Kamakou Preserve on Molokai (J. Yoshioka, personal communication 1999).

Seeds, spores, and/or plants of 25 of these taxa have been collected by botanical gardens or by university researchers. However, the viability of seeds in storage is likely to be minimal, since many Hawaiian plants have seeds that do not store well under standard storage methodology. Fifteen of the Multi-island plant taxa have been successfully propagated in botanical gardens or university research facilities (Table 3; S.

Weller, personal communication 1997). Plans for these holdings include population and pollination studies, research into propagation methods, and feasibility of long-term seed storage. There are no collections of seeds, tissue, or plants of *Sanicula purpurea* in any botanical gardens or university research facilities.

Corporate ownership of the Waimea Falls Park changed hands in 1997. In a move to downsize, the entire technical staff of the Waimea Arboretum and Botanical Gardens were dismissed (Honolulu Weekly, May 14–20, 1997). Currently, two full-time and two part-time employees, who are paid by the nonprofit Waimea Arboretum Foundation, maintain the collection. The future of the endangered plant holdings at the arboretum remains uncertain as foundation capital is being used to pay the botanists (D. Orr, personal communication 1999).

Six of the 26 plants treated in this recovery plan are maintained in *ex situ* holdings in the four botanical institutions for the Center for Plant Conservation's National Collection of Endangered Plants program. The botanical institutions include the Amy B. H. Greenwell Ethnobotanical Garden, Lyon Arboretum, National Tropical Botanical Garden, and Waimea Arboretum. These 6 taxa are subject to the Center's national collecting and genetic management guidelines for *ex situ*[5] holdings. The Center cooperates with the Service and other agencies and organizations wishing to undertake actions associated with the controlled propagation of listed plants. Many conservation, research, education, monitoring, and restoration projects associated with all 26 taxa are being prioritized and coordinated by the Hawaii Rare Plant Restoration Group — a Center for Plant Conservation-Hawaii chaired body made up of representatives of Federal, State, and private agencies and organizations.

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[5] ***Ex situ.*** Off-site, as in a botanical garden, as opposed to *in situ*, in a plant's native habitat.

Table 3. Seeds, cultures, and plants of the Multi-island plants in storage/propagation at botanical gardens, nurseries, or research facilities. NTBG = National Tropical Botanical Garden. LA = Lyon Arboretum. WA = Waimea Arboretum. PN = Pahole Mid-Elevation Nursery. HBG = Honolulu Botanical Gardens. Note: numbers of seeds stored at the Lyon Arboretum were not available.

Taxon	Seed accessions/total number of seeds in storage				Tissue accessions/total number of cultures			Number of plants in nursery				Number of Plants planted on grounds			
	NTBG	LA	PN	WA	NTBG	LA	WA	NTBG	LA	PN	WA	NTBG	LA	HBG	WA
Achyranthes mutica	567											21			
Adenophorus periens	many spores											0*			
Bonamia menziesii	100	5 seeds							2			15			8
Cenchrus agrimonioides						2				30	4				
Centaurium sebaeoides	100														
Cyanea grimesiana ssp. *grimesiana*	1,466					343			10	9		0*	2		
Cyperus trachysanthos	3,800											18			
Diellia erecta	many spores														
Euphorbia haeleeleana	367	seeds		80		9		10				4			
Flueggea neowawraea	2,414		38							1		21			
Hibiscus brackenridgei	987			190					20	200	19	304	10	19	78
Isodendrion laurifolium						15						0*			
Isodendrion longifolium						1						0*			

Table 3 (Continued). Seeds, cultures and plants of the Multi-island plants in storage/propagation at botanical gardens, nurseries, or research facilities. NTBG = National Tropical Botanical Garden. LA = Lyon Arboretum. WA = Waimea Arboretum. PN = Pahole Mid-Elevation Nursery. HBG = Honolulu Botanical Gardens.

Taxon	Seed accessions/total number of seeds in storage			Tissue accessions/total number of cultures			Number of Plants in nursery				Number of Plants planted on grounds			
	NTBG	LA	WA	NTBG	LA	WA	NTBG	LA	PN	WA	NTBG	LA	HBG	WA
Mariscus pennatiformis			2,000		30					184	0*			5
Neraudia sericea	1,330										0*			
Panicum niihauense	3,180													
Phyllostegia parviflora								5			0*			
Plantago princeps							2		9		0*			
Platanthera holochila		seeds									0*			
Sanicula purpurea											0*			
Schiedea hookeri **	17,185						9		2	7	0*			24
*Schiedea nuttallii***	5,489				20		13		2		3			
Sesbania tomentosa	8,224				29				45	1	58		38	2
Solanum incompletum		seeds												
Spermolepis hawaiiensis					20		7				0*			
*Vigna o-wahuensis****	69										0*			

* indicates that specimens were propagated but did not survive transplantation.

** currently propagated for population or genetic studies in a university research facility.

*** successfully propagated at Volcano Rare Plant Facility.

E. Species Accounts

1. *Achyranthes mutica*

(No common name) Recovery Priority Number 2

(Recovery Priority Number system is described in Appendix E)

a. Description

Appendix B contains a line drawing of *Achyranthes mutica.*

Achyranthes mutica, a member of the amaranth family (Amaranthaceae), is a many-branched shrub with stems ranging from 30 to 60 centimeters (12 to 24 inches) long. The opposite leaves, usually 3.2 to 4 centimeters (1.3 to 1.6 inches) long and 1.5 to 2 centimeters (0.6 to 0.8 inch) wide, are inversely egg-shaped to elliptic or inversely lance-shaped. The stalkless flowers are arranged in spikes (flowers directly attached to the main flower axis) that are 0.4 to 1.5 centimeters (0.2 to 0.6 inch) long. The petalless flowers are perfect (containing both female and male parts). The sepals are of unequal length, 3 to 4.2 millimeters (0.1 to 0.2 inch) long, and have sharply pointed tips. This species is distinguished from others in the genus by the shape and size of the sepals and by characteristics of the spike, which is short and congested (Wagner *et al.* 1990).

b. Taxonomy

Achyranthes mutica was first described by Asa Gray (*in* Mann 1867) based on a specimen collected on Kauai between 1851 and 1855 by Ezechiel Jules Rémy, a French naturalist and ethnologist (St. John 1979; Wagner *et al.* 1990). *Achyranthes nelsonii* (St. John 1979) is considered to be synonymous with *Achyranthes mutica* by the authors of the current treatment of Hawaiian members of the family (Wagner *et al.* 1990).

c. Current and Historic Ranges and Population Status

Historically *Achyranthes mutica* was known from three collections from opposite ends of the main archipelago — Kauai and Hawaii (USFWS 1996a). Currently, this species is known only from Hawaii Island, from the Keawewai Stream area, the south slope of Puu Loa in the Kohala Mountains, and Lanikepu Gulch on private land (Linda Pratt, US Geological Survey–Biological Resources Division [BRD], *in litt.* 1997; Rick Warshauer, BRD *in litt.* 1996). Between 20 and 50 plants are known to exist.

d. Life History

Little is known about the life history of this plant. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Achyranthes mutica is found in *Acacia koaia* (koaia) lowland dry forest at an elevation of about 920 meters (3,030 feet) (USFWS 1996a). Associated species include *Dodonaea viscosa* (aalii), *Myoporum sandwicense* (naio), *Nestegis sandwicensis* (olopua), *Osteomeles anthyllidifolia* (ulei), and *Sophora chrysophylla* (mamane) (Hawaiian Plant Conservation Center [HPCC] 1992).

f. Reasons for Decline and Current Threats

The primary threats to *Achyranthes mutica* are habitat degradation and/or destruction by ungulates such as cattle (*Bos taurus*) and feral goats (*Capra hircus*), competition with alien plants, and a risk of extinction from naturally occurring events (such as landslides or hurricanes) and/or reduced reproductive vigor due to the small number of existing individuals and populations (USFWS 1996a).

g. Conservation Efforts

Achyranthes mutica has been successfully propagated at the National Tropical Botanical Garden. Currently, more than 500 seeds are in storage and 21 plants are in cultivation (Melany Chapin, NTBG, personal communication 1997).

One plant, in an area called Kalopi, is protected by a fence that the landowner constructed recently. Cattle are not allowed to graze this area (L. Pratt, *in litt.* 1997).

No other specific conservation actions are known for this species.

h. Needed Recovery Actions[6]

1) Construct protective fences around the known populations, and initiate removal of cattle and feral goats from its habitat.

Exclosures should be constructed to reduce impacts from domestic cattle and feral goats. Cattle could be moved away from the preferred habitat of *Achyranthes mutica* while various methods of feral goat removal, which have been tried successfully elsewhere in the State, could be implemented. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control alien plants.

A long-range management plan to control alien plants such as panini, kikuyu grass, common guava, hairy horseweed, and Hamakua pamakani, needs to be developed and implemented. Commitment for long-term stewardship and conservation of the few remaining populations needs to be developed.

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6 In the individual species accounts, the suggested species-specific recovery actions are not necessarily listed in the order in which they should be accomplished, nor do they necessarily take priority over any other recovery tasks. The overall recovery strategy is presented in the Step-down Narrative section of this plan, starting on page 169.

3) Maintain adequate genetic stock.

To prevent extinction of this species, efforts should be initiated to propagate this species and maintain adequate genetic stock (*ex situ*). Propagation material should be collected immediately, if possible, from all populations so that all genetic lineages are represented.

4) Outplant additional plants in areas of reduced threats.

Outplanting to enhance the remaining wild populations should begin after they have been protected from ungulates, weed control has begun, and adequate propagated material is available. Because the historical range of *Achyranthes mutica* is highly vulnerable, establishment of new populations within and beyond its historical range may be considered in areas free from the impacts of cattle, feral goats, and natural events such as landslides.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

2. *Adenophorus periens*

(Common name: pendant kihi fern) Recovery Priority Number 11

a. Description

No line drawing is available for this species.

Adenophorus periens, a member of the grammitis family (Grammitidaceae), is a small, pendant, epiphytic (not rooted on the ground) fern. The rhizome (prostrate stem) is covered with small dark, stiff scales 2 to 4 centimeters (0.8 to 1.6 inches) long. Its yellowish green fronds are usually between 10 and 40 centimeters (4 and 16 inches) long and covered with hairs. The fronds have slightly hairy stalks less than 1 centimeter (0.4 inch) long. Each frond is comprised of oblong or narrowly triangular pinnae (divisions or leaflets) 5 to 15 millimeters (0.2 to 0.6 inch) long with margins that are smooth or toothed and lined with sparse hairs. The pinnae are situated perpendicular to the axis of the midrib, with each pinna twisted such that its upper surface faces upward. Round sori (groups of spore-producing bodies) usually develop in the central portion of the fertile frond, forming 2 regular rows on each pinna. This species differs from other species in this endemic Hawaiian genus by having hairs along the pinna margins, by the pinnae being at right angles to the midrib axis, by the placement of the sori on the pinnae, and the degree of dissection of each pinna (Bishop 1970, 1974; Hillebrand 1888; Linney 1989).

b. Taxonomy

Adenophorus periens was first collected by Captain Frederick William Beechey in the 1820's or 1830's. It was not formally described until 1974, when L. Earl Bishop published the name *Adenophorus periens*. Prior to its description, the names *Polypodium adenophorus* and *Adenophorus pinnatifidus* had been erroneously applied to the species represented by Beechey's specimen (Bishop 1974).

c. Current and Historic Ranges and Population Status

Historically, *Adenophorus periens* was known from the following general areas: Halemanu on Kauai, the Koolau Mountains of Oahu, the summit of Lanai, Kula Pipeline on East Maui, and Hilo and Waimea on Hawaii Island (HINHP 1995).

Currently, *Adenophorus periens* is known from several locations on Kauai, Molokai, and Hawaii. The statewide total of 13 to 18 current populations comprises approximately 1,295 to 1,330 individuals of this species: on Kauai there are about 79 to 84 individuals, on Molokai, there are 6, and on Hawaii there are approximately 1,215 to 1,241 individuals (HPCC 1995; Lorence and Flynn 1991; USFWS 1996b; L. Pratt, *in litt.* 1997; R. Warshauer, *in litt.* 1996; J. Yoshioka, personal communication 1997).

On Kauai, one population is known from the boundary of Hono O Na Pali Natural Area Reserve and Na Pali Coast State Park on State land, one from Waioli on State land, one from Wainiha Valley on private land, one from south of Mt. Namahana, and four are clustered in the Wahiawa area over a distance of 2 square kilometers (0.8 square mile) on private land (USFWS 1996b).

On Molokai, a single population of six plants is on private land at Kamakou Preserve (USFWS 1996b; Joan Yoshioka, TNCH, personal communication 1997).

On the island of Hawaii, there are between 5 and 10 populations on private, State, and Federal land. One is on the Olaa Tract (although these plants have not been seen in more than 13 years), one occurs on Kane Nui o Hamo and in Kahaualea Natural Area Reserve, and several others occur in or near this area, perhaps including the Hawaii Volcanoes National Park (USFWS 1996b; D. Paul, *in litt.* 1998; L. Pratt, *in litt.* 1997; R. Warshauer, *in litt.* 1996).

d. Life History

Little is known about the life history of *Adenophorus periens*, which seems to grow only in closed canopy dense forest with high humidity. Its breeding system is unknown but outbreeding is very likely to be the predominant mode of reproduction. Spores are dispersed by wind, possibly by water, and perhaps on the feet of birds or insects (Linney 1989). Spores lack a thick resistant coat which may indicate their longevity is brief, probably measured in days at most. Due to the weak differences between the seasons, there seems to be no evidence of seasonality in growth or reproduction. *Adenophorus periens* appears to be susceptible to volcanic emissions and/or resultant acid precipitation (Linney 1989). Additional information on reproductive cycles, longevity, specific environmental requirements, and limiting factors is not available.

e. Habitat Description

Adenophorus periens, an epiphyte usually growing on *Metrosideros polymorpha* (ohia) trunks, is found in the Ohia/*Cibotium glaucum* (hapuu) Lowland Wet Forest at elevations between 470 and 1,265 meters (1,540 and 4,150 feet) (USFWS 1996b). It is found in habitats of well-developed, closed canopy providing deep shade and high humidity (Linney 1989). Associated species include *Broussaisia arguta* (kanawao keokeo), *Cheirodendron trigynum* (olapa), *Cyanea* spp. (haha), *Cyrtandra* sp. (haiwale), *Dicranopteris linearis* (uluhe), *Freycinetia arborea* (ieie), *Hedyotis* sp. (manono), *Labordia hirtella*, and *Psychotria hawaiiensis* (kopiko) (Linney 1989; USFWS 1996b).

f. Reasons for Decline and Current Threats

On Hawaii Island, the primary threat to *Adenophorus periens* is habitat degradation by pigs, which damage the understory plants, such as tree ferns, altering the moist, shady conditions apparently required by the fern (L. Pratt, *in litt.* 1995). An additional threat to *Adenophorus periens* is infestation and replacement of the native wet forest with the alien plant strawberry guava (D. Paul, *in litt.* 1998).

Another threat to this plant is habitat destruction by fires and fumes from volcanic eruptions (Winona Char, Char & Associates, *in litt.* 1995; L. Pratt, *in litt.* 1996). Of note is the population of *Adenophorus periens* reported from the Kahaualea Natural Area Reserve on the island of Hawaii (HINHP 1995; L. Pratt, *in litt.* 1996), which has been affected by tephra fallout and lava flows from Kilauea Volcano over the past several years. Wildfires ignited by volcanic activity have destroyed some of the Natural Area Reserve's mesic and wet forests. In addition, tephra fallout and noxious volcanic gasses have caused extensive damage to surrounding native forests. While 65,000 to 100,000 plants were reported from this area in 1988, no *Adenophorus periens* plants were found here during a 1993 survey. Many of these plants may have been killed by either sulfur dioxide fumes from Puu Oo or by several periods of drought (L. Pratt, *in litt.* 1997). However, Paul (*in litt.* 1998) reported that an undetermined number of plants have persisted in the Natural Area Reserve throughout this period.

On Kauai, competition with the alien plant, strawberry guava, and predation and habitat degradation by feral goats are major threats (USFWS 1996b).

g. Conservation Efforts

In 1996, spores were collected from an individual on Molokai for *ex situ* propagation at the University of Hawaii's Lyon Arboretum. However, germination was not successful (Koob 1997; Edwin Misaki, TNCH, *in litt.* 1997). An unknown number of spores are in storage at the National Tropical Botanical Garden (M. Chapin, personal communication 1997). No other specific conservation actions are known.

h. Needed Recovery Actions

1) Construct exclosures to protect against feral ungulates.

Exclosures should be constructed on private, State, and Federal land to reduce impacts to the wet forest habitat from feral ungulates. Control or removal of feral ungulates from lands that are protected as natural conservation areas or parks will alleviate the impact of feral ungulates on the native ecosystems within those lands. A commitment should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Develop a volcanic hazard contingency plan.

To reduce the risk that populations of *Adenophorus periens* will be extirpated in volcanically active areas, a volcanic hazard contingency plan is needed. It may be necessary to "rescue" these populations if habitat is threatened by fire, tephra fallout, or lava flows during some future volcanic event.

3) Maintain adequate genetic stock and reestablish the plant in its historic range.

Micropropagation will be necessary to successfully reestablish this species throughout its historical range (Michael Buck, DOFAW, *in litt.* 1996). Although micropropagation efforts have not yet been successful, they should be continued. *In situ* (on site–in the wild) propagation of fresh spores on old growth ohia within protected habitat may also be beneficial (D. Paul, *in litt.* 1998).

4) Control alien plants.

A long-range management plan to control alien plants such as strawberry guava, one of the greatest threats to windward, lowland wet forest on Hawaii Island, needs to be developed and implemented.

5) Conduct/encourage research into the reasons for its decline.

Research that may lead to understanding of the reasons for decline of *Adenophorus periens*, in addition to studies of habitat degradation and destruction from feral ungulates or volcanic activity, may include study of life history requirements and/or other limiting factors that are not yet well understood.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

3. *Bonamia menziesii*
(No common name) Recovery Priority Number 5

a. Description

Appendix B contains a line drawing of *Bonamia menziesii.*

Bonamia menziesii, a member of the morning-glory family (Convolvulaceae), is a vine with twining branches up to 10 meters (33 feet) long that are fuzzy when young. The leathery, oblong to oval leaves measure 3 to 9 centimeters (1.2 to 3.5 inches) in length and 1 to 4 centimeters (0.4 to 1.6 inches) wide. The upper leaf surface is usually hairless or covered with sparse hairs and the lower surface is covered with dense fuzzy hairs. The white to greenish funnel-shaped flowers, each 2 to 2.5 millimeters (0.08 to 0.1 inch) long, are produced singly or in clusters of three on stalks 1 to 2 centimeters

(0.4 to 0.8 inch) long with tiny bracts (modified leaves) at the base of each stalk. Stamens usually have glandular hairs at their bases. The flower has 2 styles, which are separate or partly fused. The fruits are tan or yellowish brown capsules 1 to 1.5 centimeters (0.4 to 0.6 inch) long, which contain 1 or 2 oval seeds imbedded in black pulp. This species is the only member of the genus that is endemic to the Hawaiian Islands and differs from other genera in the family by its two styles, longer stems and petioles, and rounder leaves (Austin 1990).

b. Taxonomy

Asa Gray gave the name *Bonamia menziesii* (NCN) to a plant from the Sandwich Islands (Hawaii) in honor of its collector, Archibald Menzies (Gray 1862). Wilhelm Hillebrand (1888) placed the species into the segregate genus *Breweria*. Otto Degener (1932a, 1932b) described a new genus, *Perispermum*, and placed *Bonamia menziesii* in it. He also described another species of *Perispermum*, *P. albiflorum*. T. Myint and D.B. Ward (1968) recognized only one Hawaiian species and placed it in the genus *Bonamia*. They recognized two varieties: variety *menziesii* and a new variety, *rockii*. The current treatment (Austin 1990) recognizes only one species with no subspecific taxa.

c. Current and Historic Ranges and Population Status

Historically, *Bonamia menziesii* was known from the following general areas: scattered locations on Kauai, the Waianae Mountains of Oahu, scattered locations on Molokai, one location on West Maui, and eastern Hawaii (HINHP 1995).

Currently, *Bonamia menziesii* is known from 31 to 44 populations on 5 islands. The total current population throughout the State consists of several thousand individuals, most of them on Kauai (Steven Perlman and Kenneth Wood, NTBG, personal communications 1997). On Kauai, there are several thousand, on Oahu no more than 150, on Lanai approximately 12, on Maui between 10 and 15, and on the island of Hawaii at least one individual has been observed (HINHP 1995; Robert Hobdy, DOFAW, personal communication 1997; Lorence and Flynn 1991; J. Moribe, personal communication 1997; S. Perlman and K. Wood, personal communications 1997).

On Kauai, at least a dozen populations are known from Kalalau, upper Waioli Valley, scattered across the north coast from Limahuli, Hanakapiai to Milolii, Kawaiula Valley, Hipalau Valley, Paaiki Valley, Mount Kahili, and the Hono O Na Pali Natural Area Reserve on State and private land; and Wahiawa drainage on private land (HINHP 1995; Lorence and Flynn 1991; S. Perlman and K. Wood, personal communications 1997).

On Oahu, *Bonamia menziesii* is known from both the Waianae and the Koolau Mountains. In the Waianae Mountains between Kuaokala and Nanakuli, 7 to 8 populations totaling 25 to 50 individuals, are spread over a distance of 24 kilometers (15 miles) on the Lualualei Naval Reservation and the U.S. Army's Makua Military Reservation, private land, and State land. Seven of these populations are clustered on the northernmost section over a distance of 8 kilometers (5 miles) (HINHP 1995; J. Moribe, personal communication 1997). In the southeastern part of the Koolau Mountains, 4 populations totaling 75 to 100 individuals are found over an area of 6 square kilometers (2.5 square miles) on private and State land (HINHP 1995).

On Lanai, *Bonamia menziesii* is known from three scattered locations: about six individuals at Kaa, two individuals on Puhielelu Ridge, and four individuals at Paomai, on private land (Garnett 1991; HINHP 1995; HPCC 1995; Barrie Morgan, formerly with TNCH, personal communication 1997). On Maui, 1 population of a single individual is known from private land on the western slopes of West Maui, and 3 to 5 populations of 9 to 14 individuals are on private and State land on East Maui (HINHP 1995; R. Hobdy, personal communication 1997; R. Hobdy and Lloyd Loope, BRD, *in litt.* 1997).

On the island of Hawaii, a single population of at least 1 individual is located at Kaupulehu on private land (HINHP 1995).

d. Life History

Little is known about the life history of this plant. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Bonamia menziesii is found on steep slopes as well as on level ground in dry to mesic forest and sometimes in wet forest at elevations between 150 and 625 meters (490 and 2,050 feet) (Austin 1990; R. Hobdy and L. Loope, *in litt.* 1997; B. Morgan, personal communication 1997). Associated species include ohia, *Canthium odoratum* (alahee), *Diospyros sandwicensis* (lama), aalii, naio, *Nestegis sandwicense* (olopua), *Pisonia* sp. (papala kepau), and *Sapindus oahuensis* (lonomea) (HINHP 1995; R. Hobdy and L. Loope, *in litt.* 1997).

f. Reasons for Decline and Current Threats

The primary threats to *Bonamia menziesii* are habitat degradation and possible predation by wild and feral ungulates (pigs, goats, axis deer, black-tailed deer, and cattle); competition with a variety of alien plant species, particularly fountain grass on Hawaii Island; and, fire (USFWS 1996b). An alien beetle (*Physomerus grossipes*), which has recently become established on Oahu, is potentially a significant threat to *Bonamia menziesii* (D. Orr, personal communication 1999). Military activities are a possible threat to populations on the Lualualei Naval Reservation and a demonstrated threat on the U.S. Army's Makua Military Reservation.

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The

Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Bonamia menziesii* plants found on the Army's Makua Military Reservation. In addition, the Army is currently conducting weed control actions in *Bonamia* habitat and monitoring phenology quarterly (Kapua Kawelo, U.S. Army Garrison, personal communication 1997).

The *Bonamia menziesii* plant on the Navy's Lualualei Naval Reservation has been fenced for protection from cattle. A program of alien plant removal within the exclosure is ongoing (J. Moribe, personal communication 1997).

Most of the *Bonamia menziesii* at Kanepuu Preserve on Lanai are found within fenced exclosures. In addition, the Nature Conservancy of Hawaii has implemented a fuel reduction treatment strategy for the Kanepuu Preserve on Lanai that includes mowing, at least yearly, of the seven distinct fenced units (C. Cory, personal communication 1999). In addition, the Kanepuu Preserve fire protection plan is updated each year and incorporates the participation of local, State, and private agencies (A. Remec, personal communication 1999). It is expected that these actions may enhance conservation of the *Bonamia menziesii* plants found there.

Bonamia menziesii has been successfully propagated at the Lyon Arboretum's micropropagation laboratories, at the Waimea Arboretum, and the National Tropical Botanical Garden (Koob 1997; M. Chapin, personal communication 1997; Greg Koob, formerly with the Lyon Arboretum, personal communication 1997; D. Orr, personal communication 1997). Currently, approximately 25 individuals exist in cultivation (Koob 1997; M. Chapin, personal communication 1997; D. Orr, personal communication 1997). Reintroduction of cultivated individuals to the wild has not been attempted.

h. <u>Needed Recovery Actions</u>

1) Construct exclosures to protect against wild and feral ungulates.

Exclosures should be constructed around the known populations on private, State, and Federal land to reduce impacts from wild and feral ungulates. Subsequent control or removal of ungulates from these lands will alleviate their impact on the native ecosystems. A commitment should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan needs to be developed to control alien plants such as fountain grass, lantana, koa haole, Christmas berry, strawberry guava, and silk oak. Additionally, immediate efforts should be made to weed and protect those populations that consist of only one remaining individual (Kalalau on Kauai; Makaleha, Waialae Nui-Kapakahi Ridge, Keawaula, Nanakuli Valley, Kului Gulch, and Kapuna Gulch on Oahu; Puu o Kali, and Honokowai Ditch Trail on Maui; and Kaupulehu on Hawaii).

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation materials should be collected immediately from those populations that consist of only one remaining individual.

4) Enhance wild populations.

The remaining *in situ* wild populations should be enhanced by outplanting when adequate propagated material is available, and after the populations have been protected from ungulates and weed control is underway. New populations should be established within the historic range of *Bonamia menziesii*, in areas free from the impacts of ungulates, alien plants, and military activities.

5) Protect endangered plants from fire.

Management actions to protect endangered species such as *Bonamia menziesii* should be implemented by the Army on the Makua Military Reservation, where current ordnance training exercises could unintentionally ignite fires.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

4. *Cenchrus agrimonioides*

(Hawaiian name: kamanomano) Recovery Priority Number 5

a. Description

Appendix B contains a line drawing of *Cenchrus agrimonioides* var. *agrimonioides*. No line drawing is available for *Cenchrus agrimonioides* var. *laysanensis*.

Cenchrus agrimonioides, a member of the grass family (Poaceae), is a perennial grass with stems 0.3 to 2 meters (1 to 7 feet) tall. The leaf blades, 20 to 40 centimeters (8 to 16 inches) long and 5 to 25 millimeters (0.2 to 1 inch) wide, are flat or folded and have a prominent midrib. The inflorescence (flower cluster) is a raceme (an unbranched inflorescence with flowers opening from the bottom upward, each on its own stalk) 5 to 10 centimeters (2 to 4 inches) long, bearing cylindrical to lance-shaped burs 8 to 18 millimeters (0.3 to 0.7 inch) long. The burs are densely hairy with an outer series of numerous, somewhat spreading bristles. Each bur partially envelops one spikelet (ultimate flower cluster). This species is distinguished from others in the genus by the cylindrical to lance-shaped bur and the arrangement and position of the bristles. *Cenchrus agrimonioides* var. *agrimonioides* differs from var. *laysanensis* in generally having smaller burs, shorter stems, and narrower leaves (O'Connor 1990).

b. Taxonomy

A botanist on the Russian vessel "Rurik," Ludolf K. A. von Chamisso, first collected *Cenchrus agrimonioides* on Oahu during a world exploring expedition between 1816 and 1817. Carl Bernhard von Trinius described the species several years later (Degener and Whitney 1937). Other published names considered synonymous with *Cenchrus agrimonioides* include *Cenchrus calyculatus* var. *uniflorus*, *Cenchrus laysanensis*, and *Cenchrus pedunculatus* (O'Connor 1990). Currently, the species is recognized as consisting of two varieties — variety *agrimonioides* and variety *laysanensis*, described by F. B. Brown (Brown 1931).

c. Current and Historic Ranges and Population Status

Historically, *Cenchrus agrimonioides* var. *agrimonioides* was known from three general areas — the Waianae Mountains of Oahu, Kaaukuu on Lanai, and the south slope of Haleakala and Ulupalakua on Maui. It may possibly have occurred on the island of Hawaii; undocumented observations of this taxon have been reported from unspecified locations on this island (USFWS 1996a; Hillebrand 1888).

Currently *Cenchrus agrimonioides* var. *agrimonioides* is known from Oahu and Maui. The total number of individuals statewide is fewer than 100.

In the Waianae Mountains on Oahu, approximately 27 to 28 individuals are found in the following populations — 3 to 4 individuals in Pahole Gulch in the State's Pahole Natural Area Reserve; about 10 individuals on the Makaha-Waianae Kai Ridge on City and County of Honolulu land; 19 individuals in three distinct populations in or near Kahanahaiki Gulch on the Army's Makua Military Reservation; 6 individuals in east Makaleha on State land; and 2 individuals in the Pualii drainage on private land (USFWS 1996a; K. Kawelo, personal communication 1997; B. Totten, *in litt.* 1998).

On Maui, a patch of *Cenchrus agrimonioides* var. *agrimonioides* plants, 0.9 square meters (10 square feet) in size, is known from State land within Kanaio Natural Area Reserve (R. Hobdy, personal communication 1997).

The other variety of this species, *Cenchrus agrimonioides* var. *laysanensis*, was known historically from the northwestern Hawaiian Islands of Laysan, Kure, and Midway, all within the Northwestern Hawaiian Islands National Wildlife Refuge. This variety has not been seen since 1973. These islands are infrequently surveyed for plants, the last comprehensive survey being completed in the 1980's, so it is possible that the variety still exists and will be found with further survey efforts (Corn 1980; USFWS 1996a).

d. Life History

Little is known about the life history of this plant. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are generally unknown, however, this species has been observed to produce fruit year round (B. Totten, *in litt.* 1998).

e. Habitat Description

Cenchrus agrimonioides var. *agrimonioides* is usually found on dry, rocky ridges or slopes, or ridges in mesic ohia-*Acacia koa* (koa) forest at elevations between 560 and 820 meters (1,830 and 2,700 feet). Associated plants include *Alyxia oliviformis* (maile), alahee, *Carex* sp., *Diospyros* sp. (lama), *Styphelia tameiameiae* (pukiawe), and *Eragrostis variabilis* (kawelu) (K. Kawelo, *in litt.* 1998; USFWS 1996a).

f. Reasons for Decline and Current Threats

The major threats to *Cenchrus agrimonioides* var. *agrimonioides* are habitat degradation and/or destruction by feral pigs (*Sus scrofa*) (Oahu only), competition with alien plants, and a risk of extinction from naturally occurring events and/or reduced reproductive vigor due to the small number of existing individuals. The Pahole Gulch population on Oahu is potentially threatened by trampling and fire from military activities and the Maui population is potentially threatened by goats and cattle (USFWS 1996a). The populations near Kahanahaiki Valley on Oahu are also threatened by fire from the Makua Military Reservation (K. Kawelo, *in litt.* 1998).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of *Cenchrus agrimonioides* var. *agrimonioides* plants found on the Army's Makua Military Reservation. In addition, the Army has constructed a fence around 2 populations of 18 plants in or near Kahanahaiki Gulch and removed all pigs from within the exclosure. Weed control and quarterly phenological monitoring are in progress (K. Kawelo, personal communication 1997).

A long-range management plan for the Honouliuli Preserve prescribes actions for alien plant management, ungulate control, fire control, rare species recovery, and native habitat restoration (TNCH 1997). It is expected that these actions will benefit *Cenchrus agrimonioides* var. *agrimonioides* within the Preserve.

The *Cenchrus agrimonioides* var. *agrimonioides* plants at the Pahole Natural Area Reserve are found within a fenced exclosure (B. Garnett, DOFAW, personal communication 1997).

Cenchrus agrimonioides var. *agrimonioides* has been successfully propagated at the Lyon Arboretum's micropropagation laboratory, at the Waimea Arboretum, at the Division of Forestry and Wildlife's Pahole Plant Nursery, and at the National Tropical Botanical Garden (Koob 1997; B. Garnett, personal communication 1997; G. Koob, personal communication 1997; D. Orr, personal communication 1997). Reintroduction has not been attempted.

No other specific conservation actions are known for this plant.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral ungulates.

Exclosures should be constructed around the known populations to reduce impacts from feral ungulates. Subsequent control or removal of feral ungulates from these areas will alleviate their impact on native ecosystems. A commitment should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan must be developed to control alien plants such as Christmas berry, lantana, strawberry guava, silk oak, molasses grass, Hilo grass, and prickly Florida blackberry. Additionally, efforts should be made immediately to weed and protect the population in Pualii Drainage that has only two remaining individuals.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from the populations that have only one or two remaining individuals, such as the unfenced individual on the Makua Military Reservation and the population in Pualii Drainage.

4) Enhance wild populations and establish new populations.

Once adequate propagated material is available, the remaining *in situ* populations are protected from ungulates, and weed control is underway, outplanting to enhance the remaining wild populations should occur. New populations should be established within the historic range of *Cenchrus agrimonioides* var. *agrimonioides*, in areas free from the impacts of ungulates, alien plants, and military activities.

5) Survey the Northwestern Hawaiian Islands of Laysan, Kure, and Midway and collect genetic material.

A survey of the Northwestern Hawaiian Islands of Laysan, Kure, and Midway for extant populations of *Cenchrus agrimonioides* var. *laysanensis* should be initiated. At the same time, genetic material should be collected from any relocated plants, and *ex situ* propagation should be initiated. Once adequate propagated material is available and the remaining *in situ* populations have been protected, if appropriate, the remaining wild populations should be enhanced by outplanting. Establishment of new populations within the historic range of *Cenchrus agrimonioides* var. *laysanensis* may also be appropriate.

6) Protect endangered plants from fire.

Coordinated fire protection is needed for endangered plant species on State natural area reserves, such as Pahole on Oahu where fewer than five individuals of *Cenchrus agrimonioides* var. *agrimonioides* occur.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

5. *Centaurium sebaeoides*
(Hawaiian name: 'awiwi) Recovery Priority Number 2

a. Description

Appendix B contains a line drawing of *Centaurium sebaeoides*.

Centaurium sebaeoides is the only species of the gentian family (Gentianaceae) native to the Hawaiian Islands. It is an annual herb about 6 to 20 centimeters (2.4 to 8 inches) tall. The leaves are rather fleshy, inversely ovate or elliptic, and 0.7 to 3.2 centimeters (0.3 to 1.3 inches) long by less than 2 centimeters (1 inch) wide. Flowers are stalkless and are arranged along the stems near their ends. The fused sepals are 8 millimeters (0.3 inch) long and are divided into uneven lobes. The white or pale pink petals are fused into a tube up to 10 millimeters (0.4 inch) long, with lobes up to 4.5

millimeters (0.2 inch) long. The cylindrical capsules are up to 9.5 millimeters (0.4 inch) long and contain numerous tiny brown seeds. This species is distinguished from *Centaurium erythraea*, which is naturalized in Hawaii, by its fleshy leaves and the unbranched arrangement of the flower cluster (Degener 1934; Degener and Degener 1960; Wagner *et al.* 1990).

b. Taxonomy

On the basis of a collection of specimens by Berthold Carl Seeman of what is now called *Centaurium sebaeoides*, August Grisebach (1853) named a new genus of plants, *Schenkia*, and gave it the specific epithet of *sebaeoides*, indicating its resemblance to a species of *Sabaea*, another genus in the gentian family. The species was transferred to the genus *Erythraea* in 1862 by Asa Gray (1862), and later by G. Claridge Druce (1917) to the genus *Centaurium*.

c. Current and Historic Ranges and Population Status

Historically, *Centaurium sebaeoides* was known from scattered localities on State and private land on the islands of Kauai, Oahu, Molokai, Lanai, and Maui (Wagner *et al.* 1990). This species remains on State and private land in Awaawapuhi Valley, Kalalau Beach, and Pohakuao seacliffs on Kauai; at Kaena Point (possibly), and on the slopes above Halona Point on Oahu; near Mokio Point and Manaeopapa on Molokai; Maunalei Valley on Lanai; and on West Maui (USFWS *in litt.* 1997; R. Hobdy, personal communication 1997; Christa Russell, USFWS, personal communication 1997; Wesley Wong, Jr., DOFAW, *in litt.* 1998).

The 13 currently-known populations contain fewer than an estimated 580 to 2,250 plants (USFWS *in litt.* 1997). Kauai has 3 known populations of fewer than 100 individuals, about 4 miles (6 kilometers) apart. West Maui has 1 population between Waihee and Makamakaole, 1 population of 1 individual at Makamakaole, 1 population with an unknown number of individuals at Puu Koae, 1 population of 104 individuals at

Pohakupule, 1 population of 1,636 individuals at Kahakulao, and 1 population of 192 individuals at Mokulea (Art Medeiros, BRD, personal communication 1999; W. Wong, Jr. *in litt.* 1998). Oahu has 1 population consisting of 500 individuals; Molokai has 2 populations with at least 2 individuals; and Lanai has 1 population with approximately 23 individuals.

d. Life History

Centaurium sebaeoides has been observed flowering in April. Flowering may be induced by heavy rainfall. Populations are found in dry areas, and plants are more likely to be found following heavy rains (USFWS 1995).

e. Habitat Description

Centaurium sebaeoides typically grows in volcanic or clay soils or on cliffs in arid coastal areas below 120 meters (400 feet) elevation (USFWS 1995; Wagner *et al.* 1990). Associated species include *Bidens* sp. (kookoolau) and *Lipochaeta* sp. (nehe) (USFWS 1995).

f. Reasons for Decline and Current Threats

The major threats to *Centaurium sebaeoides* are habitat degradation by feral goats and cattle; competition from the alien plant species, koa haole; trampling by humans on or near trails; and fire (USFWS 1995). The threats are believed to be similar on Kauai, Oahu, Molokai, and West Maui (USFWS 1995).

f. Conservation Efforts

Seeds from the Oahu population were collected during July 1997 and are stored at the National Tropical Botanical Garden (B. Garnett, personal communication 1997). No other specific recovery actions are known for this plant.

g. Needed Recovery Actions

1) Construct exclosures to protect populations against ungulates.

Exclosures should be constructed around the known populations of *Centaurium sebaeoides* on State and private land to reduce impacts from feral ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Additionally, those populations that have only a few remaining individuals, such as at Mokio Point and Manaeopapa on Molokai should be fenced and protected immediately.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as koa haole needs to be developed. Additionally, populations that have only a few remaining individuals such as those at Mokio Point and Manaeopapa on Molokai should be weeded and protected immediately.

3) Protect endangered plants from fire.

Implement a coordinated effort of fire protection actions for endangered plant species on State and private land where just a few individuals occur.

6. *Cyanea grimesiana* ssp. *grimesiana*

(Hawaiian name: haha) Recovery Priority Number 6

a. Description

Appendix B contains a line drawing of *Cyanea grimesiana* ssp. *grimesiana.*

Cyanea grimesiana ssp. *grimesiana*, a member of the bellflower family (Campanulaceae), is a shrub 1 to 3.2 meters (3.3 to 10.5 feet) tall. The leaves are pinnately divided, with 9 to 12 segments per side. The leaf blades are 27 to 58 centimeters (10.6 to 22.9 inches) long and 14 to 32 centimeters (5.5 to 12.6 inches) wide (across the segments). The inflorescence comprises 6 to 12 flowers. The calyx lobes, 10 to 44 millimeters (0.4 to 2 inches) long and 4 to 14 millimeters (0.2 to 0.55 inch) wide, are egg-shaped to lance-shaped and overlap at the base. The petals are purplish or greenish to yellowish-white, often suffused or striped with magenta, and 55 to 80 millimeters (2 to 3 inches) long. The orange berries are 18 to 30 millimeters (0.7 to 1.2 inches) long.

This species is distinguished from others in this endemic Hawaiian genus by the pinnately lobed leaf margins and the width of the leaf blades. This subspecies is distinguished from the other two subspecies by the shape and size of the calyx lobes which overlap at the base (Lammers 1990).

b. Taxonomy

Cyanea grimesiana ssp. *grimesiana* was collected by Charles Gaudichaud-Beaupré in 1819 on Oahu while he was the pharmaceutical botanist on the vessel "Uranie" (Rock 1919, Wagner *et al.* 1990). Gaudichaud later described this taxon and named it for the French Navy's head pharmacist (Thomas G. Lammers, Field Museum, personal communication 1994). Other published names considered synonymous with *Cyanea grimesiana* ssp. *grimesiana* include *C. grimesiana* var. *lydgatei*, *C. grimesiana* var. *mauiensis*, *C. grimesiana* var. *munroi*, and *C. lobata* var. *hamakuae* (Lammers 1990).

Currently, three subspecies are recognized — the extinct ssp. *cylindrocalyx* (Rock 1917); ssp. *grimesiana*; and the federally endangered ssp. *obatae* (St. John 1978a).

c. Current and Historic Ranges and Population Status

Historically, *Cyanea grimesiana* ssp. *grimesiana* was known from at least 40 populations located in the Waianae and Koolau Mountains on Oahu, Wailau Valley and Puu Kahea on Molokai, central and northern Lanai, and scattered locations on Maui (USFWS 1996a; Heidi Bornhorst, formerly with TNCH, and S. Perlman, *in litt.* 1992).

Currently, *Cyanea grimesiana* ssp. *grimesiana* is known from 14 populations on those 4 islands (USFWS 1996a; H. Bornhorst and S. Perlman, *in litt.* 1992; USFWS *in litt.* 1997). The total current population statewide consists of fewer than 50 individuals (USFWS 1996a; H. Bornhorst and S. Perlman, *in litt.* 1992; USFWS *in litt.* 1997; B. Garnett, personal communication 1997).

On Oahu, the following populations are known from the Waianae Mountain — one population of three individuals from Mt. Kaala Natural Area Reserve, two populations of one individual each from North Haleauau Gulch on the federally owned Schofield Barracks Military Reservation and North Kaluaa Gulch on private land, and perhaps three populations of an unknown number of individuals from the Pahole Natural Area Reserve on State land. The three populations reported from Pahole have not been seen since the late 1970's, and have not been relocated during surveys there over the last year (B. Garnett, personal communication 1997). Two populations are known from Oahu's Koolau Mountains: four individuals in Kului Gulch and three individuals in "Waialae Iki-Kapakahi" on State and private land (USFWS 1996a; H. Bornhorst and S. Perlman, *in litt.* 1992; B. Garnett, personal communication 1997; U.S. Army Garrison Hawaii 1997a).

On Molokai, one population of five individuals is known from Kukuinui Ridge on State land and the other population of two individuals is within the State's Olokui Natural Area Reserve (USFWS 1996a).

On Lanai, one population of an unknown number of individuals from Kaiholena Gulch and one population of two individuals from Waiakeakua are known. Both populations are on private land (USFWS 1996a; USFWS *in litt.* 1997).

On Maui, two populations of an unknown number of individuals are known from Iao Valley on private land. A population previously reported in lower Kipahulu Valley within Haleakala National Park has been determined to be *Cyanea asplenifolia*, based on recently available flowering material (USFWS 1996a; L. Loope, *in litt.* 1995; A. Medeiros, personal communication 1995).

d. Life History

Little is known about the life history of this plant. On Molokai, flowering plants have been reported in July and August. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Cyanea grimesiana ssp. *grimesiana* is typically found in mesic forest often dominated by ohia or ohia and koa, or on rocky or steep slopes of stream banks, at elevations between 350 and 945 meters (1,150 and 3,100 feet). Associated plants include *Antidesma* sp. (hame), *Bobea* sp. (ahakea), *Myrsine* sp. (kolea), olopua, *Psychotria* sp. (kopiko), *Xylosma* sp. (maua), and various native and alien ferns (USFWS 1996a; H. Bornhorst and S. Perlman, *in litt.* 1992).

f. Reasons for Decline and Current Threats

The major threats to *Cyanea grimesiana* ssp. *grimesiana* are habitat degradation and/or destruction caused by wild and feral ungulates (axis deer, goats, and pigs); competition with various alien plants; and randomly naturally occurring events causing extinction due to the small number of existing individuals. Fire threatens the Oahu populations of *Cyanea grimesiana* ssp. *grimesiana* on Mt. Kaala and Pahole Natural Area Reserves. Potential overcollection, trampling by hikers and/or military activities threaten the Palikea population on Oahu. The Oahu populations are also threatened by landslides (USFWS 1996a; H. Bornhorst and S. Perlman, *in litt.* 1992; B. Garnett, personal communication 1997; Loyal Mehrhoff, USFWS, personal communication 1995). Potential threats include rats (*Rattus* spp.), which are known to eat the fruits and girdle the stems of species in the bellflower family, and various slugs that feed on the stems of species in the bellflower family (Marie Bruegmann, USFWS, personal communication 1997).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, personal communication 1998). When they are implemented, actions outlined in the Report may enhance conservation of *Cyanea grimesiana* ssp. *grimesiana* plants growing on the Army's Schofield Barracks Military Reservation.

A long-range management plan for the Honouliuli Preserve prescribes actions for alien plant management, ungulate control, fire control, rare species recovery, and native habitat restoration (TNCH 1997). It is expected that these actions will benefit *Cyanea grimesiana* ssp. *grimesiana* within the Preserve.

Cyanea grimesiana ssp. *grimesiana* has been successfully propagated and outplanted at the Lyon Arboretum and at the Division of Forestry and Wildlife's Pahole Plant Nursery (Koob 1997; B. Garnett, personal communication 1997; G. Koob, personal communication 1997). More than 1,000 seeds are in storage at the National Tropical Botanical Garden (M. Chapin, personal communication 1997). No other specific recovery actions are known for this plant.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral and wild ungulates.

Exclosures should be constructed around the known populations on Federal, State, and private land to reduce impacts from feral and wild ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. A commitment should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as Christmas berry, strawberry guava, clidemia, lantana, and thimbleberry should be developed. Additionally, those populations that consist of only one remaining individual, such as at North Haleauau Gulch and North Kaluaa Gulch, should be weeded and protected immediately.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from populations that have only one remaining individual, such as at North Haleauau Gulch and North Kaluaa Gulch.

4) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining *in situ* populations by outplanting should begin when adequate propagated material is available, after weed control begins and the populations have been protected from ungulates. New populations should be started within the historic range of *Cyanea grimesiana* ssp. *grimesiana* in areas free from the impacts of ungulates, alien plants, and, on Oahu, natural events such as landslides.

5) Protect endangered plants from fire.

A coordinated effort of fire protection actions for endangered plant species on State natural area reserves, such as Pahole and Mt. Kaala on Oahu where fewer than 10 individuals of *Cyanea grimesiana* ssp. *grimesiana* occur, should be instigated.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

7. *Cyperus trachysanthos*
(Hawaiian name: puukaa) Recovery Priority Number 2

a. Description

Appendix B contains a line drawing of *Cyperus trachysanthos*.

Cyperus trachysanthos, a member of the sedge family (Cyperaceae), is a perennial grass-like plant with a short rhizome (underground stem). The culms (aerial stems) are densely tufted, obtusely triangular in cross section, 20 to 45 centimeters (8 to 18 inches) tall, sticky, and leafy at the base. The linear leaf blades are green, covered with a waxy coating, and somewhat leathery. The leaf sheath is yellowish brown and partitioned with nodes. The flower clusters are 5 to 9 centimeters (2 to 3.5 inches) long and 6 to 12 centimeters (2 to 5 inches) wide. Each flower head contains 10 to 30 pale, yellowish-brown spikelets, each of which contains 8 to 20 flowers. The glumes (small pair of bracts at the base of each spikelet) are broadly egg-shaped. The fruit is a dark-brown, egg-shaped achene. This species is distinguished from others in the genus by the short rhizome, the leaf sheath with partitions at the nodes, the shape of the glumes, and the length of the culms (Koyama 1990).

b. Taxonomy

First collected by Chamisso between 1816 and 1817 in the "Sandwich Islands," *Cyperus trachysanthos* was described by William J. Hooker and G. A.W. Arnott in 1832 (Hillebrand 1888, Mill *et al.* 1988). This species has been maintained in the most recent treatment of Hawaiian members of the genus (Koyama 1990). The specific epithet refers to the rough or papery flowers.

c. Current and Historic Ranges and Population Status

Historically *Cyperus trachysanthos* was known from Niihau, Kauai, scattered locations on Oahu, Mauna Loa on Molokai, and Kaena on Lanai (USFWS 1996a). Currently this species is known from 8 populations with a total of 517 or more individuals on Niihau, Kauai, and Oahu (USFWS 1996a; M. Bruegmann, 1997; Carolyn Corn, formerly with DOFAW, personal communication 1997; D. Hopper and Chris Swenson, USFWS, personal communications 1997). On privately-owned Niihau, an unknown number of individuals are known from an area west of Mokouia Valley (USFWS 1996a). On Kauai, more than 300 individuals are known from State land in the Nualolo Valley. On Oahu, 5 individuals are known from the Kaena Point Natural Area Reserve, 110 individuals are known from and scattered nearby Manini Gulch, 38 individuals are known from State land at Diamond Head, 37 to 39 individuals are reported at Makapuu, 3 individuals are reported at Queens Beach, and about 24 individuals are reported from the Kawainui Marsh area (M. Bruegmann, *in litt.* 1997; C. Corn, personal communication 1997; D. Hopper and C. Swenson, personal communications 1997; USFWS 1996a).

d. Life History

Little is known about the life history of this species. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Cyperus trachysanthos is usually found in wet sites (mud flats, wet clay soil, or wet cliff seeps) on coastal cliffs or talus slopes at elevations between 3 and 160 meters (10 and 525 feet) (Koyama 1990; USFWS 1996a). On Kauai, associates include *Hibiscus tiliaceus* (hau), *Plantago lanceolata* (narrow-leaved plantain), and *Pteris vittata* while in Diamond Head, *Cyperus trachysanthos* is found in association with koa haole, kiawe, *Brachiaria mutica* (California grass), *Ammania auriculata*, *Lythrum maritimum*, and *Leonotis nepetifolia* (lion's tail) (D. Hopper, personal communication 1997).

f. Reasons for Decline and Current Threats

Cyperus trachysanthos risks extinction from naturally occurring events due to the small number of populations and, on Oahu, competition with alien plants, fire, and off-road vehicles. The population in Diamond Head may also potentially be threatened by pumping of the wetland for flood and mosquito control, modifications to the wetland topography, mowing and herbicide application, and run-off from nearby Hawaii Army National Guard (HIARNG) activities such as the cleaning of vehicles, dumping of paints or thinners, or the use of pesticides (USFWS 1996a; C. Corn, personal communication 1997; D. Hopper, personal communication 1997).

g. Conservation Efforts

In 1995, HIARNG funded the U.S. Fish and Wildlife Service to conduct endangered species surveys of its lands throughout the State. Recommendations for management of endangered species on these lands, including *Cyperus trachysanthos*, are included in the final report entitled "Endangered and Rare Species Surveys and Management Recommendations for Hawaii Army National Guard Lands on the Island of Oahu" (USFWS 1998). Management recommendations for the endangered *Cyperus trachysanthos* in Diamond Head include weed control, deterrents to vehicle access, modification of mowing and herbicide application regimes, modification of water pumping regime, a documented protocol for contaminant spill cleanup, *ex situ* propagation, and enhancement of the existing population (USFWS 1998). The State has constructed barriers to off-road vehicle traffic in Kaena Point Natural Area Reserve, which may protect the population there.

Cyperus trachysanthos has been successfully cultivated at the National Tropical Botanical Garden, where more than 3,000 seeds are in storage (M. Chapin, personal communication 1997).

No other specific recovery actions are known for this plant.

h. Needed Recovery Actions

1) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued.

2) Enhance wild populations and establish new populations.

Once adequate propagated material is available and weed control is underway in the areas of the remaining *in situ* populations, outplanting to enhance the remaining wild populations by should occur. New populations should be established within the historic range of *Cyperus trachysanthos*, in areas free from the impacts of alien plants.

3) Control competing alien plant species.

Develop and implement a long-range management plan to control alien plants such as Guinea grass, koa haole, kiawe, and California grass.

4) Protection from fire.

Management actions to protect endangered species such as *Cyperus trachysanthos* from fire should be developed for areas where fire is known to be a threat to individuals that occur there, such as at Kaena Point and nearby.

5) Protect plants from off-road vehicles.

Fences or other vehicle obstruction devices are needed to prevent vehicle impact to the plants outside the Kaena Point Natural Area Reserve and the population at Makapuu.

6) Implement management recommendations for the Diamond Head population.

Management recommendations may include weed control, deterrents to vehicle access, modification of mowing and herbicide application regimes, modification of water pumping regime, a documented protocol for contaminant spill cleanup, *ex situ* propagation, and enhancement of the existing population.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

8. *Diellia erecta*
(No common name) Recovery Priority Number 2

a. Description

No line drawing is available for this plant.

Diellia erecta, a member of the spleenwort family (Aspleniaceae), is a fern that grows in tufts of 3 to 9 lance-shaped fronds, each 20 to 70 centimeters (8 to 28 inches) long. The fronds emerge from a 1- to 2.5-centimeter (0.4- to 1-inch) long rhizome covered with brown to dark gray scales. The frond stalks are reddish brown to black and smooth and glossy, 2 to 21 centimeters (0.8 to 8.3 inches) long, and have a few stiff scales at their bases. Each frond has 15 to 50 lance-shaped pinnae arranged oppositely along the midrib. The pinnae are usually between 2 and 4 centimeters (0.8 and 1.6 inches) long and 4 to 8 millimeters (0.2 to 0.3 inch) wide. Ten to 20 sori, which may be separate or fused, are borne on each margin of the pinna. Each sorus is covered by an indusium (protective membrane) that falls short of the edge of the frond and runs parallel to the edge of each pinna. This species differs from other members of the genus in having brown or dark gray scales usually more than 2 centimeters (0.8 inch) in length, fused or separate sori along both margins, shiny black midribs that have a hardened surface, and veins that do not usually encircle the sori (Degener and Greenwell 1950, Hillebrand 1888, Robinson 1912, Smith 1934, Wagner 1952).

b. Taxonomy

Diellia erecta (NCN) was described by William Dunlop Brackenridge based on a specimen collected during the Wilkes Expedition in 1840 (Brackenridge 1854). He also described *Diellia pumila*, which subsequently has been considered a depauperate form of *Diellia erecta*. *Davallia alexandri* was published by Hillebrand in 1873. It has subsequently been considered a form of *D. erecta* with finely dissected fronds. *Diellia erecta* and *Davallia alexandri* had been placed in the genus *Lindsaya* by certain early authors, and *Diellia erecta* had been placed in the genus *Schizoloma* by other authors. Degener and Amy B. Greenwell (1950) published the new combination *Diellia erecta* var. *falcata* for what Brackenridge had originally described as *Diellia falcata*. Further study has since established that *Diellia falcata* is best considered a separate species, so *Diellia erecta* is now considered to be a species with no subspecific taxa (Wagner 1952; Wagner and Wagner 1992).

c. Current and Historic Ranges and Population Status

Historically, *Diellia erecta* was known from the Kokee area on Kauai; the Koolau Mountains on Oahu; Kahuaawi Gulch, Puu Kolekole, Pukoo, Pelekunu Valley, and Kaunakakai Gulch on Molokai; Mahana Valley and Hauola Gulch on Lanai; scattered locations on Maui; and various locations on Hawaii Island (USFWS 1996b, *in litt.* 1997; R. Warshauer, *in litt.* 1996). Currently, *Diellia erecta* is only known from Molokai, Maui, and Hawaii. Statewide, this species has a total of 6 to 7 populations and approximately 34 to 36 known individuals. On Molokai, 1 individual is known from Halawa Valley on private land (USFWS 1996b; R. Hobdy, personal communication

1991). On Maui, a total of at least 12 to 14 individuals occurs at these 3 or 4 locations: on West Maui, an unconfirmed population at Iao Valley on private land, 10 to 12 individuals at Manawainui Plant Sanctuary, and 1 individual at Papalaua Gulch on State land; and on East Maui, 1 individual at Waiopai Gulch on State land (HPCC 1995; Kahikinui Forest Partnership Working Group 1995; USFWS 1996b; R. Hobdy, personal communication 1997). On the island of Hawaii, 2 populations exist on State land: 1 at Honomalino with more than 20 plants and 1 at Manuka Natural Area Reserve with at least 1 plant (USFWS 1996b; R. Warshauer, *in litt.* 1996).

d. Life History

Little is known about the life history of this taxon. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Diellia erecta is found in Lama/Ohia Lowland Mesic Forest at elevations between 210 and 1,590 meters (700 and 5,200 feet) (HPCC 1995; USFWS 1996b; R. Warshauer, *in litt.* 1996). Other associated plant species include *Coprosma* sp. (pilo), aalii, *Dryopteris unidentata*, *Myrsine* sp. (kolea), *Psychotria* sp. (kopiko), *Pleomele auwahiensis* (halapepe), *Syzygium sandwicensis* (ohia ha), and *Wikstroemia* sp. (akia) (HINHP 1995; HPCC 1995; USFWS 1996b).

f. Reasons for Decline and Current Threats

The major threats to *Diellia erecta* are habitat degradation by pigs, goats, and cattle; competition with alien plant species, including *Blechnum occidentale*; and random naturally occurring events causing extinction due to the small number of existing individuals (USFWS 1996b).

g. Conservation Efforts

A fence, built in the 1980's, protects the population of *Diellia erecta* in the Manawainui Plant Sanctuary. The Native Hawaiian Plant Society conducts periodic weeding at this site (R. Hobdy, personal communication 1997).

An unspecified number of spores are in storage at the National Tropical Botanical Garden (M. Chapin, personal communication 1997). No other specific conservation actions are known for this species.

h. Needed Recovery Actions

Diellia erecta is expected to recover rapidly with implementation of recovery actions controlling its major threats (M. Bruegmann, personal communication 1996). The most important actions will be to:

1) Construct exclosures to protect populations against ungulates.

Exclosures should be constructed around the known populations of *Diellia erecta* on State and private land to reduce impacts from ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. A commitment should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as Christmas berry, strawberry guava, and molasses grass should be developed. Additionally, populations that have only one remaining individual, such as those at Papalaua Gulch on Maui and Halawa Valley on Molokai should be weeded and protected immediately.

3) Maintain adequate genetic stock.

Ex situ propagation should be initiated to prevent extinction of this species (M. Buck, *in litt.* 1996). Propagation material should be collected immediately from populations that have few individuals such as at Papalaua Gulch on Maui and Halawa Valley on Molokai.

4) Enhance wild populations and establish new populations.

Outplantings to enhance the remaining wild populations should begin when adequate propagated material is available, and after fencing of the populations and weed control are underway. New populations should be established within the historic range of *Diellia erecta* in areas free from the impacts of alien plants and ungulates.

9. *Euphorbia haeleeleana*

(No common name) Recovery Priority Number 5

a. Description

Appendix B contains a line drawing of *Euphorbia haeleeleana.*

Euphorbia haeleeleana, a member of the spurge family (Euphorbiaceae), is a dioecious (female and male flowers on separate plants) tree 3 to 14 meters (10 to 46 feet) tall. The alternate leaves are papery in texture, elliptic, and usually 10 to 15 centimeters (4 to 6 inches) long and 4 to 6 centimeters (2 inches) wide. Male trees bear many small male flowers within a cyathium (a compact inflorescence with small individual flowers). The female trees have cyathia with a single female flower surrounded by numerous abortive male flowers. The capsules (dry fruit that open at maturity) are round. This species is distinguished from others in the genus in that it is a tree, whereas most of the other species are herbs or shrubs, as well as by the large leaves with prominent veins (Wagner *et al.* 1990).

b. Taxonomy

In 1970, Steven Montgomery and the late Wayne Gagné collected a specimen of an unidentified tree in Mahanaloa Valley on Kauai. The following year, Derral Herbst (1971) described it as *Euphorbia haeleeleana*, naming it for another valley where the plant grows. This species has been maintained in the most recent treatment of Hawaiian members of the genus (Wagner *et al.* 1990).

c. Current and Historic Ranges and Population Status

Euphorbia haeleeleana is known historically and currently from 15 populations and between 450 and 625 individuals from northwestern Kauai and the Waianae Mountains of Oahu (USFWS 1996a; USFWS *in litt.* 1997). On Kauai, 11 populations of approximately 360 to 510 individuals are known from valley slopes and cliffs along Kauai's northwestern coast from Pohakuao to Haeleele Valley and Hipalau Valley within Waimea Canyon. All of the Kauai populations occur on State land, including Kuia Natural Area Reserve and the Na Pali Coast State Park (USFWS 1996a; S. Perlman, personal communication 1996). On Oahu, 2 populations of approximately 90 to 115 individuals are known from the northern Waianae Mountains. One population of 79 individuals occurs at Keawaula on the Army's Makua Military Reservation, and one population occurs on privately owned land (B. Totten, *in litt.* 1998; USFWS 1996a).

d. Life History

Individual trees of *Euphorbia haeleeleana* bear only male or female flowers, and must be cross-pollinated from a different tree to produce viable seed (Wagner *et al.* 1990). This species sets fruit between August and October (B. Totten, *in litt.* 1998). Little else is known about the life history of this species. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Euphorbia haeleeleana is usually found in lowland mixed mesic or dry forest that is often dominated by ohia, ohia and koa, lama, or *Aleurites moluccana* (kukui). The plant is typically found at elevations between 205 and 670 meters (680 and 2,200 feet), but a few populations have been found up to 870 meters (2,860 feet). Associated plants include aalii, *Erythrina sandwicensis* (wiliwili), *Pleomele* sp. (halapepe), *Reynoldsia sandwicensis* (ohe), and *Sapindus oahuensis* (aulu) (USFWS 1996a).

f. Reasons for Decline and Current Threats

Habitat degradation and/or destruction by wild and feral ungulates including black-tailed deer, goats, and pigs; predation by rats; fire; potential military activities; and competition with alien plants seriously threaten *Euphorbia haeleeleana* (USFWS 1996a; M. Bruegmann, *in litt.* 1994; USFWS *in litt.* 1997; S. Perlman, personal communication 1996).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Euphorbia haeleeleana* plants growing on the Army's Makua Military Reservation. In addition, Army Environmental staff have conducted intensive rat control around the Keawaula population in order to collect mature seed and have propagated plants in their shadehouse (B. Totten, *in litt.* 1998).

Several years ago, the State Division of Forestry and Wildlife constructed a fence enclosing about half the individuals of *Euphorbia haeleeleana* in Mahanaloa Valley on Kauai (M. Bruegmann, personal communication 1997).

Euphorbia haeleeleana has been successfully propagated at the National Tropical Botanical Garden and the Waimea Arboretum. Currently more than 440 seeds are in storage and 16 individuals are in cultivation (M. Chapin, personal communication 1997; D. Orr, personal communication 1997). An unspecified number of seeds are at the Lyon Arboretum (G. Koob, personal communication 1997).

h. Needed Recovery Actions

1) Construct exclosures to protect populations against wild and feral ungulates.

Exclosures should be constructed around the known populations of *Euphorbia haeleeleana* on State, Federal, and private land to reduce impacts from ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Additionally, populations that have only one or two remaining individuals, such as those at Haeleele Valley and Koaie Canyon on Kauai, and Keawaula Gulch on Oahu should be fenced and protected immediately. Once they have been fenced, commitments should be developed for long-term stewardship and conservation of these areas.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as lantana, strawberry guava, silk oak, molasses grass, *Passiflora mollisima* (banana poka), and thimbleberry, should be developed. Additionally, populations that have only a few remaining individuals, such as those at Haeleele Valley and Koaie Canyon on Kauai should be weeded and protected immediately. Weed control is also necessary within existing exclosures, such as in Mahanaloa Valley.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from populations that have few individuals, such as at Haeleele Valley, Kawaiula Valley, Koaie Canyon, and Pohakuao on Kauai, and Kahanahaiki Valley, and Kaumokuiki Ridge on Oahu.

4) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining wild populations should begin when adequate propagated material is available, and after fencing and weed control are underway. New populations should be established within the historic range of *Euphorbia haeleeleana* in areas free from the impacts of ungulates and alien plants.

5) Reduce threat from rats.

The largest population of *Euphorbia haeleeleana* on Oahu is seriously threatened by rat predation. A management plan to control rats should be developed and implemented. This should include the use of the currently approved Diphacinone bait blocks and ultimately a more broad-scale method such as aerial dispersal of rodenticide.

6) Protect endangered plants from fire.

Management actions to protect endangered species such as *Euphorbia haeleeleana* should be implemented by the Army on the Makua Military Reservation, where current ordnance training exercises could unintentionally ignite fires.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

10. *Flueggea neowawraea*

(Hawaiian name: Mehamehame) Recovery Priority Number 5

a. Description

Appendix B contains a line drawing of *Flueggea neowawraea.*

Flueggea neowawraea, a member of the spurge family (Euphorbiaceae), is a large tree up to 30 meters (100 feet) tall and 2 meters (7 feet) in diameter with white oblong pores covering its scaly, pale brown bark. The thin, papery, oval leaves, 4 to 14 centimeters (1.5 to 5.5 inches) long and 2 to 9 centimeters (0.8 to 3.5 inches) wide, are green on the upper surface and pale green on the lower surface. This species is usually dioecious (having separate male and female plants) with unisexual flowers lacking petals. Male flowers, on stalks less than 4 millimeters (0.2 inch) long, have 5 green sepals with brownish tips. The female flowers, on stalks 1 to 2.5 millimeters (0.04 to 0.1 inch) long, have sepals of unequal length with irregular margins. The 2-lobed stigma is positioned atop a 2.5- to 3- millimeter (0.1-inch) long, round ovary with a nectary disk. The fleshy, round fruits, about 5 millimeters (0.2 inch) in diameter, are reddish brown to black and contain 2 slightly curved seeds about 3 millimeters (0.1 inch) long that are somewhat triangular in cross section. This species is the only member of the genus found in Hawaii and can be distinguished from other species in the genus by its large size; scaly bark; the shape, size, and color of the leaves; flowers clustered along the branches; and the size and shape of the fruits (Hayden 1990; Linney 1982; Neal 1965).

b. Taxonomy

In 1912, Joseph F. Rock collected the first specimens of *Flueggea neowawraea* (mehamehame) from Kapua on the island of Hawaii (Rock 1913). Based on his specimens, he described and named the monotypic genus *Neowawraea*, for his colleague Dr. Heinrich W. Wawra. He named the species *Neowawraea phyllanthoides* because of its apparent resemblance to *Phyllanthus*, a member of the same family (Euphorbiaceae). Earl Edward Sherff (1939) later transferred the taxon to the genus *Drypetes*. W. John Hayden (1987), upon further investigation, placed the species in the genus *Flueggea*. The specific epithet could not be retained because it would have resulted in a later homonym, so Hayden chose to maintain the tribute to Wawra in the new epithet, *neowawraea*.

c. Current and Historic Ranges and Population Status

Historically, *Flueggea neowawraea* was known from Waihii near Kapuna on Molokai, but is now presumed extinct on that island (HINHP 1995; Hayden 1990). This species was also known from Kealia Trail, Kahanahaiki Valley, and Pohakea Gulch in the Waianae Mountains of Oahu and from Kauai and Hawaii Islands (HINHP 1995).

Currently, *Flueggea neowawraea* is known from Kauai, Oahu, east Maui, and Hawaii. Statewide, the species totals 34 populations containing approximately 124 to 195 individuals.

On Kauai, *Flueggea neowawraea* from Limahuli Valley, Kalalau, Pohakuao, and from the Koaie and Poomau branches of Waimea Canyon (HINHP 1995; HPCC 1995; S. Perlman and K. Wood, personal communications 1997). Also, 3 individuals (some of which may be dead) are located in the two adjacent valleys of Mahanaloa and Paaiki, near Makaha Point, on State-owned land (HINHP 1995). Only 1 unhealthy individual is known from Limahuli Valley on privately owned land (HINHP 1995). At least 4 trees are known from Kalalau and 10 from Pohakuao on State-owned land (HINHP 1995; J. Lau, personal communication 1992; S. Perlman and K. Wood, personal communications 1997). Sixteen trees are found in the Poomau branch of Waimea Canyon, and 40 to 80 individuals are in 4 scattered populations along the Koaie branch of Waimea Canyon on State-owned land (HINHP 1995; HPCC 1995; J. Lau, personal communication 1992; S. Perlman, personal communication 1996).

On Oahu, *Flueggea neowawraea* is known from 19 locations with approximately 28 to 30 individuals in the Waianae Mountains. The populations are spread from East

Kapuahikahi Gulch to Puumaialau Gulch over a distance of about 15.5 kilometers (9.6 miles) on the Lualualei Naval Reservation, the U.S. Army's Schofield Barracks Military Reservation and Makua Military Reservation, State land, County land, and private land (HINHP 1995; K. Kawelo, personal communication 1997; J. Lau, personal communication 1992; J. Moribe, personal communication 1997).

On East Maui, 1 or 2 individuals are located at Auwahi on the southwest slope of Haleakala at approximately 850 meters (2,800 feet) elevation on privately owned land (HINHP 1995) and at least 1 other individual is east of Auwahi at approximately 730 meters (2,380 feet) elevation on State land (A. Medeiros and L. Loope, *in litt.* 1997).

Five populations are known from the island of Hawaii on State and private land in South Kona and Kau, extending over an area of about 10 by 5 kilometers (6 by 3 miles) from Papa to Manuka, and numbering approximately 20 individuals (HINHP 1995; J. Lau, personal communication 1990). A Hawaii Island population on private land at Huehue Ranch in North Kona consists of an unknown number of individuals (Hayden 1990).

d. Life History

Individual trees of *Flueggea neowawraea* bear only male or female flowers, and must be cross-pollinated from a different tree to produce viable seed (Hayden 1990). Little else is known about the life history of this species. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Flueggea neowawraea occurs in dry to mesic forest at elevations of 250 to 1,000 meters (820 to 3,280 feet) (Hayden 1990). Associated plant species include lama, *Aleurites moluccana* (kukui), *Antidesma pulvinatum* (hame), *Bobea* sp. (ahakea), alahee, olopua, *Rauvolfia sandwicensis* (hao), and *Streblus pendulina* (aiai) (HINHP 1995; S. Perlman, personal communication 1997).

f. Reasons for Decline and Current Threats

The primary threat to the continued existence of *Flueggea neowawraea* is the black twig borer that has affected all known *Flueggea neowawraea* plants (HINHP 1995; USFWS 1996b; M. Bruegmann, personal communication 1997). Other major threats include habitat degradation by feral and wild ungulates (pigs, goats, deer, and cattle), competition with alien plant species, and fire. The small population size with its limited gene pool and depressed reproductive vigor, compounded by a requirement for cross-pollination because the species is dioecious, must be considered a serious threat (USFWS 1996b; S. Perlman, personal communication 1996). Military activities are possible threats at the Lualualei Naval Reservation and the U.S. Army's Schofield Barracks and a demonstrated threat on the Makua Military Reservation. Predation of the fruit by rats is another possible threat (M. Bruegmann, personal communication 1997).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Flueggea neowawraea* plants growing on the Army's Makua Military Reservation and Schofield Barracks Military Reservation. One *Flueggea neowawraea* is within the Kahanahaiki Gulch fenced area on the Makua Military Reservation (K. Kawelo, personal communication 1999). Additionally, a mature plant in Kahanahaiki Gulch was experimentally treated with insecticide to control the black twig borer. If successful, this method could also be applied to other populations of *Flueggea neowawraea* (B. Totten, *in litt.* 1998).

One of the *Flueggea neowawraea* plants on the Navy's Lualualei Naval Reservation has been fenced for protection from cattle and feral pigs. A program of alien plant removal within the exclosure is on-going (J. Moribe, personal communication 1997).

A long-range management plan for the Honouliuli Preserve prescribes actions for alien plant management, ungulate control, fire control, small mammal control, rare species recovery, and native habitat restoration (TNCH 1997). These actions are expected to benefit *Flueggea neowawraea* on the Preserve.

The National Tropical Botanical Garden has more than 2,000 seeds and the Pahole mid-elevation nursery has close to 40 seeds in storage. The National Tropical Botanical Garden has 21 individuals in cultivation, while Pahole has 1 plant in its nursery (M. Chapin, personal communication 1997; B. Garnett, personal communication 1998). Micropropagation has been attempted at the Lyon Arboretum but has not been successful to date (Koob 1997).

No other specific conservation actions are known for this plant.

h. Needed Recovery Actions

1) Conduct further research into, and implement, control methods for the black twig borer.

The black twig borer has been identified as the single most important threat to the continued survival of *Flueggea neowawraea*. All known plants of this species suffer slight to severe defoliation and reduced vigor due to infestations of this alien insect. A number of parasitoids have been introduced to control the beetle, though none of them have become established. Further research on biological control of the beetle will need to proceed cautiously as there are a number of rare native scolytids in Hawaii which are closely related to the black twig borer (P. Conant, personal communication 1997; J. Nakatani, *in litt.* 1996).

If successful, the experimental insecticide treatment to control black twig borer on an individual on the Makua Military Reservation could be applied to other populations.

2) Construct exclosures to protect populations against feral ungulates.

Since most populations of *Flueggea neowawraea* have only one or two remaining individuals, efforts should be made immediately to fence and protect these trees to reduce impacts from feral and wild ungulates on Federal, State, and private land. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

3) Control competing alien plant species.

A long-range management plan to control alien plants such as lantana, strawberry guava, common guava, and Christmas berry should be developed and implemented.

4) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation from several populations should be tried again, though to date it has not been successful. Since most populations of *Flueggea neowawraea* have only one or two remaining individuals, propagation material should be collected from these individuals immediately.

5) Enhance the wild populations and reestablish the plant in its historic range.

Outplanting to enhance the remaining wild populations can begin when adequate propagated material is available, control of the black twig borer has proven successful, and the *in situ* populations have been protected from ungulates. New populations can be established within the historic range of *Flueggea neowawraea* when control of the black twig borer has proven successful in areas free from the impacts of feral and wild ungulates.

6) Cross-pollinate trees to ensure seed set.

Since individual trees of *Flueggea neowawraea* bear only male or female flowers, the flowers must be cross-pollinated from a different tree to produce viable seed (Hayden 1990). Most populations of *Flueggea neowawraea* have only one or two remaining individuals, so specific efforts should be made, when practicable, to hand-pollinate isolated populations.

7) Protect endangered plants from fire.

Management actions to protect endangered species such as *Flueggea neowawraea* should be implemented by the Army on the Makua Military Reservation and the Schofield Barracks Military Reservation, where current ordnance training exercises could unintentionally ignite fires. Coordinated fire protection for endangered plant species should be instigated on State natural area reserves where populations of *Flueggea neowawraea* occur, such as Mt. Kaala and Pahole on Oahu, and Manuka on Hawaii. A fire protection plan is also warranted for endangered plants on the Lualualei Naval Magazine, where five populations occur.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

11. *Hibiscus brackenridgei*

(Hawaiian name: Mao hau hele) Recovery Priority Number 2

a. Description

Appendix B contains a line drawing of *Hibiscus brackenridgei.*

Hibiscus brackenridgei, Hawaii's State flower, a member of the mallow family (Malvaceae), is a sprawling to erect shrub or small tree up to 5 meters (16 feet) tall. Most plant parts (young branches, leaves, and some flower parts) vary in the degree of hairiness. The leaves, about 5 to 15 centimeters (2 to 6 inches) long and equally wide, have 3 to 7 lobes but are generally heart-shaped in outline. Beneath each leaf stalk is a pair of very thin stipules (leaf-like appendages), 5 to 15 millimeters (0.2 to 0.6 inch) long, which fall off early in development, leaving an elliptic scar. Flowers are borne singly or in small clusters. The petals, between 3.5 and 8 centimeters (1.4 and 3.1

inches) long, are yellow, usually with a maroon spot in the center of the flower. Each triangular calyx lobe is reddish to yellow, and usually has a raised, elongated gland on the midrib. Seven to 10 bracts are attached below the calyx. The staminal column, which has anthers attached to the upper three-fourths or nearly to the base, extends beyond the petals. The fruits are somewhat round or oval capsules 1.1 to 2 centimeters (0.4 to 0.8 inch) long, which have a beak-like appendage at one end. This species differs from other members of the genus in having the following combination of characteristics: yellow petals, a calyx consisting of triangular lobes with raised veins and a single midrib often bearing a prominent elongated gland, 7 to 10 bracts attached below the calyx, and thin stipules 5 to 15 millimeters (0.2 to 0.6 inch) long that fall off, leaving an elliptic scar (Bates 1990).

b. Taxonomy

In 1838, Asa Gray described *Hibiscus brackenridgei* from a specimen collected on West Maui (Roe 1961). Then, in 1930, Edward Leonard Caum published two varieties, *molokaiana* and *kauaiana*, based upon type specimens from the islands of Molokai and Kauai. An additional variety, var. *mokuleiana*, was named by Sister Margaret James Roe in 1961. In 1990, David Bates recognized two subspecific taxa: ssp. *mokuleianus* and ssp. *brackenridgei* (including var. *molokaiana*). He placed *Hibiscus brackenridgei* var. *kauaiana* in synonymy with a non-Hawaiian species of *Hibiscus, H. calyphyllus.*

c. Current and Historic Ranges and Population Status

Hibiscus brackenridgei is currently known from Oahu, Lanai, Maui, and Hawaii; it may possibly occur on Kauai. Twelve populations are known to exist, containing a total of approximately 311 to 364 individuals. One population was planted at the Kanepuu Preserve and appears to be reproducing naturally (B. Morgan, *in litt.* 1997). The two recognized subspecies are discussed separately below.

Hibiscus brackenridgei ssp. *brackenridgei* was known historically from Laau Point on Molokai, from scattered locations on Lanai, and from Pohakea Gulch south to near McGregor Point on West Maui (HINHP 1995). *Hibiscus brackenridgei* was also collected from an unspecified site on Kahoolawe (HINHP 1995). However, the specimen is unavailable, and the subspecies was not determined (Bates 1990). Currently, *Hibiscus brackenridgei* ssp. *brackenridgei* consists of about 5 to 8 populations containing probably fewer than 150 individuals on State and private land on the islands of Lanai, Maui, and Hawaii (HINHP 1995; HPCC 1995; S. Bergfeld, personal communication 1997; R. Hobdy, personal communication 1997; J. Lau, personal communication 1992).

On Lanai, only eight or nine wild plants remain, near Keomuku Road at 275 meters (900 feet) elevation on privately owned land (HINHP 1995; HPCC 1995). An unknown number of plants were planted on the Kanepuu Preserve in the 1970's and appear to be reproducing naturally (B. Morgan *in litt.* 1997). Three seedlings are also known to be surviving in a fenced area on the dry plains of Kaena Point (W. Wong, Jr. *in litt.* 1998).

On West Maui, *Hibiscus brackenridgei* ssp. *brackenridgei* is known from two populations occurring at Kaunohua Gulch and the West Maui Natural Area Reserve (HINHP 1995; R. Hobdy, personal communication 1997; J. Lau, personal communication 1992). The Kaunohua Gulch population, numbering fewer than 100 individuals, is found within a fenced area of 5 to 10 square meters (55 to 110 square feet) on privately owned land (HINHP 1995; R. Hobdy, personal communication 1997). The West Maui Natural Area Reserve population, consisting of 2 to 14 individuals, is located in the Lihau section at about 400 meters (1,300 feet) elevation in lowland dry forest on State-owned land (HINHP 1995; R. Hobdy, personal communication 1997; J. Lau, personal communication 1992).

On East Maui, two of the three known populations extend over a 6.25 square kilometer (2.4 square mile) area, numbering no more than 12 to 15 individuals (HINHP 1995; HPCC 1995; R. Hobdy, personal communication 1997). These populations are near Puu o Kali on State-owned land at elevations between 250 and 440 meters (800 and 1,450 feet) (HINHP 1995; R. Hobdy and L. Loope, *in litt.* 1997). An additional population is known from Keokea at elevations between 250 and 390 meters (800 and 1,000 feet) on State-owned land (HINHP 1995).

On the island of Hawaii, *Hibiscus brackenridgei* ssp. *brackenridgei* is known from two populations on State land: 5 plants at Lalamilo on land leased for pasture, and 4 adult plants with close to 100 seedlings at Puu Anahulu (S. Bergfeld, personal communication 1997).

Undocumented observations of *Hibiscus brackenridgei* ssp. *mokuleianus* have been reported from Lihue and Olokele Canyon on Kauai (Bates 1990). On Oahu, *H. b.* ssp. *mokuleianus* was known historically from scattered locations in the Waianae Mountains (HINHP 1995). These scattered populations occurred in the area from which this subspecies is currently known. Scattered within this 12- by 5-kilometer (7.5- by 3-mile) area extending from Puu Pane to Kealia-Kawaihapai are currently three current populations containing between 153 and 203 individuals (J. Lau, personal communication 1997). The northernmost population, consisting of 3 individuals and occupying an area of 10 to 100 square meters (110 to 1,080 square feet), is in the mountains south of the Dillingham Military Reservation at an elevation of 170 meters (560 feet) on privately owned land (HINHP 1995; HPCC 1995). Another population is known from two adjacent gulches between the Dupont Trail and Puu Iki at elevations between 120 and 240 meters (400 and 800 feet) (J. Lau, personal communication 1997). This population on State and privately owned land consists of 150 to 200 individuals (J. Lau, personal communication 1997). A population of *Hibiscus brackenridgei* ssp. *mokuleianus* reported from the Puu Pane area has not been seen for more than 40 years (HINHP 1995).

d. Life History

Hibiscus brackenridgei is known to flower continuously from early February through late May, and intermittently at other times of year. Intermittent flowering may possibly be tied to day length (Keith Wooliams, formerly with the Waimea Arboretum, personal communication 1996). Little else is known about the life history of this plant.

Pollination biology, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Hibiscus brackenridgei occurs in lowland dry to mesic forest and shrubland from 130 to 800 meters (425 to 2,625 feet) in elevation (Geesink *et al.* 1990; HINHP 1995). Associated plant species include aalii, alahee, wiliwili, ohe, and *Sida fallax* (ilima) (HINHP 1995).

f. Reasons for Decline and Current Threats

The primary threats to *Hibiscus brackenridgei* are habitat degradation and possible predation by pigs, goats, axis deer, sheep, and cattle; competition with alien plant species; road construction; fire; and random naturally occurring events causing extinction and/or reduced reproductive vigor due to the small number of populations (J. Lau, personal communication 1997; USFWS 1996b). Predation by rats may also be a potential threat to this species (M. Bruegmann, personal communication 1997). Climate change due to habitat alteration may be a limiting factor (Cliff Smith, University of Hawaii, *in litt.* 1995).

g. Conservation Efforts

Most, if not all, of the Kaunohua Gulch population, numbering fewer than 100 individuals, is in a fenced area maintained by the State Division of Forestry and Wildlife. The Puu Anahulu population, of approximately four individuals, was enclosed by a fence in 1993, also maintained by the State Division of Forestry and Wildlife. Currently only 1 original adult individual remains, though there are close to 100 seedlings (S. Bergfeld, *in litt.* 1996).

Approximately 25 propagated plants of *Hibiscus brackenridgei* ssp. *brackenridgei* were outplanted by the Division of Forestry and Wildlife in the Puuwaawaa/Kaupulehu area before 1993. Some of these plants were burned during the Kaupulehu fire of 1993 but have resprouted from the base, and appear to be thriving (S. Bergfeld, *in litt.* 1996). In 1996, the Division of Forestry and Wildlife fenced five seedlings on dry plains at Kaena Point, Lanai and three seedlings survived to the spring of 1998. These plants may have germinated from long-dormant seeds (W. Wong, Jr., *in litt.* 1998).

In 1994, two propagated plants of *Hibiscus brackenridgei* ssp. *mokuleianus* were outplanted by TNCH on the Honouliuli Preserve in fenced exclosures for protection from ungulates. Weeds, slugs, and rodents are also controlled. Both plants have survived and at least one has flowered (B. Morgan, personal communication 1997).

The Nature Conservancy of Hawaii has implemented a fuel reduction treatment strategy for the Kanepuu Preserve on Lanai that includes mowing the seven distinct fenced units at least once a year (C. Cory, personal communication 1999). In addition, the Kanepuu Preserve fire protection plan is updated each year and incorporates the participation of local, State, and private agencies (A. Remec, personal communication 1999). These actions are expected to enhance conservation of the Preserve's *Hibiscus brackenridgei* ssp. *brackenridgei* plants.

Hibiscus brackenridgei ssp. *brackenridgei* has been successfully propagated (G. Koob, personal communication 1997; D. Orr, personal communication 1997; M. Chapin, personal communication 1997; Winnie Singeo, Honolulu Botanical Gardens, *in litt.* 1999). Plants exist in cultivation at all major facilities. More than 900 seeds of *Hibiscus brackenridgei* ssp. *brackenridgei* are in storage at the National Tropical Botanical Garden (M. Chapin, personal communication 1997). While seed germination tests indicate a germination rate of 30 percent for fresh seeds, no germination of seeds occurred after a minimum of 45 days in storage (Ragone 1993).

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral and wild ungulates.

Exclosures should be constructed around the known, unfenced populations of *Hibiscus brackenridgei* on State and private land to reduce impacts from ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Additionally, populations that have only one or two remaining individuals, such as those at Mahana on Lanai, should be fenced and protected immediately. Once these areas have been enclosed, a commitment should be developed for their long-term stewardship and conservation.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as koa haole, lantana, fountain grass, Christmas berry, *Panicum maximum* (Guinea grass), and *Ricinus communis* (castor bean) should be developed and implemented.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from populations that have few individuals such as at Kaumoku Gulch on Oahu, and Mahana on Lanai.

4) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining wild populations should begin when adequate propagated material is available, and fencing and weed control are underway at the remaining *in situ* populations. New populations should be established within the historic range of *Hibiscus brackenridgei*, in areas free from the impacts of ungulates and alien plants.

5) Protect endangered plants from fire.

Management actions to protect endangered species such as *Hibiscus brackenridgei* from fire should be planned and implemented for areas where fire is known to be a threat, such as at Puu o Kali on Maui.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

12. ***Isodendrion laurifolium***
(Hawaiian name: aupaka) Recovery Priority Number 8

a. Description
Appendix B contains a line drawing of *Isodendrion laurifolium.*

Isodendrion laurifolium, a member of the violet family (Violaceae), is a slender, straight shrub, generally 1 to 2 meters (3 to 6 feet) tall, with few branches. The leaves, 4 to 16 centimeters (2 to 6 inches) long and 1.5 to 5 centimeters (0.6 to 2 inches) wide, are somewhat leathery, oblong-elliptic, narrowly elliptic lance-shaped, or rarely elliptic. The fragrant flowers are perfect and borne singly along the stems. The five petals, which are clawed and somewhat unequal, are purple with greenish white edges externally, and dusty purple on the inner face of the lobe. The fruit is a green, lance-shaped capsule. This species is distinguished from others in this endemic Hawaiian genus by the shape of its leaves (Wagner *et al.* 1990).

b. Taxonomy

Isodendrion laurifolium was first described by Gray in 1852 based on a collection made on Oahu by members of the U.S. Exploring Expedition in 1840 (St. John 1952). Other published names considered synonymous with *Isodendrion laurifolium* are *I.*

forbesii, *I. lydgatei*, *I. subsessilifolium*, and *I. waianaeense* (Wagner *et al.* 1990). The specific epithet refers to the resemblance in the leaves to those of the laurel tree.

c. Current and Historic Ranges and Population Status

Historically, *Isodendrion laurifolium* was known from scattered locations on Kauai and both the Waianae and Koolau mountains of Oahu (USFWS 1996a). Fourteen populations on two islands comprising approximately 190 to 210 individuals are currently known statewide.

On Kauai, approximately 130 to 140 individuals are known from eight populations in the following locations: 5 individuals in Paaiki Valley, about 20 individuals in Kawaiula Valley, 50+ individuals in Haeleele Valley, 40+ individuals in Makaha Valley, 10 to 20 individuals in Poopooiki Valley, 2 individuals in Mahanaloa and Kuia valleys, and 1 individual in the Koaie branch of Waimea Canyon. All Kauai populations are on State-owned land, with several in the Kuia Natural Area Reserve (USFWS 1996a).

On Oahu, approximately 60 to 70 individuals of this species are known from six populations: 40+ individuals in Makaha in the Waianae Mountains on City and County of Honolulu land; 4 individuals in East Makaleha Valley, 2 to 10 individuals in Waianae Kai, 9 individuals in Kaawa Gulch, 6 individuals in Kaumokunui Gulch in the Waianae Mountains on State land (including Mt. Kaala Natural Area Reserve); and 2 individuals in south Kaukonahua Gulch within the federally-owned Schofield Barracks Military Reservation in the Koolau Mountains (U.S. Army Garrison Hawaii 1997; USFWS 1996a).

d. Life History

Little is known about the life history of this plant. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Isodendrion laurifolium is usually found at elevations between 490 and 820 meters (1,620 and 2,700 feet) in diverse mesic forest, or rarely wet forest, dominated by ohia or koa-ohia, or ohia-lama with hame, maua, *Hedyotis terminalis* (manono), *Pisonia* sp. (papala kepau), and *Pouteria* sp. (alaa) (USFWS 1996a; S. Perlman, personal communication 1996).

f. Reasons for Decline and Current Threats

The primary threats to *Isodendrion laurifolium* are habitat degradation by ungulates (black-tailed deer, goats, and pigs), competition with alien plants, and a potential threat from military activities (USFWS 1996a; M. Bruegmann, *in litt.* 1994; S. Perlman, personal communication 1996).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Isodendrion laurifolium* plants growing on the Army's Schofield Barracks Military Reservation.

One individual of *Isodendrion laurifolium* is found in each of two of the State Division of Forestry and Wildlife's fenced exclosures on Kauai in Mahanaloa Valley and Paaiki Valley (M. Bruegmann, *in litt.* 1994).

Isodendrion laurifolium has been successfully propagated at the Lyon Arboretum's micropropagation laboratory (G. Koob, personal communication 1997). Outplanting has been attempted at the National Tropical Botanical Garden but the plants did not survive.

No other specific recovery actions are known for this plant.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral and wild ungulates.

To reduce impacts from ungulates, exclosures should be constructed around the known, unfenced populations of *Isodendrion laurifolium* on Federal, State, and private land. Control or removal of ungulates from these areas, after the exclosures are built, will alleviate their impact on native ecosystems. Additionally, unfenced populations that have only one or two remaining individuals such as at Kaukonahua Gulch on Oahu should be fenced and protected immediately. Once these areas have been enclosed, commitments should be developed for their long-term stewardship and conservation.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as lantana, thimbleberry, strawberry guava, Christmas berry, and clidemia should be developed. Weed control within existing exclosures, such as in Mahanaloa Valley and Paaiki Valley, is also necessary.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from populations that have few individuals — such as at Paaiki Valley and several populations within Waimea Canyon on Kauai; and Waianae Kai, Kaukonahua Gulch, and Makaleha Valley on Oahu.

4) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining wild populations should begin when adequate propagated material is available, and fencing and weed control are underway in the areas of the remaining *in situ* populations. New populations should be established within the historic range of *Isodendrion laurifolium*, in areas free from the impacts of ungulates and alien plants.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

13. *Isodendrion longifolium*
(Hawaiian name: aupaka) Recovery Priority Number 8

a. Description

Appendix B contains a line drawing of *Isodendrion longifolium.*

Isodendrion longifolium, a member of the violet family (Violaceae), is a slender, straight shrub generally 0.6 to 2 meters (2 to 7 feet) tall. The hairless, somewhat leathery leaves are lance-shaped, 10 to 30 centimeters (4 to 12 inches) long, and 3.4 to 6.5 centimeters (1 to 3 inches) wide. The fragrant flowers are perfect and are borne singly along the branches. The five petals are purple, clawed, and somewhat unequal. The purple capsular fruit is 10 millimeters (0.4 inch) long. This species is distinguished from others in this endemic Hawaiian genus by the shape of its leaves (Wagner *et al.* 1990).

b. Taxonomy

Isodendrion longifolium was first collected in 1840 in the "Kaala" [Waianae] Mountains of Oahu by members of the U.S. Exploring Expedition. Gray later named this species for its long leaves (St. John 1952). *Isodendrion christensenii* and

Isodendrion maculatum (St. John 1952, 1978b) are considered synonymous with *Isodendrion longifolium* (Wagner *et al.* 1990).

c. Current and Historic Ranges and Population Status

Historically *Isodendrion longifolium* was known from scattered locations on Kauai and the Waianae Mountains on Oahu (Lorence and Flynn 1991, 1993; USFWS 1996a; Hawaii and Pacific Plants Recovery Coordinating Committee, *in litt.* 1996). Currently *Isodendrion longifolium* is known from 19 populations on Kauai and Oahu. The total current population throughout the State consists of fewer than 1,000 individuals, with most of the populations and individuals occurring on Kauai.

On Kauai, 16 populations totaling 500 to 800 individuals are scattered over ridges and valley slopes of northwestern Kauai: several hundred individuals in Limahuli Valley, about 100 individuals on Mt. Kahili, 3 individuals east of Haupu Peak, an unknown number of individuals in the Iliiliula drainage, 1 individual in the Wainiha-Manoa drainage, 25 individuals near Wainonoia Stream, and several hundred individuals in the Wahiawa Mountains on private land; 1 individual on Hanakapiai-Hoolulu Ridge, 15 to 20 individuals in Hanakapiai, at least 9 individuals in Kawaiula Valley, 10 individuals in Kalalau Valley, 80 to 90 individuals in Waioli Valley, and approximately 20 individuals in Limahuli on State land, which includes the Hono O Na Pali Natural Area Reserve and the Na Pali Coast State Park (Lorence and Flynn 1991, 1993; USFWS 1996a; M. Bruegmann, *in litt.* 1994; S. Perlman, personal communication 1996).

Three populations totaling fewer than 30 to 40 individuals are known from Oahu. Two populations, 1 in Palikea Gulch of an unknown number of individuals and 1 of 25 to 30 individuals in Kaawa Gulch, are found within the Mt. Kaala Natural Area Reserve on State-owned land in the Waianae Mountains, and an unconfirmed specimen was collected in Makaua Gulch in the Koolau Mountains on private or State land (USFWS 1996a; Hawaii and Pacific Plants Recovery Coord. Comm., *in litt.* 1996; J. Lau, personal communication 1997).

d. Life History

Little is known about the life history of this plant. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Isodendrion longifolium is found on steep slopes, gulches, and stream banks in mixed mesic or wet ohia forest, usually at elevations between 410 and 760 meters (1,350 and 2,500 feet). Associated plants include ahakea, hame, *Cyanea* sp. (haha), *Cyrtandra* sp. (haiwale), *Hedyotis* sp. (manono), *Peperomia* sp. (alaala wai nui), *Perrottetia sandwicensis* (olomea), and *Pittosporum* sp. (hoawa), *Psychotria* sp. (kopiko) (Lorence and Flynn 1991, 1993; USFWS 1996a; S. Perlman, personal communication 1996).

f. Reasons for Decline and Current Threats

The major threats to *Isodendrion longifolium* are habitat degradation and/or destruction by feral goats and pigs, and competition with various alien plants. On Oahu, the Palikea Gulch population is potentially threatened by overcollection and fire (Lorence and Flynn 1993; USFWS 1996a; USFWS, *in litt.* 1997).

g. Conservation Efforts

Isodendrion longifolium has been successfully propagated at the Lyon Arboretum's micropropagation laboratory (Koob 1997). Outplanting has been attempted at the National Tropical Botanical Garden but he plants did not survive. No other specific recovery actions are known for this plant.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral ungulates.
Exclosures should be constructed around the known populations of *Isodendrion longifolium* on State and private land to reduce impacts from feral ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Additionally, immediate efforts are needed to fence and protect the unfenced populations with only one or two remaining individuals, such as at Hanakapiai-Hoolulu Ridge on Kauai and Makaua Gulch on Oahu. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

Develop and implement a long-range management plan to control alien plants such as clidemia, thimbleberry, strawberry guava, *Erechtites valerianifolia*, Hilo grass, and lantana.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from populations that have few individuals, such as at Hanakapiai-Hoolulu Ridge on Kauai and Makaua Gulch on Oahu.

4) Enhance wild populations and establish new populations.

Once adequate propagated material is available, and fencing and weed control are underway in the areas of the remaining *in situ* populations, outplanting to enhance the remaining wild populations should begin. New populations should be established within the historic range of *Isodendrion longifolium*, in areas free from the impacts of feral ungulates and alien plants.

5) Protect endangered plants from fire.

Coordinated fire protection is needed for endangered plant species on State natural area reserves, such as Mt. Kaala, where one of three Oahu populations of *Isodendrion longifolium* occurs.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

14. *Mariscus pennatiformis*

(No common name) Recovery Priority Number 5

a. Description

Appendix B contains a line drawing of *Mariscus pennatiformis*.

Mariscus pennatiformis (NCN), a member of the sedge family (Cyperaceae), is a perennial plant with a woody root system covered with brown scales. The stout, smooth, three-angled stems are between 0.4 and 1.2 meters (1.3 and 4 feet) long, slightly concave, and 3 to 7 millimeters (0.1 to 0.3 inch) in diameter in the lower part. The three to five linear, somewhat leathery leaves are 8 to 17 millimeters (0.3 to 0.7 inch) wide and at least as long as the stem. Each flower cluster, umbrella-shaped and moderately dense, is 4 to 15 centimeters (1.5 to 6 inches) long and 5 to 25 centimeters (2 to 10 inches) wide. About 5 to 18 spikes, comprised of numerous spikelets, form each cluster. Each spikelet, measuring about 8 to 14 millimeters (0.3 to 0.6 inch) in length, is yellowish brown or grayish brown and is comprised of 8 to 25 densely arranged flowers. The glumes (bracts beneath each flower), which are less than twice as long as wide, are spreading and overlap tightly. The lowest glume does not overlap the base of the uppermost glume.

This species differs from other members of the genus by its three-sided, slightly concave, smooth stems; the length and number of spikelets; the leaf width; and the length and diameter of stems. The two subspecies are distinguished primarily by larger and more numerous spikelets, larger achenes (dry, one-seeded fruits), and more overlapping and yellower glumes in ssp. *pennatiformis* as compared with ssp. *bryanii* (Koyama 1990).

b. Taxonomy

In 1931, the name *Cyperus pennatiformis* was published by Georg Kukenthal based on a specimen collected from Hana on Maui (Christophersen and Caum 1931). He also described a variety of the species, variety *bryanii*, for plants collected from the Northwestern Hawaiian Island of Laysan. Tetsuo Koyama moved the species into the genus *Mariscus* and maintained the two subspecific taxa, preferring to call them subspecies rather than varieties (Wagner *et al.* 1989).

c. Current and Historic Ranges and Population Status

Historically, *Mariscus pennatiformis* ssp. *pennatiformis* was known from six populations, on Kauai at Halemanu in Kokee State Park, on Oahu in the Waianae Mountains on a ridge above Makaha Valley, on East Maui at Keanae Valley, Hana, and Nahiku, and on the island of Hawaii at an unspecified location (HINHP 1995). Only one population has been seen in the last 70 years, when an unknown number of plants were seen sometime in the 1970's in Keanae Valley (HINHP 1995; Roy Kam, Hawaii Natural Heritage Program, personal communication 1997).

Mariscus pennatiformis ssp. *bryanii* is known only from Laysan Island in the Hawaiian Islands National Wildlife Refuge. This subspecies was found until recently on the southeast end of the central lagoon, and the west and northeast sides of the island on sandy substrate at an elevation of 5 meters (16 feet) (HINHP 1995; Koyama 1990). The population has fluctuated from as many as 200 to as few as 1 individual over the past 10 years. Currently, only 1 population of about 200 individuals remains on the southeast end of the lagoon (Elizabeth Flint, USFWS, personal communication 1997).

d. Life History

Individuals of *Mariscus pennatiformis* ssp. *bryanii* on Laysan Island have been closely monitored for 10 years, but flowering was never observed until the continuous flowering of one individual from November 1994 to December 1995 (M. Bruegmann, personal communication 1995). This flowering event coincided with record high rainfall on Laysan (M. Bruegmann, personal communication 1995). Little else is known about the life history of this plant.

Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown for *Mariscus pennatiformis* ssp. *pennatiformis*.

e. Habitat Description

Populations of *Mariscus pennatiformis* ssp. *pennatiformis* were reported on open sites in mesic forests and low elevation grasslands from sea level to 1,200 meters (3,900 feet) in elevation while *Mariscus pennatiformis* ssp. *bryanii* is found on coastal sandy substrate at an elevation of 5 meters (16 feet). Associated species include *Cyperus laevigatus* (makaloa), kawelu, and *Ipomoea* sp. (HINHP 1995; Koyama 1990).

f. Reasons for Decline and Current Threats

The initial decline of *Mariscus pennatiformis* ssp. *bryanii* was probably caused by the release of rabbits on Laysan Island, and subsequent destruction of almost all of the island's vegetation (M. Bruegmann, personal communication 1995). Causes of the recent decline and current threats to *Mariscus pennatiformis* ssp. *bryanii* are unclear, but seed predation by the endangered Laysan finch (*Telespiza cantans*) is a probable threat since the finches have been observed feeding on the seeds, and destruction of the remaining individuals during burrowing activities of nesting seabirds is also a possible threat (M. Bruegmann, personal communication 1995). The native beach morning glory

(*Ipomoea pes-caprae*) is another possible threat since it periodically grows over the *Mariscus* individuals (Jeff Marks, USFWS, personal communication 1995).

Threats are unknown for *Mariscus pennatiformis* ssp. *pennatiformis* which was last seen in the wild in the 1970's. Threats to the historical locations for this subspecies include grazing and habitat degradation caused by ungulates; competition for light, water, space, and nutrients from a variety of alien plant species; and fire (USFWS 1996b).

The small number of individuals and only two known wild populations of *Mariscus pennatiformis* make this species vulnerable to random naturally occurring events causing extinction and/or reduced reproductive vigor.

g. Conservation Efforts

Mariscus pennatiformis ssp. *pennatiformis* existed in cultivation at the Maui Zoological and Botanical Gardens, according to an unconfirmed report. Since the gardens were closed to the public in early 1997, the current status of this subspecies in the gardens is unknown (Richard Nakagawa, DOFAW, personal communication 1997). The cultivated plants were originally from Nahiku, East Maui (J. Davis and R. Silva, Maui Zoological and Botanical Gardens, *in litt.* 1978).

Seeds from a single flowering individual of *Mariscus pennatiformis* ssp. *bryanii* were collected by U.S. Fish and Wildlife Service personnel in October 1994 and propagated at the University of Hawaii's Lyon Arboretum and at the Waimea Arboretum (Koob 1997; M. Bruegmann, *in litt.* 1994; D. Orr, personal communication 1997). Currently, 219 individuals are in cultivation at the Lyon and Waimea Arboretums (G. Koob, personal communication 1997; D. Orr, personal communication 1997). Reintroduction of cultivated individuals has been considered, but a method to keep the plants healthy during the long sea voyage has not yet been developed (M. Bruegmann, personal communication 1995).

U.S. Fish and Wildlife Service personnel on Laysan Island have begun an ongoing monitoring and protection program for the current wild individuals, which includes bagging of the seed heads to prevent Laysan finch predation (J. Marks, *in litt.* 1995).

Mature seed has also been spread in suitable areas, but no germination has occurred (M. Bruegmann, personal communication 1995). Control of beach morning glory is conducted when it begins to cover the *Mariscus* plants, and a Laysan albatross (*Diomedea immutabilis*) chick was relocated when it began to tear pieces from a *Mariscus* individual (J. Marks, *in litt.* 1995). Most of the individuals have been enclosed by a small fence erected to prevent albatrosses from trampling the plants (E. Flint, personal communication 1997).

h. <u>Needed Recovery Actions</u>

The most important recovery actions for *Mariscus pennatiformis* ssp. *pennatiformis* are:

1) Conduct surveys.

Surveys to determine if there are additional extant wild populations of this plant should be conducted in appropriate habitat in historical locations on Kauai, Oahu, and Maui.

2) Maintain adequate genetic stock.

To prevent extinction of this plant, *ex situ* propagation should be initiated immediately if extant individuals are found.

3) Enhance wild populations and establish new populations.

Outplanting to enhance these populations should begin when adequate propagated material is available, and fencing and weed control, as appropriate, are underway. New populations should be established within the historic range of *Mariscus pennatiformis* ssp. *pennatiformis*, in areas free from the impacts of ungulates and alien plants.

Recovery actions for *Mariscus pennatiformis* ssp. *bryanii* should include:

1) Protect plants from Laysan finch predation and seabird roosting/nesting.

Bagging of seed heads has been partially successful, but some seed heads have suffered molding as a result. Other methods of protecting the plants should be devised that will keep out Laysan finches and discourage roosting and/or nesting of seabirds in the immediate area (M. Bruegmann, personal communication 1995).

2) Protect plants from burrowing seabirds.

Protection from burrowing seabirds should also be implemented, possibly through sturdy wire mesh covering the ground for 3 meters (10 feet) around each plant (M. Bruegmann, personal communication 1995).

3) Re-establish populations into historic range.

New populations should be established within the historic range of *Mariscus pennatiformis* ssp. *bryanii.*

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

15. *Neraudia sericea*
(Hawaiian name: Maaloa) Recovery Priority Number 5

a. Description

No line drawing is available for this plant.

Neraudia sericea, a member of the nettle family (Urticaceae), is a 3- to 5-meter- (10- to 16-foot) tall shrub with densely hairy branches. The elliptic or oval leaves are between 4.3 and 13 centimeters (1.7 and 5.1 inches) long and have smooth margins or slightly toothed margins on young leaves. The upper leaf surface is moderately hairy and the lower leaf surface is densely covered with irregularly curved, silky gray to white hairs up to 1 millimeter (0.04 inch) long along the veins. The male flowers may be stalkless or have short stalks. The female flowers are stalkless and have a densely hairy calyx that is either toothed, collar-like, or divided into narrow unequal segments. The fruits are 1 millimeter (0.04 inch) long achenes with the apical section separated from the basal portion by a deep constriction. Seeds are oval with a constriction across the upper half. *Neraudia sericea* differs from the other four closely related species of this endemic Hawaiian genus by the density, length, color, and posture of the hairs on the lower leaf surface and by its mostly entire leaf margins (Wagner *et al.* 1990).

b. Taxonomy

The name *Neraudia sericea* (maaloa) was published by Gaudichaud-Beaupré in 1851 (Cowan 1949). In 1888, Hillebrand reduced it to a variety of *N. melastomaefolia* (*N. melastomaefolia* var. *sericea*). He also described a new species, *N. kahoolawensis*, named from a specimen collected by J. M. Lydgate on the island of Kahoolawe. In the most current treatment (Wagner *et al.* 1990), the reduction of *N. sericea* to a variety of *N. melastomaefolia* is not accepted and *N. kahoolawensis* is considered a Kahoolawe population of *N. sericea*.

c. Current and Historic Ranges and Population Status

Neraudia sericea was known historically from Kamalo and near Waianui on Molokai, from Kaiholena on central Lanai, Olowalu Valley on West Maui, the southern slopes of Haleakala on East Maui, and from an unspecified site on Kahoolawe (HINHP 1995). Currently, three populations of this species are known, from the slopes below Puu Kolekole on Molokai (specifically along the bottom and lower slopes of Makolelau Gulch on private land); from Pohakea Gulch on West Maui on private land; and two individuals in the Kahikinui area, East Maui (on State land) (HINHP 1995; M. Bruegmann, *in litt.* 1995; A. Medeiros, *in litt.* 1995). The Makolelau population contains an estimated 50 to 100 individuals in an area of over 100 square meters (1,080 square feet) (HINHP 1995). The population size of the Pohakea population is undetermined (HINHP 1995).

d. Life History

Little is known about the life history of this species. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Neraudia sericea generally occurs in lowland dry to mesic Ohia/Aalii/ *Styphelia tameiameiae* (pukiawe) shrubland or forest at elevations between 670 and 1,370 meters (2,200 and 4,500 feet) (HINHP 1995; Wagner *et al.* 1990). Other associated plant species include ilima, lama, *Bobea* sp. (ahakea), *Coprosma* sp. (pilo), *Hedyotis* sp. (manono), as well as the endangered *Clermontia lindseyana*, *Phlegmariurus mannii* (listed as *Lycopodium mannii*), and *Phyllostegia mollis*, and several species of concern — *Cyrtandra oxybapha*, *Hillebrandia sandwicensis*, *Ranunculus hawaiiensis*, and *Rubus macraei* (HINHP 1995; M. Bruegmann, *in litt.* 1995; A. Medeiros, *in litt.* 1995).

f. Reasons for Decline and Current Threats

The primary threats to *Neraudia sericea* are habitat degradation by feral pigs and goats; competition with molasses grass; fire, especially on Molokai and at sites with molasses grass (L. Pratt, *in litt.* 1995; USFWS 1996b); and random naturally occurring events causing extinction and/or reduced reproductive vigor due to the small number of existing populations and individuals (USFWS 1996b). In addition, the population in the Kahikinui area, East Maui, is potentially threatened by feral cattle (A. Medeiros, *in litt.* 1995).

g. Conservation Efforts

More than 1,000 seeds are in storage at the National Tropical Botanical Garden (M. Chapin, personal communication 1997). Seed germination tests show a germination rate of only 2 percent for fresh seeds, and no germination of seeds occurred after a minimum of 45 days in storage (Ragone 1993).

No other specific conservation actions are known for this species.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral ungulates.

Exclosures should be constructed around the known populations of *Neraudia sericea* to reduce impacts from feral ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as molasses grass should be developed.

3) Protect endangered plants from fire.

Management actions to protect endangered species such as *Neraudia sericea* from fire should be developed for areas such as Makolelau Gulch where fire is known to be a threat to individuals occurring there.

4) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from populations that have only one or two individuals, such as at Kahikinui.

5) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining wild populations should begin when adequate propagated material is available, and fencing and weed control are underway. New populations should be established within the historic range of *Neraudia sericea*, in areas free from the impacts of feral ungulates and alien plants.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

16. *Panicum niihauense*

(Hawaiian name: lauehu) Recovery Priority Number 2

a. Description

No line drawing is available for this plant.

Panicum niihauense, a member of the grass family (Poaceae), is a perennial bunchgrass with unbranched culms (stems) 50 to 125 centimeters (20 to 49 inches) long. The leaf blades are flat, 15 to 35 centimeters (6 to 14 inches) long and 0.7 to 1.9 centimeters (0.3 to 0.7 inch) wide. The panicles (loosely branched inflorescences) are 13 to 35 centimeters (5 to 14 inches) long. The panicle branches lie close to the main stem of the inflorescence (not spreading outward), and the spikelets are borne densely along the inflorescence branches. The spikelets, which contain two flowers, are 2.6 to 3.2 millimeters (0.1 inch) long. This species is distinguished from others in the genus by the shape of the inflorescence branches, which are erect and appressed, and the arrangement of the spikelets, which are densely clustered (Davidse 1990).

b. Taxonomy

In 1912, J.F. Stokes collected a grass on Niihau that St. John later named *Panicum niihauense* (St. John 1931). This species has been maintained in the most recent treatment of Hawaiian members of the genus (Davidse 1990).

c. Current and Historic Ranges and Population Status

Panicum niihauense was known historically from Niihau, where it was last collected in 1949, and one location on Kauai (USFWS 1996a). Currently this species is only known from 23 individuals on State-owned land at the Polihale State Park on Kauai.

d. Life History

Little is known about the life history of this species. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Individuals of the single population are found scattered in sand dunes in a coastal shrubland at between 9 and 15 meters (30 and 50 feet) elevation. Associated plants include aalii, *Cassytha filiformis* (kauna oa pehu), kiawe, *Scaevola sericea* (naupaka), ilima, and *Vitex* sp. (kolokolo kahakai) (USFWS 1996a).

f. Reasons for Decline and Current Threats

The primary threats to the single known population of *Panicum niihauense* are off-road vehicles, competition with alien plants, and a risk of extinction from naturally occurring events and/or reduced reproductive vigor due to the small number of individuals in the one remaining population (USFWS 1996a; S. Perlman, personal communication 1996).

g. Conservation Efforts

More than 3,000 seeds of *Panicum niihauense* are in storage at the National Tropical Botanical Garden. No plants are in cultivation there (M. Chapin, personal communication 1997).

No other specific conservation actions are known for this grass.

h. Needed Recovery Actions

1) Construct exclosure to protect population against off-road vehicular traffic.

The plants at the Polihale State Park are being impacted by off-road vehicle traffic. A fence is needed to protect them, or other vehicle-obstruction devices to prevent vehicular access to their dune habitat.

2) Control alien plants.

A long-range management plan to control alien plants such as kiawe, *Atriplex semibaccata* (Australian saltbush), and koa haole needs to be developed. Also, a commitment needs to be developed for long-term stewardship and conservation of the remaining population.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be initiated immediately.

4) Enhance wild population and establish new populations.

Outplanting to enhance this population should begin when adequate propagated material is available, and fencing and weed control are underway. New populations should be established within the historic range of *Panicum niihauense*, in areas free from the impacts of vehicles, ungulates, and alien plants.

5) Conduct surveys.

Surveys in appropriate habitat in historical locations on Niihau and Kauai should be conducted to determine if there are additional extant populations of this grass.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

17. *Phyllostegia parviflora*
(No common name) Recovery Priority Number 5

a. Description

Appendix B contains a line drawing of *Phyllostegia parviflora*.

Phyllostegia parviflora, a member of the mint family (Lamiaceae), is a perennial herb. The egg-shaped to broadly egg-shaped, wrinkled leaves are usually 19 to 33 centimeters (7.5 to 13 inches) long and 7.5 to 15.3 centimeters (3 to 6 inches) wide. The leaf stalks are typically 6 to 13.5 centimeters (2.4 to 5.3 inches) long. Usually six flowers are arranged along a flowering stalk. The corolla is white, sometimes tinged with purple, and about 9 to 13 millimeters (0.4 to 0.5 inch) long. The upper corolla lip is about 3 millimeters (0.1 inch) long while the lower lip is about 6 to 9 millimeters (0.2 to 0.4 inch) long. The fruits are nutlets.

The species is distinguished from others of the genus by the leaf shape and length of the leaf stalk and lower corolla lip. *Phyllostegia parviflora* var. *glabriuscula* has fewer glandular hairs in the inflorescence, less pubescent leaves, and usually unbranched inflorescences, as compared to *P. parviflora* var. *parviflora*. A recently discovered, unnamed variety of *Phyllostegia parviflora* has shorter leaf stalks, spreading hairs on the leaf stalks, and fewer gland-tipped hairs in the inflorescence (Wagner *et al.* 1990).

b. Taxonomy

Phyllostegia parviflora was first described by Gaudichaud-Beaupré as *Prasium parviflorum* based on a specimen collected on Oahu (Hillebrand 1888). Later, Bentham transferred the species to *Phyllostegia* and this is the name accepted in the current treatment of Hawaiian members of the genus (Wagner *et al.* 1990). Currently two varieties are recognized — var. *parviflora* and var. *glabriuscula*, which was described by Asa Gray in 1862 (Wagner *et al.* 1990). A third, recently-discovered, variety has not yet been formally named (Wagner *et al.* 1990). These recent collections of *Phyllostegia parviflora* from the Waianae Mountains differ from the two other varieties by several characters and represent a new variety previously considered to be *Phyllostegia mollis* var. *lydgatei* (Wagner *et al.* 1990; Warren L. Wagner, Smithsonian Institution, *in litt.*, 1994; W. L. Wagner, personal communication 1994). Published names that Wagner *et al.* (1990) consider to be synonymous with *Phyllostegia parviflora* var. *parviflora* include *P. leptostachys*, *P. parviflora* var. *canescens*, *P. parviflora* var. *gaudichaudii*, and *P. parviflora* var. *major* (Wagner *et al.* 1990).

c. Current and Historic Ranges and Population Status

Historically *Phyllostegia parviflora* was known from three islands — Oahu, Hawaii, and Maui (Sherff 1935, USFWS 1996a; Wagner *et al.* 1990). This species is now known only from two populations on Oahu. *Phyllostegia parviflora* var. *glabriuscula* was only known from the island of Hawaii and has not been observed since the 1800's (USFWS 1996a). In 1995, Steve Perlman (NTBG) observed a population of over 30 individuals of *Phyllostegia parviflora* var. *parviflora* near the cliffs above Punaluu Valley off of the Koolau Summit Trail (J. Lau, personal communication 1999). The new, undescribed variety of *Phyllostegia parviflora* is known from only 19 plants in North Palawai Gulch on private land at the Honouliuli Preserve (USFWS 1996a).

d. Life History

Little is known about the life history of this species. Plants on Oahu have been observed in fruit in January (K. Kawelo, *in litt.* 1998). Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Phyllostegia parviflora is typically found on moderate to steep slopes in diverse mesic to wet forest from 500 to 830 meters (1,640 to 2,700 feet) elevation. Native plants associated with *Phyllostegia parviflora* include ohia, kanawao keokeo, *Mrysine* sp. (kolea), *Pipturus albidus* (mamaki), *Psychotria* sp. (kopiko), *Urera kaalae*, and *Cyrtandra* sp. (haiwale) (USFWS 1996a; Wagner *et al.* 1990).

f. Reasons for Decline and Current Threats

The major threats to *Phyllostegia parviflora* are habitat degradation and/or destruction by feral pigs, competition with several alien plants, and a risk of extinction from naturally occurring events and/or reduced reproductive vigor due to the small number of remaining individuals and populations (USFWS 1996a; S. Perlman, *in litt.* 1996; C. Russell, personal communication 1994). In addition, military activities are a possible threat to the North Kaukonahua Stream population. The new, undescribed variety of *Phyllostegia parviflora* is potentially threatened by fire and cattle (USFWS 1996a; USFWS, *in litt.* 1997).

g. Conservation Efforts

A long-range management plan for the Honouliuli Preserve prescribes actions for alien plant management, ungulate control, fire control, rare species recovery, and native habitat restoration (TNCH 1997). It is expected that these actions will benefit *Phyllostegia parviflora* within the Preserve.

Phyllostegia parviflora has been successfully propagated at the Lyon Arboretum (G. Koob, personal communication 1997).

No other specific conservation actions are known for this species.

h. Needed Recovery Actions

1) Control competing alien plant species.

A long-range management plan should be developed and implemented to control alien plants such as clidemia, Christmas berry, and Maui pamakani.

2) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from the two extant populations.

3) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining wild populations should begin when adequate propagated material is available, and fencing of the populations and weed control are underway. New populations should be established within the historic range of *Phyllostegia parviflora* var. *parviflora* and within the range of the new, undescribed variety of *Phyllostegia parviflora*, in areas free from the impacts of feral ungulates and alien plants.

4) Conduct surveys.

Surveys should be conducted in appropriate habitat in historical locations on the island of Hawaii to determine if there are any extant populations of this plant.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

18. *Plantago princeps*
(Hawaiian name: Ale) Recovery Priority Number 5

a. <u>Description</u>
Appendix B contains a line drawing of *Plantago princeps*.

Plantago princeps, a member of the plantain family (Plantaginaceae), is a small shrub or robust perennial herb. Its erect or ascending stems are hollow, about 2 to 250 centimeters (1 to 100 inches) long, and often branched with young internodes that are more or less woolly with reddish brown hairs. The oblong to elliptic, thick, leathery leaves are between 6 and 30 centimeters (2.4 and 12 inches) long and up to 5 centimeters (2 inches) wide and are tufted near the ends of stems. The leaves have smooth or minutely toothed margins, a pointed tip, and primary veins that converge at the base of the leaves. Numerous stalkless flowers are densely arranged in a cluster 11 to 28 centimeters (4.3 to 11 inches) long with each cluster on a stalk 10 to 50 centimeters (4 to 20 inches) long. Each flower spreads at an angle of nearly 90 degrees to the axis of the stalk or grows upright. The sepals are somewhat distinct and elliptic in shape. The fruits are capsules, which contain 3 or 4 tiny black seeds; the surface of the seeds is covered with a sticky membrane.

This species differs from other native members of the genus in Hawaii by its large branched stems, flowers at nearly right angles to the axis of the flower cluster, and fruits that break open at a point two-thirds from the base. The four varieties (*anomala*, *laxiflora*, *longibracteata*, and *princeps*) are distinguished by the branching and pubescence of the stems; the size, pubescence, and venation of the leaves; the density of the inflorescence; and the orientation of the flowers (Wagner *et al.* 1990).

b. Taxonomy

In 1826, Ludolf Karl Adelbert von Chamisso and Diederich Franz Leonhard von Schlectendal described the species *Plantago princeps* (ale) (Rock 1920a). In 1829, *P. queleniana* was described by Gaudichaud-Beaupré. An additional species, *P. fauriei*, was described by Herbert Léveillé (1911) from a specimen collected by Abbé Urbain Jean Faurie from Hanapepe Falls on Kauai. Several varieties and forms of *P. princeps* have also been described. The currently accepted classification places *P. queleniana* and *P. fauriei* in synonymy with *P. princeps* and recognizes only four varieties: *anomala*, *laxifolia*, *longibracteata*, and *princeps* (Gaudichaud-Beaupré 1829; Gray 1862; Hillebrand 1888; Mann 1867; Rock 1920a; Wagner *et al.* 1990; Wawra 1874).

c. Current and Historic Ranges and Population Status

Plantago princeps was historically found on Kauai, Oahu, Molokai, Maui, and the island of Hawaii. It is no longer extant on the Big Island. A total of 29 populations containing approximately 640 to 1,750 individuals is currently known. Historically, *Plantago princeps* var. *anomala* was known from a ridge west of Hanapepe River on Kauai (HINHP 1995). Currently on Kauai, one population of 40 individuals on Mt. Kahili, one population of 12 individuals on upper Pohakuao (near Puu Ki), and four populations with 45 individuals are known from the south rim and upper reaches of Kalalau Valley on State land (HINHP 1995; HPCC 1995; S. Perlman and K. Wood, personal communications 1997). Historically, *Plantago princeps* var. *laxiflora* was known from Waikolu, Olokui, Kamakou, and Pelekunu on the east side of Molokai; in back of Lahaina on West Maui; and Hamakua and Kohala on Hawaii Island (HINHP 1995). Currently on Molokai, *Plantago princeps* var. *laxiflora* is known from one population with 5 individuals at Kawela Gulch on private land (HINHP 1995). On

Maui, it is known from 2 locations with a total of 51 individuals in Iao Valley; 1 location with an unspecified number of individuals in Kauaula Valley on West Maui on State and private land; and 5 locations with a total of 27 to 37 individuals in Haleakala National Park on East Maui, on Federal land. The total number of plants on Maui is between 78 and 88 (HINHP 1995; HPCC 1995; S. Perlman and K. Wood, personal communications 1997).

Plantago princeps var. *longibracteata* was historically known from Hanalei, the Wahiawa Mountains, and Hanapepe Falls on Kauai, and from Kaala and the Koolau Mountains on Oahu (HINHP 1995). Currently, 6 populations are known from Kauai at Namolokama, Iliiliula drainage, Wainiha Valley, Waioli Valley and Waialeale on State and private land; they are estimated to contain between 400 to more than 1,400 individuals (HINHP 1995; S. Perlman, *in litt.* 1994; S. Perlman, personal communication 1996; S. Perlman and K. Wood, personal communications 1997). On Oahu, only 1 population is known, in the Poamoho area on private or State land. This population was last observed in 1976 and the number of individuals is not known (HINHP 1995).

Historically, *Plantago princeps* var. *princeps* was known from Nuuanu Pali and Kalihi in the Koolau Mountains and from Makaleha and Napepeiauolelo Gulch in the Waianae Mountains of Oahu (HINHP 1995; USFWS, *in litt.* 1997). Six current populations of this plant are known from the Waianae Mountains: North Palawai and Ekahanui Gulches, Makua Valley, Palikea, Pahole, and Napepeiouolele Gulch, on Federal, State, and private land. There are an estimated 50 to 150 individuals in the Waianae Mountains (HINHP 1995; U.S. Army Garrison Hawaii 1997; USFWS, *in litt.* 1997; J. Lau, personal communication 1997; S. Perlman and K. Wood, personal communications 1997). Currently 1 population of about 100 individuals is known from the Waianae Mountains, in N. Mohiakea Gulch on the Army's Schofield Barracks Military Reservation, west range (K. Kawelo, personal communication 1997).

d. Life History

Little is known about the life history of this plant. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are generally unknown. However, individuals have been observed in fruit from April through September (K. Kawelo, *in litt.* 1998).

e. Habitat Description

Plantago princeps is typically found on steep slopes, rock walls, or at bases of waterfalls from 480 to about 1,100 meters (1,580 to 3,600 feet) in elevation (Wagner *et al.* 1990). Associated plant species include aalii, kopiko, ohia, uluhe, *Cyanea* spp. (haha), *Hedyotis* spp. (manono), *Melicope* spp., and *Dubautia plantaginea*, as well as the endangered *Exocarpus luteolus*, *Poa siphonoglossa*, *Nothocestrum peltatum*, *Remya montgomeryi*, and *Stenogyne campanulata*, and the threatened *Myrsine linearifolia* (HINHP 1995; HPCC 1995; M. Bruegmann, *in litt.* 1994; S. Perlman and K. Wood, personal communications 1997).

f. Reasons for Decline and Current Threats

The primary threats to *Plantago princeps* are predation and habitat degradation by ungulates (pigs and goats) and competition with various alien plant species (USFWS 1996b). Ungulate predation is especially severe, with numerous observations of *Plantago princeps* individuals exhibiting browse damage (M. Bruegmann, personal communication 1996). In Palawai Gulch, *Plantago princeps* var. *princeps* is seriously threatened by *Erigeron karvinskianus* (daisy fleabane) (K. Kawelo, *in litt.* 1998).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Plantago princeps* plants found on the Army's Makua Military Reservation and Schofield Barracks West Range.

A long-range management plan for the Honouliuli Preserve prescribes actions for alien plant management, ungulate control, fire control, small mammal control, rare species recovery, and native habitat restoration (TNCH 1997). These actions, including the proposed construction of a fence near South Ekahanui Gulch, are expected to benefit *Plantago princeps* in the Preserve (J. Yoshioka, personal communication 1999).

The *Plantago princeps* plants at the Pahole Natural Area Reserve are found within a fenced exclosure. In addition, nine plants are growing in the Division of Forestry and Wildlife's Pahole mid-elevation nursery (B. Garnett, personal communication 1997).

Two plants of an unspecified variety of *Plantago princeps* are in cultivation at the National Tropical Botanical Garden (M. Chapin, personal communication 1997).

Micropropagation of *Plantago princeps* var. *anomala* has been attempted at the Lyon Arboretum but has not yet been successful (Koob 1997). No other specific conservation actions are known for this plant.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral ungulates.

Exclosures should be constructed around the known, unfenced populations of *Plantago princeps* to reduce impacts from feral ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan should be developed to control alien plants such as prickly Florida blackberry, banana poka, strawberry guava, Christmas berry, molasses grass, Hilo grass, Maui pamakani, *Melastoma candidum*, *Setaria gracilis* (yellow foxtail), *Tibouchina herbacea*, and thimbleberry.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be attempted again. Propagation material should be collected immediately from populations that have only one or two individuals, such as at Poamoho on Oahu and Nakalaloa Stream on Maui.

4) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining wild populations should begin when adequate propagated material is available, and fencing of the remaining populations and weed control are underway. New populations should be started within the historic range of *Plantago princeps*, in areas free from the impacts of feral ungulates and alien plants.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

19. *Platanthera holochila*

(No common name) Recovery Priority Number 5

a. Description

Appendix B contains a line drawing of *Platanthera holochila.*

Platanthera holochila, a member of the orchid family (Orchidaceae), is an erect, deciduous herb. The stems arise from underground tubers and are 15 to 60 centimeters (6 to 24 inches) long. The pale-green leaves, generally 4 to 12 centimeters (2 to 5 inches) long and 1 to 3 centimeters (0.4 to 1 inch) wide, are lance to egg-shaped. The greenish-yellow flowers occur in open spikes. The back sepal is inversely egg-shaped and hooded and the lateral sepals are erect and elliptic. The lateral petals, 2 to 2.5 centimeters (1 inch) long, are irregularly egg-shaped and enclosed by the sepals. The lowest petal is strap-like, about 3 millimeters (0.1 inch) long, with a spur at the base, 3 to 5 millimeters (0.1 to 0.2-inch) long. The fruit is an ellipsoid capsule with six ribs. This is the only species of this genus that occurs in the Hawaiian Islands (Wagner *et al.* 1990).

b. Taxonomy

Hillebrand (1888) described and named *Habenaria holochila* based on his collections and on material sent to him by J. M. Lydgate and V. Knudsen. Subsequently, F. W. Kraenzlin transferred the species to the genus *Platanthera*, resulting in the new combination *Platanthera holochila*; this name is accepted in the current treatment of Hawaiian members of the family (Kores 1979, Wagner *et al.* 1990). C.A. Luer (1975) published the combination *Platanthera hyperborea* var. *viridiflora*, now considered synonymous with *Platanthera holochila* (Wagner *et al.* 1990). The specific epithet refers to the undivided lip of the flower.

c. Current and Historic Ranges and Population Status

Historically *Platanthera holochila* was known from the Alakai Swamp and Kaholuamano area and the Wahiawa Mountains on Kauai, the Koolau Mountains on Oahu, scattered locations on Molokai, and various locations on Maui (USFWS 1996a).

Currently, *Platanthera holochila* is known from five locations on Kauai, Molokai, and Maui. Before the devastation of Hurricane Iniki on Kauai in September 1992, two populations were known from the Alakai Swamp within the Alakai Wilderness Preserve on State land (USFWS 1996a). One population, last seen in 1977, was not seen when the location was revisited in 1994 (M. Bruegmann, *in litt.* 1994). The other population comprised 100 plantlets representing 3 clones before Hurricane Iniki, but only 10 immature plantlets representing 1 clone remained over a year after the hurricane (Perlman 1995; S. Perlman, personal communication 1996). On Molokai, a single population of 20 plants occurs on private land on the Kamakou Preserve (E. Misaki, *in litt.* 1997). On Maui, three populations are known — at Hanaula, on State and private land, and at the Waikamoi and Kapunakea Preserves on private land (USFWS 1996a). The 5 current populations contain fewer than 41 individuals; 1 individual on Kauai; 20 on Molokai; and between 15 and 20 on Maui (USFWS 1996a; E. Misaki, *in litt.* 1997).

d. Life History

Little is known about the life history of this plant. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Platanthera holochila is found in ohia-uluhe montane wet forest or ohia mixed montane bog between 1,050 and 1,870 meters (3,450 and 6,120 feet) elevation. Associated native plants include hapuu, *Coprosma ernodeoides* (kukaenene), *Oreobolus* sp., *Styphelia* sp. (pukiawe), and *Vaccinium* spp. (ohelo) (USFWS 1996a).

f. Reasons for Decline and Current Threats

The primary threats to *Platanthera holochila* are habitat degradation and/or destruction by ungulates such as cattle and feral pigs, competition with alien plants, overcollection, and a risk of extinction from naturally occurring events and/or reduced reproductive vigor, due to the small number of remaining populations and individuals (USFWS 1996a; C. Russell, personal communication 1994). Predation by slugs may also be a potential threat to this species (M. Bruegmann, personal communication 1997).

g. Conservation Efforts

In February and March of 1997, under the auspices of a U.S. Fish and Wildlife Service-funded genetic material collection project, S. Perlman and K. Wood attempted to collect propagation material from the Kauai and the Hanaula, Maui, plants of *Platanthera holochila*. However, all plants were dormant (no sign of growth above ground) (S. Perlman and K. Wood, personal communications 1997). During their collecting trips, Perlman and Wood noted that the plants at Hanaula had recently been fenced by the Division of Forestry and Wildlife. Perlman and Wood also visited the plants at the Kamakou Preserve in hopes of collecting material for propagation. However, while several plants were seen, they decided not to take cuttings at that time as the plants appeared feeble and very yellow (S. Perlman and K. Wood, personal communications 1997). These plants were fenced in 1995 by The Nature Conservancy of Hawaii, using funds provided by the U.S. Fish and Wildlife Service (E. Misaki, *in litt.* 1997). Early in 1997, the Kauai plant was protected by fencing funded by the U.S. Fish and Wildlife Service (M. Bruegmann, personal communication 1997).

Micropropagation of *Platanthera holochila* is being attempted at the Lyon Arboretum though successful results have not yet been attained (Koob 1997).

No other specific conservation actions are known for this species.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against cattle and feral ungulates.

Fxclosures should be constructed around the known, unfenced populations of *Platanthera holochila* to reduce impacts from feral ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as *Hypochoeris radicata* (hairy cat's ear) and *Holcus lanatus* (velvet grass) should be developed.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should continue. Propagation material should be collected immediately from populations that have only one or two individuals, such as in the Alakai Swamp on Kauai and Hanaula on Maui.

4) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining wild populations should begin when adequate propagated material is available, and protection of the populations by fencing and weed control is underway. New populations should be established within the historic range of *Platanthera holochila* in areas free from the impacts of feral ungulates and alien plants.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

20. *Sanicula purpurea*

(No common name) Recovery Priority Number 5

a. Description

Appendix B contains a line drawing of *Sanicula purpurea*.

Sanicula purpurea, a member of the parsley family (Apiaceae), is a stout perennial herb, 8 to 36 centimeters (3 to 14 inches) tall, arising from a massive stem. The basal leaves are numerous and leathery in texture. The leaves are 2 to 8 centimeters (0.8 to 3 inches) wide, kidney-shaped or circular to egg-heart-shaped, with 3 to 7 lobes. The small flowers are purple or cream-colored with a purple tinge and occur in branched terminal clusters, each of which contains 6 to10 flowers. Each flower cluster contains one to three perfect flowers and five to seven staminate flowers. The nearly spherical fruits are covered with prickles. This species is distinguished from others in the genus by the number of flowers per cluster and by the color of the petals (Constance and Affolter 1990).

b. Taxonomy

While hiking the Schofield-Waikane Trail on Oahu, St. John collected a plant that he and Edward Hosaka described in 1935 as *Sanicula purpurea*. Other published names considered synonymous with this species include *S. lobata* and *S. sandwicensis* (Constance and Affolter 1990). The specific epithet refers to the purple petals.

c. Current and Historic Ranges and Population Status

Historically, *Sanicula purpurea* was known from six scattered locations along the Koolau Mountains of Oahu and from four locations on West Maui (USFWS 1996a). This species is currently known from four to five populations on Oahu and Maui. On Oahu, there is one population of six individuals in the Koolau Mountains on the boundary of State land and the federally owned Schofield Barracks Military

Reservation; another population, last seen on the summit between Aiea and Waimano in 1985, was not seen during a 1987 survey and may no longer be extant. Recently, an additional population consisting of about five individuals has been located at the Poamoho summit in the Koolau Mountains (K. Kawelo, personal communication 1998). On West Maui, in the Puu Kukui watershed, *Sanicula purpurea* is sporadically scattered along 2.5 kilometers (1.6 miles) of the Puu Kukui Trail on private land (J. Scott Meidell, Maui Pineapple Company, Ltd., personal communication 1997). Two other populations are known on State land, including the West Maui Natural Area Reserve (USFWS 1996a). On Maui, this species totals between 175 and 255 individuals. The total number of plants of this species is estimated to be between 181 and 261 individuals.

d. Life History

Little is known about the life history of this species. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

This species typically grows in open ohia mixed montane bogs, or occasionally ohia mixed montane wet shrubland at elevations between 700 and 1,698 meters (2,300 and 5,570 feet). Associated native plants include pukiawe, *Argyroxiphium grayanum* (greensword), *Coprosma ochracea, Lagenifera* sp., *Machaerina* sp. (uki), *Oreobolus furcatus*, *Vaccinium reticulatum* (ohelo), and *Viola maviensis* (USFWS 1996a; J. S. Meidell, personal communication 1997).

f. Reasons for Decline and Current Threats

The major threats to *Sanicula purpurea* are habitat degradation by feral pigs; human trampling and overcollection, and the subsequent introduction of alien plants following ingress by humans through intact bog areas; a risk of extinction from naturally occurring events and/or reduced reproductive vigor due to the small number of existing populations (USFWS 1996a; J. S. Meidell, personal communication 1997). On Oahu, the Kaukonahua-Kahana Divide population is additionally threatened by competition with an alien grass (narrow-leaved carpetgrass) and potentially by military activities (USFWS 1996a).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Sanicula purpurea* plants found on the Army's Schofield Barracks Military Reservation.

The bog habitat of the *Sanicula purpurea* plants in the Puu Kukui watershed has been strategically fenced by the landowner against feral pigs, and additional fences are planned to insure the long-term security of this unique and important ecosystem. To prevent degradation of this bog habitat and unintentional trampling of the rare plants in the bogs, the landowner is constructing a boardwalk that will span the known range of this population of *Sanicula purpurea*. A very strict policy is maintained by the landowner prohibiting entry into the watershed to prevent the inadvertent introduction of aggressive alien plants (J. S. Meidell, personal communication 1997).

No other specific conservation actions are known for this species.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral ungulates.

Exclosures should be constructed around the known populations of *Sanicula purpurea* to reduce impacts from feral ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plants.

A long-range management plan to control the alien grass, narrow-leaved carpet grass, is needed for the Kaukonahua-Kahana Divide population.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be initiated. Propagation material should be collected immediately from the Kaukonahua-Kahana population that has few individuals and is highly threatened.

4) Enhance wild populations and establish new populations.

Outplantings to enhance the remaining wild populations should begin when adequate propagated material is available, and fencing of populations and weed control are underway. New populations should be started within the historic range of *Sanicula purpurea* should in areas free from the impacts of feral ungulates and alien plants.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

21. ***Schiedea hookeri***

(No common name) Recovery Priority Number 8

a. Description

No line drawing is available for this species.

Schiedea hookeri, a member of the pink family (Caryophyllaceae), is a sprawling or clumped perennial herb. The stems, 0.3 to 0.5 meters (1 to 1.6 feet) long, curve slightly upward or lie close to the ground and often produce matted clumps. The thin, opposite leaves, 3 to 8 centimeters (1.2 to 3.2 inches) long and 0.4 to 1.5 centimeters (0.2 to 0.6 inch) wide, are narrowly lance-shaped to narrowly elliptic. The petalless, perfect flowers are borne in open branched inflorescences, which are hairy, somewhat sticky, and 5 to 22 centimeters (2 to 9 inches) long. The lance-shaped sepals are green to purple and 3 to 4.5 millimeters (1.2 to 1.8 inches) long. The fruit is a capsule about 3 millimeters (0.1 inch) long. This species is distinguished from others in this endemic Hawaiian genus by its open, hairy, and sometimes sticky inflorescence, and by the size of the capsules (Wagner *et al.* 1990).

b. Taxonomy

Schiedea hookeri was first described by Gray in 1854 based on a specimen collected on Oahu by Archibald Menzies of the U.S. Exploring Expedition (Wagner *et al.* 1990). Later, Earl Sherff described *S. hookeri* var. *acrisepala* and *S. hookeri* var. *intercedens*, considered synonyms of *S. hookeri* (Sherff 1944, 1945; Wagner *et al.* 1990).

c. Current and Historic Ranges and Population Status

Historically *Schiedea hookeri* was known from the Waianae Mountains of Oahu and from a single fragmentary collection from Haleakala on Maui that may represent *Schiedea menziesii* rather than *Schiedea hookeri* (USFWS 1996a; Weller *et al.* 1990;

USFWS, *in litt.* 1997). Currently this species is known from 11 populations in Oahu's Waianae Mountains. Between 220 and 330 individuals are scattered on slopes and ridges from Kaluakauila Gulch to Lualualei Valley — one population of 60 individuals on private land on the Honouliuli Preserve; three populations on City and County of Honolulu land, including 40 individuals on the Makaha-Waianae Kai Ridge, between 30 and over 100 individuals in Waianae Kai, and an unknown number of individuals on the Makua-Makaha Ridge; three populations on State land, including about 3 individuals in East Makaleha Gulch and about 20 individuals on a ridge between Kalalula and Kanewai streams; and 5 populations on Federal land (three populations with a total of 55 individuals on the Lualualei Naval Magazine, one population of about 6 individuals on the Makua Military Reservation, and one population of 5 individuals on the Schofield Barracks Military Reservation) (USFWS 1996a; T. Rubenstein, *in litt.* 1995; USFWS, *in litt.* 1997).

d. Life History

Little is known about the life history of *Schiedea hookeri*. Based on field and greenhouse observations, it is hermaphroditic, which means each individual has both male and female reproductive organs (Weller *et al.* 1990). Mature fruits have been observed in June and August (HINHP 1995).

Schiedea hookeri appears to be an outcrossing species. Under greenhouse conditions, flowers do not set fruit unless pollinated. In the field, the species is presumed to be pollinated by insects, although none have been observed (a related species, *Schiedea lydgatei* on Molokai, is apparently pollinated by native, night-flying moths) (S. Weller, personal communication 1997).

A series of self-pollinations, intra-populational crosses, and crosses among populations have demonstrated that *Schiedea hookeri* experiences moderately strong inbreeding depression (Weller and Sakai, unpublished data). These results indicate that reductions in population size could result in expression of inbreeding depression among progeny, with deleterious consequences for the long-term persistence of this species.

Individuals of *Schiedea hookeri* appear to be long-lived, but there is no evidence of reproduction from seed under field conditions. Seedlings of *Schiedea* occurring in mesic or wet sites are apparently consumed by introduced slugs and snails, which have been observed feeding on *Schiedea membranacea*, another mesic forest species that occurs on Kauai. In contrast to mesic-forest species, *Schiedea* occurring in dry areas produce abundant seedlings following winter rains, presumably because the drier sites have fewer alien consumers (S. Weller, personal communication 1997).

Schiedea hookeri differs considerably through its range in potential for clonal growth. Plants from Kaluakauila Gulch are upright, and show little potential for clonal spread. In contrast, clonal growth has been detected for individuals at Kaluaa Gulch, where the growth form is decumbent and plants apparently root at the nodes (S. Weller, personal communication 1997).

e. Habitat Description

Schiedea hookeri is usually found in diverse mesic or dry lowland forest, often with ohia or lama dominant, between 365 and 790 meters (1,200 and 2,600 feet) elevation. One population is reported at an elevation of 850 to 900 meters (2,800 to 2,950 feet). Associated plants include aalii, *Artemisia australis* (ahinahina), *Bidens* sp. (kookoolau), *Carex meyenii*, and *Eragrostis grandis* (USFWS 1996a).

f. Reasons for Decline and Current Threats

The primary threats to *Schiedea hookeri* are habitat degradation and/or destruction by feral goats and pigs, competition with alien plants, and predation by introduced slugs and snails. The Kaluakauila Gulch population is also potentially threatened by fire and military activities (USFWS 1996a; USFWS, *in litt.* 1997).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Schiedea hookeri* plants found on the Army's Makua Military Reservation and Schofield Barracks Military Reservation.

The three populations on the Navy's Lualualei Naval Reservation are in a "natural management area," an area set aside for conservation (J. Moribe, personal communication 1997). However, this area is not fenced, though the Navy sponsors a public hunting program (bow and arrow) in this area which may alleviate the impact of ungulates on these populations.

A long-range management plan for the Honouliuli Preserve prescribes actions for alien plant management, ungulate control, fire control, small mammal control, rare species recovery, and native habitat restoration (TNCH 1997). It is expected that these actions will benefit *Schiedea hookeri* within the Preserve. In addition, in 1994, *Schiedea hookeri* was outplanted on the Honouliuli Preserve inside a fenced exclosure. Weeds, slugs, and rodents were also controlled. However, all *Schiedea hookeri* plants within the exclosure have died. Only one naturally regenerated plant remains, outside the exclosure (B. Morgan, personal communication 1997).

Schiedea hookeri has been successfully propagated at the National Tropical Botanical Garden, the Pahole mid-elevation nursery, and the Waimea Arboretum. Currently, approximately 42 individuals exist in cultivation and more than 17,000 seeds are in storage (M. Chapin, personal communication 1997; D. Orr, personal communication 1997).

No other specific conservation actions are known for this species.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral ungulates.

Exclosures should be constructed around the known populations of *Schiedea hookeri* to reduce impacts from feral ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plants.

A long-range management plan to control alien plants such as Christmas berry, clidemia, molasses grass, strawberry guava, lantana, Maui pamakani, and Hamakua pamakani should be developed.

3) Protect the species from fire.

Management actions to protect endangered species such as *Schiedea hookeri* should be implemented by the Army on the Makua Military Reservation, where current ordnance training exercises could unintentionally ignite fires. A fire protection plan for endangered plants on the Lualualei Naval Reservation, where current live fire training exercises are conducted and where three populations of *Schiedea hookeri* occur, is also warranted.

4) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from populations that have only one or two individuals, such as at East Makaleha Gulch and south Mohiakea Gulch.

5) Enhance wild populations and establish new populations.

Outplanting to enhance these wild populations should begin when adequate propagated material is available, and fencing around populations and weed control are underway. New populations should be established within the historic range of *Schiedea hookeri* in areas free from the impacts of feral ungulates and alien plants.

6) Control introduced snails and slugs.

Control of introduced snails and slugs is essential to protect this species, because evidence from other *Schiedea* species from mesic areas suggests that these alien snails and slugs consume essentially all the seeds, and probably a substantial portion of the seed crop (S. Weller, personal communication 1997). Methods to control their predation on seeds and/or seedlings of this species need to be developed and implemented.

7) Conduct research on pollinators.

Research on pollinators is necessary because this species is vulnerable to inbreeding depression. Declines in the native pollinator fauna might increase levels of inbreeding, resulting in the expression of inbreeding depression (S. Weller, personal communication 1997).

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

22. *Schiedea nuttallii*

(No common name) Recovery Priority Number 5

a. <u>Description</u>

No line drawing is available for this plant.

Schiedea nuttallii, a member of the pink family (Caryophyllaceae), is a generally hairless, erect subshrub, with stems normally 0.3 to 1.5 meters (1 to 5 feet) long, and internodes usually 0.8 to 4 centimeters (0.3 to 1.6 inches) long. The green, sometimes purple-tinged leaves are opposite, narrowly egg-shaped or lance-shaped to narrowly or broadly elliptic, 5 to 10 centimeters (2 to 4 inches) long, and 1.5 to 2 centimeters (0.6 to 0.8 inch) wide. The petalless, perfect flowers are borne in open branched inflorescences, normally 20 to 25 centimeters (8 to 10 inches) long. The lance-shaped sepals, 2 to 3.8 millimeters (0.08 to 1.5 inches) long, are green or sometimes purple-tinged. The fruit is a capsule. The round to kidney-shaped seeds are about 1 millimeter (0.04 inch) long. This species is distinguished from others in this endemic Hawaiian genus by its habit, length of the stem internodes, length of the inflorescence, number of flowers per inflorescence, smaller leaves, smaller flowers, and smaller seeds (Wagner *et al.* 1990; S. Weller, *in litt.* 1994).

b. Taxonomy

In 1834, Thomas Nuttall collected a specimen in the Koolau Mountains of Oahu which, 10 years later, William Hooker used to describe *Schiedea nuttallii* as a new species (Mill *et al.* 1988, Nagata 1980). Other published names considered synonymous with *Schiedea nuttallii* include *S. nuttallii* var. *lihuensis* and *S. oahuensis* (Wagner *et al.* 1990; S. Weller, *in litt.* 1994).

c. Current and Historic Ranges and Population Status

Historically *Schiedea nuttallii* was known from scattered locations on southeastern Kauai, Oahu, Molokai, and Maui (USFWS 1996a; USFWS *in litt.* 1997; S. Weller, *in litt.* 1994, 1995).

Currently, 6 populations in the State contain a total of 40 to 100 individuals of this species, with 10 to 50 individuals on Kauai and 50 to 80 individuals on Oahu (USFWS 1996a; M. Bruegmann, *in litt.* 1994; S. Weller, *in litt.* 1994; K. Kawelo, personal communication 1997; Talbert Takahama, DOFAW, personal communication 1999).

Kauai has two populations of *Schiedea nuttallii* — east of Haupu Peak and in the Limahuli Valley on private land (USFWS 1996a; S. Perlman, personal communication 1996). Four populations are found on Oahu — one population of 28 individuals in

Kahanahaiki Valley on the Army's Makua Military Reservation; 4 populations of 20 to 50 individuals within the State owned Pahole Natural Area Reserve (T. Takahama, personal communication 1999); and 1 population of 2 individuals in Ekahanui Gulch, on private land in the Honouliuli Preserve (USFWS 1996a; USFWS *in litt.* 1997; K. Kawelo, personal communication 1997).

d. <u>Life History</u>

Little is known about the life history of *Schiedea nuttallii.* Based on field and greenhouse observations, it is hermaphroditic (Weller *et al.* 1990).

Plants located close to the Makua rim have been under observation for 10 years, and they appear to be long-lived (Weller and Sakai, unpublished observations).

Schiedea nuttallii appears to be an outcrossing species. Under greenhouse conditions, plants fail to set seed unless pollinated, suggesting that this species requires insects for pollination. Seedlings of *Schiedea* occurring in mesic or wet sites are apparently consumed by introduced slugs and snails. These have been observed feeding on *S. membranacea*, another mesic forest species occurring on Kauai. In contrast to mesic forest species, *Schiedea* occurring in dry areas produce abundant seedlings following winter rains, presumably because there are fewer alien consumers in drier sites (S. Weller, personal communication 1997). Fruits and flowers are abundant in the wet season but can be found throughout the year (K. Kawelo, *in litt.* 1999).

Individuals from Keawapilau Gulch (Pahole Gulch) are genetically diverse at allozyme loci, and probably would suffer from severe inbreeding depression if forced to inbreed (S. Weller, personal communication 1997).

e. <u>Habitat Description</u>

Schiedea nuttallii typically grows in diverse lowland mesic forest, often with ohia dominant, at elevations between 415 and 730 meters (1,360 and 2,400 feet). The population on Kauai is found at 790 meters (2,590 feet) elevation. Associated plants include hame, kopiko, olomea, papala kepau, and *Hedyotis acuminata* (au) (USFWS 1996a).

f. Reasons for Decline and Current Threats

Schiedea nuttallii is seriously threatened by habitat degradation and/or destruction by feral ungulates such as pigs, goats, and possibly deer on Kauai; competition with several alien plants; landslides; predation by the black twig borer, slugs, and snails; and a risk of extinction from naturally occurring events and/or reduced reproductive vigor, due to the small number of populations and individuals. This species is also potentially threatened by fire and military activities (USFWS 1996a; USFWS *in litt.* 1997; K. Kawelo, personal communication 1997; S. Weller, personal communication 1997).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Schiedea nuttallii* plants found on the Army's Makua Military Reservation. The 28 *Schiedea nuttallii* plants found on the Army's Makua Military Reservation are currently within a fenced exclosure (K. Kawelo, personal communication 1997).

A long-range management plan for the Honouliuli Preserve prescribes actions for alien plant management, ungulate control, fire control, small mammal control, rare species recovery, and native habitat restoration (TNCH 1997). It is expected that these actions will benefit any plants of *Schiedea nuttallii* still extant within the Preserve.

Schiedea nuttallii has been successfully propagated at the Lyon Arboretum, the National Tropical Botanical Garden, and the State's Pahole mid-elevation nursery. Over 5,000 seeds are in storage at the National Tropical Botanical Garden (M. Chapin, personal communication 1997; B. Garnett, personal communication 1997; G. Koob, personal communication 1997).

No other specific conservation actions are known for this species.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral and wild ungulates.

Exclosures should be constructed around the known populations of *Schiedea nuttallii* to reduce impacts from ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plants.

A long-range management plan to control alien plants such as Christmas berry, strawberry guava, Guinea grass, Australian red cedar, common guava, and silk oak, should be developed and implemented.

3) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be initiated. Propagation material should be collected immediately from populations with only one or two individuals, including the population at Ekahanui Gulch, which has not been seen since 1978.

4) Enhance wild populations and establish new populations.

Outplanting to enhance these wild populations should begin when adequate propagated material is available, and fencing of populations and weed control are underway. New populations should be established within the historic range of *Schiedea nuttallii*, in areas free from the impacts of feral ungulates and alien plants.

5) Conduct further research into, and implement, control methods for the black twig borer.

The black twig borer has been identified as an important threat to plants of *Schiedea nuttallii* on the Makua Military Reservation (K. Kawelo, personal communication 1997). Plants suffer slight to severe defoliation and reduced vigor due to infestations of this alien insect. A number of parasitoids have been introduced to control the beetle, though none of them have become established. Further research on biological control of the beetle will need to proceed cautiously as there are a number of rare native scolytids in Hawaii which are closely related to the black twig borer (P. Conant, personal communication 1997; J. Nakatani, *in litt.* 1996).

6) Control introduced slugs and snails.

Methods to control alien slug and snail predation on seedlings of this species need to be developed and implemented.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

23. *Sesbania tomentosa*
(Hawaiian name: Ohai) Recovery Priority Number 8

a. <u>Description</u>
Appendix B contains a line drawing of *Sesbania tomentosa.*

Sesbania tomentosa, a member of the pea family (Fabaceae), is typically a sprawling shrub with branches up to 14 meters (45 feet) long but may also be a small tree up to 6 meters (20 feet) in height. Each compound leaf consists of 18 to 38 oblong to elliptic leaflets, each 15 to 38 millimeters (0.6 to 1.5 inches) long and 5 to 18 millimeters (0.2 to 0.7 inch) wide, and is usually sparsely to densely covered with silky hairs. The flowers, in clusters of 2 to 9, are salmon tinged with yellow, orange-red, or scarlet — or rarely, pure yellow. The petals are between 23 and 45 millimeters (0.9 and 1.8 inches) long, the upper pair sometimes of a lighter color than the other petals. The calyx is about 7 to 12 millimeters (0.3 to 0.5 inch) long. Fruits are slightly flattened pods 7 to 23 centimeters (2.8 to 9 inches) long and about 5 millimeters (0.2 inch) wide, which contain about 6 to 27 olive to pale or dark brown, oblong seeds. *Sesbania tomentosa* is the only endemic Hawaiian species in the genus, differing from the naturalized *S. sesban* by the color of the flowers, the longer petals and calyx, and the number of seeds per pod (Geesink *et al.* 1990).

b. <u>Taxonomy</u>

Sesbania tomentosa (ohai) was first described by W. J. Hooker and G. A.W. Arnott in 1836 from collections from Oahu (Degener 1937) and was named for its silvery hairs. In 1920, Joseph F. Rock described an arborescent (tree) form of the species (*S. tomentosa* forma *arborea*) based on a Molokai specimen. Degener and Sherff (Sherff 1949) published a new variety, var. *molokaiensis*, based on plants from West Molokai. Nearly 30 years later, Otto and Isa Degener elevated that variety, as well as forma[7] *arborea*, to the specific level (Degener and Degener 1978). At that time, the Degeners also described two new species, *S. hawaiiensis* and *S. hobdyi*. In the currently accepted classification by Geesink and others (1990), *S. arborea*, *S. hawaiiensis*, *S. hobdyi*, and *S. molokaiensis* are synonymized with *S. tomentosa*. However, they note that the arborescent form of the species found on the island of Molokai probably merits formal taxonomic recognition. Recently, isozyme data suggest that the Hawaiian *Sesbania* species recognized by Char (1983), and never formally published, are indeed discrete entities (Chrissen Gemmill, University of Waikato, *in litt.* 1998).

[7] **Forma** is the lowest rank in botanical nomenclature, below variety or subspecies. It is seldom used today.

c. Current and Historic Ranges and Population Status

On the privately owned island of Niihau, *Sesbania tomentosa* was known from the south tip of the island at the headland west of Kaumuhonu Bay. In 1947, at least one collection was made at an elevation of 50 meters (160 feet) (HINHP 1995). On Kauai, as recently as 10 years ago, *Sesbania tomentosa* was found between the town of Mana and Mana Point. However, this population is no longer extant (S. Perlman and K. Wood, personal communications 1997). On Oahu, *Sesbania tomentosa* was known historically from eastern Oahu at Ulupau Crater, and on the islets of Kaohikaipu and Mokulua (HINHP 1995). This species was also known historically from western Oahu at an unspecified location along the Waianae coast (HINHP 1995). On Molokai, *Sesbania tomentosa* was known historically from Mahana on Mauna Loa, in the vicinity of the coast near Waiahewahewa Gulch, and on Molokai's west coast at Laau and Ilio Points (HINHP 1995). On Lanai, *Sesbania tomentosa* was known historically from scattered locations on the south half of the island, the northern slopes between Paomai and Maunalei, and east slope of the island at Kahinahina (HINHP 1995). *Sesbania tomentosa* was also known historically from an unspecified location on Kahoolawe (HINHP 1995).

Currently, *Sesbania tomentosa* occurs on at least six of the eight main Hawaiian Islands (Kauai, Oahu, Molokai, Kahoolawe, Maui, and Hawaii) and in the Northwestern Hawaiian Islands (Nihoa and Necker) in the Hawaiian Islands National Wildlife Refuge (HINHP 1995; E. Flint, personal communication 1997; R. Hobdy, personal communication 1997). The total currently known populations of *Sesbania tomentosa* on the main Hawaiian Islands contain an estimated 2,000 to 3,000 individuals. In the Northwestern Hawaiian Islands, the largest population occurs on Nihoa and consists of several thousand individuals (Craig Rowland, USFWS, personal communication 1997).

In the Northwestern Hawaiian Islands, one population is on the island of Nihoa, a 0.8 square kilometer (0.3 square mile) island (Dept. of Geography 1983; E. Flint and C. Rowland, personal communications 1997). The Nihoa plants have been described as relatively common in some areas, with several thousand individuals known (HINHP

1995; C. Rowland, personal communication 1997). Another population is known from Necker Island, which is only 0.2 square kilometer (0.1 square mile) in area (E. Flint, personal communication 1997). On Necker Island, *Sesbania tomentosa* is known to occur from 45 meters (150 feet) elevation to the 84 meter (276 foot) summit, growing on the tops of all hills of the main island. A few individuals are found on the Northwest Cape, as well, for a total of several hundred individuals (J. Marks, *in litt.* 1995).

On Kauai, *Sesbania tomentosa* is known only from the Polihale State Park on State-owned land (HINHP 1995, HPCC 1995; S. Perlman and K. Wood, personal communications 1997). This population consists of about 10 individuals growing in a lithified dune area at approximately 12 meters (40 feet) elevation in an area of approximately 10 to 50 square meters (110 to 540 square feet) (HINHP 1995; S. Perlman and K. Wood, personal communications 1997).

On Oahu, *Sesbania tomentosa* is currently known from 1 population of 50 to 100 wild and approximately 200 outplanted individuals on State-owned land at Kaena Point (HINHP 1995). This population is primarily within the Kaena Point Natural Area Reserve, growing in sand dunes in a *Naupaka kahakai* Mixed Coastal Dry Shrubland (HINHP 1995; HPCC 1995). However, scattered individuals are also located to the east for about 3.5 kilometers (2.25 miles) along the north coast (HINHP 1995; Woodward *et al.* 1991).

On Molokai, *Sesbania tomentosa* is known from the south slopes of central Molokai from Kamiloloa to Makolelau and along Molokai's northwest coast from Moomomi to east of Hinanaulua. The 4 populations on private and State-owned land from Kamiloloa to Makolelau total fewer than 2,000 individuals and grow in a 7- by 3-kilometer (4.5- by 2-mile) area (HINHP 1995; HPCC 1995; W. Wong, Jr. *in litt.* 1998). The 3 populations from Moomomi to east of Hinanaulua consist of about 100 to 150 plants growing on State and private land from sea level to 60 meters (200 feet) elevation in a 5- by 1-kilometer (3- by 0.5-mile) area (HINHP 1995; HPCC 1995; E. Misaki, *in litt.* 1997). The Division of Forestry and Wildlife's 10-acre Ohai Plant Sanctuary exclosure at Kamiloloa protects a population of several hundred plants (W. Wong, Jr. *in litt.* 1998).

On Maui, *Sesbania tomentosa* is only known from two areas on West Maui and two areas on East Maui. On West Maui, one plant is on State-owned land below Lihau Peak (HINHP 1995; R. Hobdy, personal communication 1997). *Sesbania tomentosa* also occurs on a 6-kilometer (4-mile) stretch of the northeast coast of West Maui, from the lighthouse near Nakalele Point to Puu Kahulianapa (HINHP 1995; HPCC 1995). This cluster of 4 populations contains an estimated 50 to 75 individuals on land owned by the State, the County of Maui, and private individuals (HINHP 1995; R. Hobdy, personal communication 1997). On East Maui, two trees exist on privately owned land in Kamaole, but they appear to have been planted (W. Char, *in litt.* 1993). *Sesbania tomentosa* also occurs on the southeastern slopes of Pimoe cinder cone at elevations between 450 and 500 meters (1,480 to 1,640 feet). This population consists of 13 plants located on the Hawaii National Guard Kanaio Training Area (Sam Gon, TNCH, *in litt.* 1993; D. Hopper, personal communication 1997). Off the south central coast of Kahoolawe, approximately 25 to 30 individuals of *Sesbania tomentosa* are found on the sparsely vegetated islet of Puu Koae, which is a State-owned seabird sanctuary (HINHP 1995; R. Hobdy and L. Loope, *in litt.* 1997).

On the island of Hawaii, *Sesbania tomentosa* is known from two regions of the southeast coast and two areas along the northwestern coast. On the southeastern coast it occurs along 16 kilometers (10 miles) of coastline between Ka Lae and Kaalela. This cluster of populations (exact number unknown) on State-owned land contains an estimated 260 individuals growing between sea level and 25 meters (80 feet) elevation, with some populations occurring in Ilima Coastal Dry Shrubland (HINHP 1995; HPCC 1995; W. Char, *in litt.* 1993). The second cluster is in Hawaii Volcanoes National Park and consists of 5 populations: Apua Point/Kahue, near sea level, has at least 80 individuals; Kipuka Nene, at 853 to 884 meters (2,800 to 2,900 feet) has 2 groups numbering 12 and 5 individuals; Kipuka Pepeiau and the adjacent area above Kukalauula Pali, at 270 to 660 meters (900 to 2,150 feet), have at least 21 plants; at Kamooalii, between 30 and 180 meters (100 and 600 feet), there are 43 individuals; and 16 individuals occur at 30 to 230 meters (100 to 750 feet) at Kuee in the far western lowlands of the Park (L. Pratt, *in litt.* 1995). This cluster of populations on federally owned land totals 177 individuals (HINHP 1995; L. Pratt, *in litt.* 1995). On the northwestern coast a single plant occurs at 30 meters (100 feet) elevation on private land at Kaupulehua (W. Char, *in litt.* 1993). The other northwest coast population is also on private land at Waiakailio, and consists of eight plants with several seedlings at 300 meters (1,000 feet) elevation (W. Char, *in litt.* 1993).

d. Life History

The pollination biology of *Sesbania tomentosa* is being studied by David Hopper, a graduate student in the Department of Zoology at the University of Hawaii at Manoa. His preliminary findings suggest that although many insects visit *Sesbania* flowers, the majority of successful pollination is accomplished by native bees of the genus *Hylaeus* and that populations at Kaena Point are probably pollinator limited. Flowering at Kaena Point is highest during the winter-spring rains, and gradually declines throughout the rest of the year (D. Hopper, *in litt.* 1996). Other aspects of this plant's life history are unknown.

e. Habitat Description

Sesbania tomentosa is found on sandy beaches, dunes, soil pockets on lava, and along pond margins (Geesink *et al.* 1990). It commonly occurs in coastal dry shrublands and grasslands, but is also known from open ohia forests and Mixed Coastal Dry Cliffs (HINHP 1995). Associated plant species include ilima, naupaka kahakai, *Heteropogon contortus* (pili), naio, and *Sporobolus virginicus* (akiaki) and the endangered *Chamaesyce celastroides* var. *kaenana* (HINHP 1995).

f. Reasons for Decline and Current Threats

The primary threats to *Sesbania tomentosa* are habitat degradation caused by axis deer, goats, and cattle; competition with various alien plant species; lack of adequate pollination (USFWS 1996b; D. Hopper, *in litt.* 1994, 1996; D. Hopper, personal communication 1997); seed predation by rats and mice and, potentially, alien insects (D. Hopper, personal communication 1997); fire; destruction by off-road vehicles; and the introduction of alien congenerics — other species of *Sesbania* that can potentially hybridize with this species, causing the loss of unique genetic characters (USFWS 1996b; D. Hopper, personal communication 1997).

g. Conservation Efforts

Sesbania tomentosa has benefitted from extensive conservation actions, many of them conducted by the State of Hawaii. On Oahu, individuals have been protected from off-road vehicles within the Kaena Point Natural Area Reserve through construction of rock barriers, and an extensive propagation and outplanting effort is ongoing. Several hundred seedlings were propagated at the the Division of Forestry and Wildlife's Makiki Rare Plant Facility and outplanted at Kaena Point from 1992 to1994. Approximately 250 individuals survived and became established, but very little natural reproduction was observed. Rat and mice controls were initiated in 1994 and 1995, respectively, and resulted in dramatic increases in seedling germination and survival (B. Garnett, personal communication 1995; D. Hopper, *in litt.* 1996). *Sesbania tomentosa* has also been propagated in the Division of Forestry and Wildlife's nursery in Kahului, Maui, and approximately 30 seedlings were planted within a protective exclosure at Mokolea Point. One seedling survived as of June 1995. In 1986, the Division of Forestry and Wildlife constructed a fence around a population of several hundred plants at Kamiloloa, Molokai. This fenced enclosure, the Ohai Plant Sanctuary, has survived three major fires (1988, 1991, 1998) in the area and remains intact (W. Wong, Jr., *in litt.* 1998). Propagation and outplanting were also conducted in the Hawaii Volcanoes National Park in the 1970's. The status of these plants is unknown, because the outplanted individuals have not been visited since they were planted (L. Pratt, *in litt.* 1995). Several plants have been outplanted at the Kilauea Point National Wildlife

Refuge on Kauai using seedlings propagated by the Kauai Division of Forestry and Wildlife (M. Castillo, personal communication 1999).

Sesbania tomentosa's pollination biology and how it is affected by population isolation and fragmentation are being studied by David Hopper.

More than 8,000 seeds are in storage at the National Tropical Botanical Garden (M. Chapin, personal communication 1997). Eighty-eight individuals are in cultivation at the Lyon Arboretum, the National Tropical Botanical Garden, the Pahole mid-elevation nursery, the Honolulu Botanical Gardens, and the Waimea Arboretum (M. Chapin, personal communication 1997; G. Koob, personal communication 1997; D. Orr, personal communication 1997; W. Singeo, *in litt.* 1999). Seed germination tests indicate 65 percent germination of fresh seeds and less than 20 percent germination after a minimum of 45 days in storage (Ragone 1993).

A research project on cultivation of *Sesbania tomentosa* is currently underway at Hawaii Community College on the island of Hawaii. The effects of different treatments of scarification and heat on seed dormancy is being examined, as well as the effects of various fertilizer regimes on seedling growth rate, vigor, and flowering. The objective is to determine optimal conditions for seed germination and seedling growth of *Sesbania tomentosa* (Lester Knight, Hawaii Community College, *in litt.* 1997).

h. Needed Recovery Actions

Although *Sesbania tomentosa* currently occurs in more than 27 populations and up to 7 of the populations have more than 300 individuals, reproduction sufficient to sustain current numbers is occurring only in the Nihoa and Necker populations. Therefore, implementation of recovery actions will be necessary before downlisting and/or delisting can be considered:

1) Find the reasons for poor reproductive success.

The most important recovery actions for this species are research into the reasons for poor reproductive success followed by implementation of measures to reduce threats to reproduction (e.g., control of rats, mice, and alien insects; and conservation of native pollinators).

2) Construct exclosures to protect populations against feral and wild ungulates (cattle, goats, and axis deer).

Exclosures should be constructed around the known populations of *Sesbania tomentosa* to reduce impacts from feral and wild ungulates. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

3) Control competing alien plant species.

A long-range management plan should be developed to control various alien grasses (bufflegrass, *Chloris barbata* [swollen fingergrass], and *Cynodon dactylon* [Bermuda grass]), and kiawe.

4) Protect endangered plants from fire.

Coordinated fire protection should be instigated for endangered plant species such as *Sesbania tomentosa* on State natural area reserves, State parks, State National Guard training areas, and Federal lands such as Hawaii Volcanoes National Park.

5) Construct devices to protect populations against off-road vehicular traffic.

Some plants, such as at Moomomi and Makolelau on Molokai, are being impacted by off-road vehicle traffic. A fence around these plants, or other vehicle obstruction devices preventing vehicle impact, is needed.

6) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be continued. Propagation material should be collected immediately from populations that have only one or two individuals such as at Lihau Peak on Maui and Makolelau on Molokai.

7) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining wild populations on the main Hawaiian Islands should begin when adequate propagated material is available, and fencing of remaining populations and weed control are underway. New populations should be established within the historical range of *Sesbania tomentosa*, in areas free from the impacts of feral ungulates and alien plants.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

24. *Solanum incompletum*
(Hawaiian name: Popolo) Recovery Priority Number 5

a. <u>Description</u>

Appendix B contains a line drawing of *Solanum incompletum.*

Solanum incompletum, a member of the nightshade family (Solanaceae), is a woody shrub up to 3 meters (10 feet) tall. Its stems and lower leaf surfaces are covered with prominent reddish prickles about 4 millimeters (0.2 inches) long or sometimes with yellow fuzzy hairs on young plant parts and lower leaf surfaces. The oval to elliptic leaves, 10 to 15 centimeters (4 to 6 inches) long and about 7 centimeters (2.8 inches) wide, have prominent veins on the lower surface, and are on stalks up to 7 centimeters (2.8 inches) long. The leaf margins are lobed with 1 to 4 lobes on each side. Numerous flowers grow in loose branching clusters with each flower on a stalk about 9 millimeters (0.4 inch) long. The calyx and flowers generally lack prickles. The white petals form a star-shaped corolla about 2 centimeters (0.8 inch) in diameter. The curved anthers, about 2 millimeters (0.08 inch) long, top short filaments that do not extend beyond the petals. Fruits are round berries about 1.5 centimeters (0.6 inch) in diameter, which mature from yellow-orange to black. This species differs from others in the genus by being generally prickly and having loosely clustered white flowers, curved anthers about 2 millimeters (0.08 inch) long, and berries 1 to 2 centimeters (0.4 to 0.8 inch) in diameter (Symon 1990).

b. Taxonomy

A specimen collected by David Nelson in 1779 from the island of Hawaii was described as a new species and named *Solanum incompletum* (thorny popolo) by Dunal (1852). In 1888, Hillebrand described two varieties of the species: var. *glabratum* and var. *mauiense*. In 1969, Harold St. John described the species *S. haleakalaense* based on a specimen collected by Hillebrand on the south slope of Haleakala on Maui. The latest treatment synonymized *S. haleakalaense* with *S. incompletum*, and recognized no subspecific taxa of *S. incompletum* (Symon 1990).

c. Current and Historic Ranges and Population Status

Historically, *Solanum incompletum* was known from central and northeastern Lanai, scattered locations on Maui, and the Kohala Mountains, Kona, Puu Waawaa, Puu Ikaaka Crater, Kanehaha, Puu Huluhulu, and Omaokoili on the island of Hawaii (HINHP 1995; Symon 1990). According to David Symon (1990), the known distribution of *Solanum incompletum* also extended to the islands of Kauai and Molokai. A specimen collected by the Division of Forestry and Wildlife's Robert Hobdy in 1983 at Honouliwai, Molokai has been tentatively identified as *Solanum incompletum* (W. Wong, Jr., *in litt.* 1998).

Currently, *Solanum incompletum* is only known from two populations, recently discovered on the Army's Pohakuloa Training Area (PTA) on the island of Hawaii.

Approximately 40 individuals of this species are known (Colorado State University [CSU], *in litt.* 1996; M. Bruegmann, *in litt.* 1997; M. Bruegmann and Mick Castillo, USFWS, personal communications 1999).

d. Life History

Little is known about the life history of *Solanum incompletum*. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Species historically associated with *Solanum incompletum* include naio, koa, and mamane in dry to mesic forest, diverse mesic forest, and subalpine forest at elevations from 300 to 2,040 meters (1,000 to 6,700 feet) (HINHP 1995; Symon 1990; J. Lau, personal communication 1992).

f. Reasons for Decline and Current Threats

The primary threats to the few remaining individuals of *Solanum incompletum* are habitat degradation by feral sheep and mouflon, competition with various alien plants, random naturally-occurring mass mortality events, and reduced reproductive vigor due to the extremely small number of existing plants. *Solanum incompletum* is potentially threatened by military activities and fire resulting from these activities at the Pohakuloa Training Area (M. Bruegmann, personal communication 1997).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The

Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Solanum incompletum* plants found on the Army's Pohakuloa Training Area. In addition, the military have built fenced exclosures to protect these plants from feral sheep and mouflon (M. Bruegmann and M. Castillo, personal communications 1997).

An unspecified number of seeds are housed at the Lyon Arboretum (G. Koob, personal communication 1997).

No other specific conservation actions are known for this species.

h. Needed Recovery Actions

1) Construct habitat exclosures to protect populations against ungulates.

Exclosures should be constructed around the known habitat of *Solanum incompletum* to reduce impacts from feral sheep and mouflon. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as fountain grass should be developed.

3) Protect endangered plants from fire.

Management actions to protect endangered species such as *Solanum incompletum* should be implemented by the Army on the Pohakuloa Training Area, where ordnance training exercises could unintentionally ignite fires.

4) Conduct surveys and collect genetic material.

Surveys of previously recorded locations and other areas of potentially appropriate habitat should be initiated to locate additional extant populations of *Solanum incompletum*. Genetic material should be collected, at the same time, from any relocated plants.

4) Maintain adequate genetic stock, enhance wild populations, and establish new populations.

To prevent extinction of this species, *ex situ* propagation should be initiated. Outplanting to enhance these wild populations should begin when adequate propagated material is available, and fencing and weed control are underway. New populations should be established within the historic range of *Solanum incompletum,* in areas free from the impacts of ungulates and alien plants.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

25. *Spermolepis hawaiiensis*
(No common name) Recovery Priority Number 5

a. Description

Appendix B contains a line drawing of *Spermolepis hawaiiensis.*

Spermolepis hawaiiensis, a member of the parsley family (Apiaceae), is a slender annual herb with few branches, which grows to a height of 5 to 20 centimeters (2 to 8 inches). Its leaves, dissected into narrow, lance-shaped divisions, are oblong to somewhat oval in outline and grow on stalks about 2.5 centimeters (1 inch) long. Flowers are arranged in a loose, compound umbrella-shaped inflorescence arising from the stem, opposite the leaves. Each cluster consists of two to six flowers, with each flower on a stalk between 2 and 6 millimeters (0.08 and 0.2 inch) long. The calyx is lacking in this species, but one to five bracts grow below the clusters of flowers. The fruits are oval and laterally compressed and constricted at the line where the two halves of the fruit meet. The fruits are 4 millimeters (0.2 inch) long and 3 millimeters (0.1 inch) wide, covered with curved bristles, and contain seeds that are marked with longitudinal grooves beneath oil tubes that are characteristic of the parsley family. *Spermolepis hawaiiensis* is the only member of the genus native to Hawaii. It is distinguished from other native members of the family by being a non-succulent annual with an umbrella-shaped inflorescence (Constance and Affolter 1990).

b. Taxonomy

Spermolepis hawaiiensis (NCN) was first described by H. Wolf in 1921. In the past, this Hawaiian species had been confused with the European plants, *Apium echinatum* and *Caucalis daucoides* (Constance and Affolter 1990; Wolf 1921).

c. Current and Historic Ranges and Population Status

Historically, *Spermolepis hawaiiensis* was known from Waimea on Kauai, Koko Head on Oahu, Paomai and Kahinahina on Lanai and Apua on Hawaii (HINHP 1995; H. Huntzinger, *in litt.* 1993). Currently, a total of 12 populations is known on Kauai, Oahu, Molokai, Lanai, West Maui, and Hawaii. The total number of individuals statewide is probably between 2,000 and 6,000 individuals.

On Kauai, this species has been observed in the Koaie branch and other unspecified locations within Waimea Canyon, Hanapepe at Kapahili Gulch, and Hipalau on State and private land. The total number of plants on Kauai is a few thousand (S. Perlman and K. Wood, personal communications 1997).

On Oahu, on State land at Diamond Head (land leased to the Department of Defense at the Diamond Head Reservation), 10 plants were observed in 1992 during the dry season. In 1988, when the site was first visited, thousands of plants were seen over an area of less than 50 square meters (540 square feet) (Wayne Takeuchi, formerly with

DOFAW, personal communication 1992). The population fluctuations probably reflect seasonal changes in precipitation (USFWS 1996b). Another Oahu population with several hundred individuals is on Ohikilolo Ridge at 600 meters (1,970 feet) on the U.S. Army's Makua Military Reservation (USFWS 1996b).

On Molokai, about 600 plants were reported from Kamalo on private land within an area of less than 400 square meters (0.1 acre) (HINHP 1995; R. Hobdy, personal communication 1997). On Lanai, 2 populations of *Spermolepis hawaiiensis* are known on private land: 1 east of Puu Manu with 50 to 100 individuals covering an area of about 0.1 hectare (0.25 acre), and 1 in Kaa Gulch with about 300 individuals (HINHP 1995; R. Hobdy, personal communication 1997).

On West Maui, 3 populations are known on State land: 1 in the Lihau section of the West Maui Natural Area Reserve, with 60 to 100 individuals within an area of about 0.4 hectare (1 acre); 1 farther east in the Lihau section of the West Maui Natural Area Reserve, with several hundred to thousands of plants scattered over a distance of 0.7 kilometers (0.4 mile); and 1 above Lahainaluna School, with about 100 individuals spread over an area of about 0.4 hectare (1 acre) (HINHP 1995; HPCC 1995; R. Hobdy, personal communication 1997).

On the island of Hawaii, 3 populations of about 500 individuals occur on the U.S. Army's Pohakuloa Training Area: Kipuka Alala, Puu Anahulu, and in a kipuka within the 1859 lava flow (CSU, *in litt.* 1996; M. Castillo, personal communication 1997; Trisha Tierney, formerly with Pohakuloa Training Area, personal communication 1997).

d. Life History

Little is known about the life history of *Spermolepis hawaiiensis*. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Spermolepis hawaiiensis is known from various vegetation types, including ohia forests, Aalii Lowland Dry Shrubland, cultivated fields, and pastures at elevations from about 300 to 600 meters (1,000 to 2,000 feet) (HINHP 1995; HPCC 1995). Associated plant species include ilima, *Doryopteris* sp., the endangered *Gouania hillebrandii*, and the alien plant, koa haole (HINHP 1995).

f. Reasons for Decline and Current Threats

The primary threats to *Spermolepis hawaiiensis* are habitat degradation by feral goats, axis deer, and mouflon; competition with various alien plants; fire resulting from military activities on the Makua Military Reservation and the Pohakuloa Training Area; and erosion, landslides, and rockslides due to natural weathering which result in the death of individual plants as well as habitat destruction (USFWS 1996b; M. Bruegmann, personal communication 1997).

g. Conservation Efforts

Army Environmental staff have completed a report entitled "U.S. Army Garrison Hawaii, Oahu Training Areas, Natural Resource Management Final Report." The Report includes very detailed management plans and descriptions of completed actions for each endangered plant species that occurs on Army land (B. Totten, *in litt.* 1998). When they are implemented, actions outlined in the Report may enhance conservation of the *Spermolepis hawaiiensis* plants found on the Army's Makua Military Reservation and Pohakuloa Training Area. In addition, approximately 15 to 25 known individuals are now protected from ungulate browsing within a 559-acre fenced exclosure that was constructed at the Pohakuloa Training Area by the Army in the fall of 1998 (M. Castillo, personal communication 1999).

Spermolepis hawaiiensis has been successfully propagated at the Lyon Arboretum and the National Tropical Botanical Garden (M. Chapin, personal communication 1997; G. Koob, personal communication 1997).

No other specific conservation actions are known for this plant.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against ungulates.

Exclosures should be constructed around the known populations of *Spermolepis hawaiiensis* to reduce impacts from feral goats, axis deer, and mouflon. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems. Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as koa haole, lantana, and Christmas berry should be developed.

3) Protect endangered plants from fire.

Management actions to protect endangered species such as *Spermolepis hawaiiensis* should be implemented by the Army on the Makua Military Reservation and Pohakuloa Training Area, where ordnance training exercises could unintentionally ignite fires.

4) Maintain adequate genetic stock, enhance wild populations, and establish new populations.

To prevent elimination of this species from any part of its current range, *ex situ* propagation should continue. Outplanting to enhance these wild populations should begin when adequate propagated material is available, and fencing and weed control are underway. New populations should be established within the historic range of

Spermolepis hawaiiensis, in areas free from the impacts of feral and wild ungulates and alien plants.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

26. *Vigna o-wahuensis*
(Common name: Oahu vigna) Recovery Priority Number 5

a. <u>Description</u>

Appendix B contains a line drawing of *Vigna o-wahuensis*.

Vigna o-wahuensis, a member of the pea family (Fabaceae), is a slender twining annual or perennial herb with fuzzy stems, which grows to 0.4 meters (1.3 feet) in length. Each leaf is made up of three leaflets, which vary in shape from round to linear, are 1.2 to 8 centimeters (0.5 to 3 inches) long and 0.1 to 2.5 centimeters (0.04 to 1 inch) wide, and are sparsely or moderately covered with coarse hairs. Flowers, in clusters of one to four, have thin, translucent, pale yellow or greenish yellow petals about 2 to 2.5 centimeters (0.8 to 1 inch) long. The two lowermost petals are fused and appear distinctly beaked. The sparsely hairy calyx is 4 to 8 millimeters (0.2 to 0.3 inch) long with asymmetrical lobes that measure about 3 millimeters (0.1 inch) long. The fruits are long slender pods 4 to 9 centimeters (1.6 to 3.5 inches) long and about 5 millimeters (0.2 inch) wide, which may or may not be slightly inflated and contain 7 to 15 gray to black seeds less than 6 millimeters (0.2 inch) long. This species differs from others in the genus by its thin yellowish petals, sparsely hairy calyx, and thin pods, which may or may not be slightly inflated (Geesink *et al.* 1990).

b. Taxonomy

Vigna o-wahuensis (Oahu vigna) was described by T. Vogel in 1836 from a specimen from the Waianae Mountains of Oahu (Gray 1854). In 1854, Gray described another species, *Vigna sandwicensis*, for which Rock later designated two varieties: var. *heterophylla* and var. *sandwicensis* (Rock 1920b). The currently accepted treatment places *V. sandwicensis* in synonymy under *V. o-wahuensis* (Geesink *et al.* 1990).

c. Current and Historic Ranges and Population Status

Historically, *Vigna o-wahuensis* was known from Niihau and from an unspecified location on Kauai (HINHP 1995). On Oahu, it was known from between Waimanalo and Makapuu Point, the Mokulua Islets, and the Waianae Mountains (HINHP 1995). On Maui, *Vigna o-wahuensis* was known from Makawao and Waiakoa on East Maui (HINHP 1995). There are no currently known populations on Niihau, Kauai, or Oahu. On Molokai, *Vigna o-wahuensis* was known historically from the western end of the island in the vicinity of Ilio Point (HINHP 1995). On Lanai, this species occurred historically at scattered locations across the island's southern half and at Kanepuu (HINHP 1995). And on the island of Hawaii, *Vigna o-wahuensis* was known from Kau (HINHP 1995).

Currently, a total of fewer than 100 individuals of *Vigna o-wahuensis* are known from 8 populations on the islands of Maui, Molokai, Lanai, Kahoolawe, and Hawaii (HINHP 1995, HPCC 1995; J. Lau, personal communication 1992). On East Maui, three plants were discovered in the winter of 1997 on the dry lava plain at Kanaio Beach (W. Wong, Jr., *in litt.* 1998). On Molokai there are two populations separated by a distance of 4 kilometers (2.5 miles). One population, south of Onini Gulch at about 850 meters (2,800 feet) elevation on privately owned land, covers an area of 18 square meters (200 square feet) in a forestry planting of *Fraxinus uhdei* (tropical ash) and *Pinus* (pine) (HINHP 1995). The other Molokai population of about 10 individuals is on privately owned land at Makolelau (J. Lau, personal communication 1992). On

Lanai, at least one individual of *Vigna o-wahuensis* is known from the arid windward slopes northeast of Kanepuu above Lapaiki at about 370 meters (1,200 feet) elevation on privately owned land (HINHP 1995). On the State-owned island of Kahoolawe, one individual of *Vigna o-wahuensis* grows in pili grassland between Makaalae and Lua Kealialalo at 140 meters (460 feet) elevation. Near the summit at about 400 meters (1,300 feet) elevation, about 20 plants grow in a 9-square-meter (100-square-foot) area with a few more plants scattered nearby. The size of the population about 0.8 kilometer (0.5 mile) south of Hanakanaea near "Sailor's Hat" has not been determined, but at least one collection has been made recently (HINHP 1995; R. Hobdy, personal communication 1997; J. Lau, personal communication 1992). On the island of Hawaii, *Vigna o-wahuensis* is known only from Nohonaohae Cinder Cone on privately owned land. Ten plants are known from Aalii Lowland Dry Shrubland within an exclosure containing pasture grass (HINHP 1995).

d. Life History

Little is known about the life history of this *Vigna o-wahuensis*. Reproductive cycles, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

Vigna o-wahuensis occurs in lowland dry to mesic grassland and shrubland at elevations from 10 to 1,370 meters (30 to 4,500 feet) (Geesink *et al.* 1990; HINHP 1995). Other associated plant species include ilima, *Chenopodium* sp. (aheahea), *Dubautia menziesii*, and ulei (HINHP 1995; HPCC 1995).

f. Reasons for Decline and Current Threats

The primary threats to *Vigna o-wahuensis* are habitat degradation by ungulates (pigs and axis deer), competition with various alien plant species, fire, and random naturally occurring events causing extinction and/or reduced reproductive vigor due to the small number of existing populations and individuals (USFWS 1996b).

g. Conservation Efforts

On Nohonaohae Cinder Cone, Hawaii island, 10 plants of *Vigna o-wahuensis* are within a fenced exclosure containing several types of pasture grass (D. Paul, *in litt.* 1998).

Vigna o-wahuensis has been successfully propagated, and one individual exists in cultivation at the University of Hawaii's Volcano Rare Plant Facility, where it has flowered.

Seeds collected from plants at Kanaio Beach on East Maui have been propagated by the Division of Forestry and Wildlife (W. Wong, Jr., *in litt.* 1998). Fewer than 100 seeds are in storage at the National Tropical Botanical Garden (M. Chapin, personal communication 1997). Seed germination tests indicate 52 percent germination of fresh seeds and less than 10 percent germination after a minimum of 45 days in storage (Ragone 1993).

No other conservation actions are known for this species.

h. Needed Recovery Actions

1) Construct exclosures to protect populations against feral and wild ungulates.

Exclosures should be constructed around the known populations of *Vigna o-wahuensis* to reduce impacts from feral pigs and axis deer. Subsequent control or removal of ungulates from these areas will alleviate their impact on native ecosystems.

Commitments should be developed for long-term stewardship and conservation of these areas once they have been enclosed.

2) Control competing alien plant species.

A long-range management plan to control alien plants such as fountain grass, kiawe, molasses grass, lantana, and Bermuda grass, should be developed.

3) Protect endangered plants from fire.

Management actions to protect endangered species such as *Vigna o-wahuensis* from fire should be developed for areas where fire is known to be a threat to individuals that occur there.

4) Maintain adequate genetic stock.

To prevent extinction of this species, *ex situ* propagation should be initiated and research on seed storage methodology continued.

5) Enhance wild populations and establish new populations.

Outplanting to enhance the remaining wild populations should begin when adequate propagated material is available, and fencing and weed control are underway. New populations should be established within the historic range of *Vigna o-wahuensis* in areas free from the impacts of feral and wild ungulates and alien plants.

Additional recovery actions, as discussed in the Step-down Narrative beginning on page 169, are also appropriate for this species.

F. Overall Recovery Strategy

Immediate action must be taken to stabilize the remaining wild populations of the Multi-island plants. These actions include propagation and maintenance of genetic stock *ex situ,* and protection of remaining wild individuals from threats. Current threats to the species should be managed through fencing and/or hunting to control ungulates; control of alien plants; protection from fire; control of rodents, damaging insects and slugs and snails; protection from human disturbance; a comprehensive monitoring program; and, if necessary, protection from disease. Simultaneously, surveys should be conducted to determine the status of the taxa for which no individuals are currently known in the wild — *Cenchrus agrimonioides* var. *laysanensis*, *Mariscus pennatiformis* ssp. *pennatiformis*, and *Phyllostegia parviflora* var. *glabriuscula*, as well as surveys for populations of other species that have not been observed in recent years. Individuals of these species may exist in former habitats, or may be present in areas that have not been surveyed recently.

Secondly, management units should be delineated to conserve not only these taxa, but their habitats as well (see Appendix F). These units should be managed to preserve as many native species (flora and fauna) as possible, through threat-control and habitat-restoration programs.

The next step in the recovery of these taxa is to enhance small populations and re-establish new populations within their historical ranges, when necessary to meet downlisting and/or delisting objectives. This includes selection of areas for augmentation and re-establishment, determination of the best methods for *ex situ* propagation and transplanting, selection of the best genetic stock for each area, propagation of suitable stock, preparation of sites for seeding and/or transplanting, and monitoring and maintenance of new individuals and populations as they are established.

A research program is also recommended to study the growth and reproductive viability of each taxon, determine the parameters of viable populations of each taxon, study the reproductive strategy and pollinators of each taxon, and study possible pests and diseases. Research results will be applied to improve management practices.

To ultimately recover the listed plant taxa in Hawaii, habitat must be protected and managed for natural expansion of the populations, as well as for reintroduction of these taxa into portions of their former range. Habitats that are potentially important for the recovery of listed plant species in Hawaii are shown in Appendix F. These maps may be used by land owners and managers to identify priority areas for management and restoration, and for wide-range planning purposes.

Finally, the recovery objectives should be refined and revised as new information becomes available.

RECOVERY

A. Objectives

This section of the plan sets objectives for stabilizing, downlisting, and delisting the Multi-island plants. The order in which the recovery tasks are listed in the step-down outline and narrative is not necessarily the order in which the tasks should be implemented. Priorities for action and recommended time-frames are contained in the Implementation Schedule of this plan.

An endangered species is defined in Section 3 of the Endangered Species Act as any species that is in danger of extinction throughout all or a significant portion of its range. A threatened species is defined as any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

For the purposes of this section, a population is defined as a discrete unit with sufficient distance between it and neighboring populations that they are not affected by the same small-scale events (such as a landslide), and are not believed to be cross-pollinated. Mature individuals are defined as those either known or believed to be capable of reproduction. In general, long-lived perennials are those taxa either known or believed to have life spans greater than 10 years; short-lived perennials are those known or believed to have life spans greater than 1 year but less than 10 years; and annuals are those known or believed to have life spans less than or equal to 1 year.

Flueggea neowawraea, *Schiedea hookeri*, and *Schiedea nuttallii* are the only long-lived perennials in this plan. The short-lived perennials in this plan are: *Achyranthes mutica*, *Adenophorus periens*, *Bonamia menziesii*, *Cenchrus agrimonioides*, *Cyanea grimesiana* ssp. *grimesiana*, *Cyperus trachysanthos*, *Diellia erecta*, *Euphorbia haeleeleana*, *Hibiscus brackenridgei*, *Isodendrion laurifolium*, *Isodendrion longifolium*, *Mariscus pennatiformis*, *Neraudia sericea*, *Panicum niihauense*, *Phyllostegia parviflora*, *Plantago princeps*, *Platanthera holochila*, *Sanicula purpurea*, *Sesbania* *tomentosa, Solanum incompletum,* and *Vigna o-wahuensis*. *Centaurium sebaeoides* and *Spermolepis hawaiiensis* are annuals.

Because we have only limited knowledge of the life history of each of these taxa with respect to specific requirements for their short-term and long-term survival, this plan establishes only tentative criteria for stabilizing, downlisting, and delisting. These criteria were formulated based on recommendations by the Hawaii and Pacific Plants Recovery Coordinating Committee, as well as the International Union for Conservation of Nature and Natural Resources' (IUCN's) draft red list categories (Version 2.2) and the advice and recommendations of various biologists and knowledgeable individuals.

Additional information is needed about each of the Multi-island plants so that recovery objectives can be quantified and made more meaningful.

Interim Objectives

The interim objective is to stabilize all existing populations of the Multi-island plants. To be considered stable, each taxon must be managed to control threats (e.g., fenced) and be represented in an *ex situ* collection. In addition, a minimum total of three populations of each taxon should be documented on islands where they now occur or occurred historically. Each of these populations must be naturally reproducing and increasing in number, with a minimum of 25 mature individuals per population for long-lived perennials, a minimum of 50 mature individuals per population for short-lived perennials and a minimum of 100 mature individuals per population for the annual taxa.

Downlisting Objectives

For downlisting, a total of five to seven populations of each taxon should be documented on islands where they now occur or occurred historically. In certain cases, however, a particular taxon may be eligible for downlisting even if all five to seven of the populations are on only one island, provided all of the other recovery criteria have been met and the populations in question are widely distributed and secure enough that one might reasonably conclude that the taxon is not in danger of extinction throughout all or a significant part of its range.

Each of these populations must be naturally reproducing, stable or increasing in number, and secure from threats, with a minimum of 100 mature individuals per population for long-lived perennials, a minimum of 300 mature individuals per population for short-lived perennials and a minimum of 500 mature individuals per population for the annual taxa. Each population should persist at this level for a minimum of five consecutive years before downlisting is considered.

Delisting Objectives

A total of 8 to 10 populations of each taxon should be documented on islands where they now occur or occurred historically. As with downlisting, there may be certain cases in which a particular taxon may be eligible for delisting even if all 8 to 10 of the populations are on only one island, provided all of the other recovery criteria have been met and the populations in question are widely distributed and secure enough that one might reasonably conclude that the taxon is not in danger of extinction throughout all or a significant part of its range. Each of these populations must be naturally reproducing, stable or increasing in number, and secure from threats, with a minimum of 100 mature individuals per population for long-lived perennials, a minimum of 300 mature individuals per population for short-lived perennials, and a minimum of 500 mature individuals per population for the annual taxa. Each population should persist at this level for a minimum of five consecutive years.

B. Step-down Outline

1. Protect habitat and control threats.
    11. Identify and map all extant wild populations.
    12. Delineate management units.
    13. Ensure long-term protection of habitat.
    14. Identify and control threats.
        141. Control feral and wild ungulates.
            1411. Construct and maintain fencing.
            1412. Evaluate the potential for controlling ungulates through eradication programs or establishment of game preserves.
        142. Conduct alien plant control.
        143. Provide necessary fire protection.
        144. Control rodents, if necessary.
        145. Propagate and maintain genetic stock *ex situ*.
        146. Ensure availability of pollination vectors.
        147. Protect areas from human disturbance.
        148. Control insects, slugs, snails, and/or disease, if necessary.
        149. Control all other identified threats.
2. Expand existing wild populations.
    21. Select populations for expansion.
    22. Prepare sites and plant.
3. Conduct essential research.
    31. Collect diagnostic data on crucial associated ecosystem components.
    32. Map alien vegetation.
    33. Study various aspects of growth.
    34. Study reproductive viability.
    35. Determine parameters of viable populations.
    36. Determine effects of insects and/or diseases, and develop control methods, as needed.
    37. Evaluate results and use in future management.
4. Develop and implement detailed monitoring plans for all species.
5. Reestablish wild populations within historic range.
    51. Investigate feasibility and desirability of reintroduction.
    52. Develop and implement specific plans for reestablishment.
6. Validate recovery objectives.
    61. Determine number of populations and individuals needed for long-term survival.
    62. Refine/revise downlisting and delisting criteria.

C. Step-down Narrative

1. Protect habitat and control threats.

Because of the altered nature of habitats of the Multi-island plants, their low numbers, and the severity of the threats acting upon them, the highest priority recovery actions must be aimed at protecting the individuals and populations that currently exist, and managing their habitat to control the threats affecting their survival. Surveys should begin immediately for taxa that have not been observed for several years, like *Cenchrus agrimonioides* var. *laysanensis*, *Mariscus pennatiformis* ssp. *pennatiformis*, and *Phyllostegia parviflora* var. *glabriuscula*. A monitoring program is essential to track the status of the populations of all of the taxa covered in this plan, and to assess the effectiveness of threat management.

11. Identify and map all extant wild populations.

Protection of extant populations will involve locating all extant individuals, mapping their precise locations, and providing this information to the land managers. Priority should be given to taxa that have not been observed in recent years, like *Cenchrus agrimonioides* var. *laysanensis*, *Mariscus pennatiformis* ssp. *pennatiformis*, and *Phyllostegia parviflora* var. *glabriuscula*.

Surveys should be conducted wherever there are reported or possible occurrences of each taxon. Occurrence data, including presence in or absence from previously reported sites (as well as site notes) and all relevant information for newly reported occurrences, should be carefully documented. Detailed site information (including directions, maps, global positioning system [GPS] data, and narratives) is recommended for each site.

12. Delineate management units.

Management units should be identified for the 26 taxa covered by this recovery plan. In most cases, the ranges of the Multi-island plants will overlap with those of other listed taxa, and management units including multiple listed taxa from multiple recovery plans can be delineated and managed under a single management plan. Management units should include areas adequate for buffer zones and fire breaks and for expansion of existing populations and establishment of new populations for recovery. Similar areas for newly discovered populations of each taxon should be identified and targeted for protection and management when necessary for recovery. The Hawaii and Pacific Plants Recovery Coordinating Committee and Plant Recovery Teams may assist the U.S. Fish and Wildlife Service, the Division of Forestry and Wildlife, and other landowners and managers in identifying these management units.

13. Ensure long-term protection of habitat.

The protection of Multi-island plants management units is a primary concern. The protection currently provided to these taxa by various landowners should be continued and enhanced, and additional protective measures pursued as needed. This includes, but is not limited to, protection provided by Federal and State laws, regulations, and policies; management plans and policies of Federal, State, and private landowners; cooperative agreements, conservation easements, and leases.

Federal agencies managing lands containing populations of Multi-island plants include the U.S. Army, U.S. Navy, National Park Service, and U.S. Fish and Wildlife Service. Federal agencies are required by section 7 of the Endangered Species Act to insure that any action authorized, funded, or carried out by them is not likely to jeopardize the continued existence of any endangered or threatened species. Section 7 further stipulates that all Federal agencies utilize their authorities in furtherance of the purposes of the Act by carrying out programs for the conservation of listed species. Endangered Species Management Plans or other similar management plans for areas managed by the Army, Navy, National Park Service, and U.S. Fish and Wildlife Service contribute to the recovery of these plants, so the agencies should be assisted in their attempts to develop and implement plans for areas that are not currently covered.

The State of Hawaii should ensure that all State departments responsible for land zoning, development projects, forestry projects, recreational programs, and other activities on their lands, are made aware of the presence of the Multi-island plants on their lands. In addition, the State should review its proposed projects and ensure that appropriate measures are taken to minimize or preclude all negative impacts to the listed plant taxa. In addition, the Division of Forestry and Wildlife should consider development and implementation of long-term management plans for each of the Multi-island plants on their lands.

Populations of Multi-island plants also occur on lands owned or managed by various private landowners. Steps should be taken to ensure that all such landowners are aware of the presence of the listed taxa on their lands, and every effort should be made by the Division of Forestry and Wildlife and/or the U.S. Fish and Wildlife Service to assist the landowners, as necessary, in developing and implementing long-term management plans for these taxa on their lands.

14. Identify and control threats.

For each population of the Multi-island plants, threats must be identified, prioritized, and steps must be taken, in priority order, to protect the populations. Many threats have already been well documented, while others need to be further defined. Additional threats may become apparent if additional populations are located. Known threats include current and future development activities, feral and wild ungulates, alien plants, fire, rodents, insects, slugs and snails, human disturbance, a lack of pollinators, and, potentially, disease.

Threat control plans should be developed for each area in which these taxa are found. When habitats are owned by more than one party, threat control plans should be developed cooperatively among the owners when possible. The delineation of management units (task #12) should allow for the cooperative management of logical groupings of populations. Threat control plans should be as all-encompassing as possible, possibly incorporating several management units and other listed, proposed, and candidate taxa into one overall plan for restoration and management of the habitats that support the 26 taxa identified in this recovery plan, along with other native components.

141. Control feral and wild ungulates.

The forests of Hawaii have large numbers of goats, pigs, cattle, deer, sheep, and other introduced ungulates. Controlling these ungulates to the point where they are no longer impacting native vegetation is absolutely imperative.

The most effective method currently available for providing immediate protection from introduced ungulates in Hawaii is to fence discrete management units, and then remove ungulates from within the fenced areas. Although this approach is costly, it does work, as demonstrated at Hawaii Volcanoes and Haleakala National Parks and elsewhere, and is a feasible means of controlling introduced ungulates in Hawaii. Eradication of introduced animals may sometimes be an option and, given public support, should also be considered.

1411. Construct and maintain fencing.

The most effective strategy will probably be to use a combination of methods. Short-term, small-scale fencing can protect populations under immediate threat from ungulates until longer-term, large-scale fencing projects are completed. However, even "small" exclosures should be large enough to offset the negative impacts of the actual fencing and fence and site maintenance (e.g., scarification of fenceline and adjacent area and potential introduction of new pests into the area). As a general guideline, minimum-sized exclosures should have their perimeters located at least 50 meters (164 feet) distant from the nearest individual of the target species.

Fences should include, if possible, the target populations and a buffer area of good-quality, similar habitat for potential replanting efforts (and/or native buffer habitat, if present, that is resistant to invasion of alien species and fire). To reduce maintenance costs, fences should be constructed along ridgelines and tied into streamcourses and natural barriers (such as the tops of waterfalls) as much as possible.

Once the best method for fencing the management areas is determined, fencing and maintenance plans should begin as soon as possible. Fences should be impervious to all ungulates found in the area. Ongoing inspection and maintenance of fences is necessary to ensure the continued exclusion of ungulates from the fenced areas.

When each fence is completed, all ungulates from within should be removed. Eradication options may include baited hunting, snaring, and poisoning. Hunting from helicopters is also a highly effective eradication method, particularly for situations such as steep cliffs. Managers must realize the potentially detrimental impacts of these management activities. Soil and vegetation disturbance can create open areas for new alien species invasions, and inappropriate or careless activities can directly damage the endangered plants. Hunters and others who will be working in the habitat of the Multi-island plants should be apprised of the existence of the plants so that they do not inadvertently damage them.

Ongoing monitoring for ungulates within the large fenced areas is necessary to ensure their continued absence. Monitoring should also include determining the effects of the exclusion of ungulates, since their herbivory may have a more dramatic impact on invasive alien plants than on the endangered taxa. If so, ungulate removal without alien plant management could release the exotics, allowing them to overwhelm native plants (see task 142).

1412. Evaluate the potential for controlling ungulates through eradication programs or establishment of game preserves.

Ideally, island-wide programs to eradicate introduced ungulates should be instigated and supported, where applicable. Fences are maintenance-intensive, cannot be built in all areas due to topography, and are not altogether a foolproof method of protecting habitats necessary for the perpetuation of the Multi-island plants. Ultimately, the eradication of introduced ungulate populations is the only way to completely eliminate ungulate damage. Such removal of introduced animals will also slow down the degradation of watershed lands. However, public support of hunting is very fervent, and the likelihood of acceptance of island-wide ungulate eradication programs is remote. Development of fenced game preserves, where areas are set aside for hunting of game animals, should be a high priority within the State.

142. Control alien plants.

Alien plants are known to be a threat to 25 of the 26 Multi-island plants, and a potential threat to 1 taxon, so control of alien weeds is one of the most important aspects of habitat management for the Multi-island plants. This may become even more important for some species if the removal of ungulates relieves grazing and browsing pressure on alien plants. Additionally, soil and vegetation disturbance by managers can create open areas for new alien species invasions, and inappropriate or careless activities can cause direct damage to endangered plants. Steps should always be taken to minimize these effects.

Effective weed control methods must be developed. Control methods may include, but are not limited to, hand-pulling, local herbicide application, and biocontrol. Weed control should be aggressively implemented in the vicinity of the Multi-island plants, particularly within and around fenced management units. Weed control should be prioritized for each population, beginning in the immediate vicinity of the existing plants, and continuing until control is achieved in the full management unit. Follow-up visits to each site are necessary to ensure that weeds are permanently controlled, so sites should be monitored periodically to determine when additional intervention is necessary.

Control efforts should be supervised by personnel experienced in safe control methods to insure that crews do not compact soil, damage root systems, or improperly apply herbicides. Consideration should be given to the effects of dramatically increasing sunlight to any area by removing alien canopy plants, and opening up an area for additional (possibly more threatening) alien species invasion. Also, care should be taken to protect associated native species, as well as the endangered species, during weed removal.

Introduction of alien plants and other species to the State of Hawaii, and between islands within the State, needs to be controlled to prevent further threats to the Multi-island plants and their habitats. In order to prevent the introduction of potentially detrimental alien species, support should be given to legislation, programs, or activities that limit the possibility of future introductions of alien species. The success of such programs or activities would contribute not only to the perpetuation of the endangered species in this plan, but to the quality of all native ecosystems as well as agricultural concerns in the State of Hawaii.

143. Provide necessary fire protection.

Protection from fire is critical to the survival of Multi-island plants that occur in dry or mesic habitats (see Table 1). These plants are not well-adapted to survive fire, particularly those fires fed by unnatural buildup of fuel (such as that provided by the growth of alien grasses). In addition, many introduced plant species are better adapted to recovery after fires and often invade burned areas, permanently changing the habitat. Protection must be both local and on a larger scale to prevent fires from spreading to areas where the plants grow.

Plans to protect each site from fire should be developed and implemented. Plans are being developed for areas owned and/or managed by the military, and plans are in place for National Park Service and U.S. Fish and Wildlife Service lands. "Fire-free" zones should be established, with hunters and other land users apprised of the dangers of smoking and open flames in sensitive areas. Presuppression actions such as construction of fuel breaks or vegetation manipulation are necessary for the protection of the fireprone populations of the Multi-island plants. Fuel breaks with a minimum width of 6 meters (20 feet) should be constructed around these taxa wherever feasible. This minimum width is a guideline only and may not be sufficient to protect populations from fire in especially dry conditions. Vegetation manipulation, such as replacing a highly flammable fuel with a less flammable fuel, may be another method to consider for fire presuppression in Hawaiian natural areas (B. Morgan, personal communication 1997). Land managers and others need more information to adequately address fire presuppression in natural areas. Support should be given to legislation, programs, or activities that will advance our understanding of wildland fuels in Hawaii. The success of such programs or activities would contribute not only to the perpetuation of the endangered species in this plan, but to the quality of all native ecosystems in the State of Hawaii.

144. Control rodents, if necessary.

In some cases, rodents must be controlled to allow endangered plant taxa to reproduce. Measures should be taken as needed to control rodent damage to the endangered plants and their fruits and seeds. Methods could include trapping, poisoning (including the use of the currently approved Diphacinone bait blocks and ultimately a more broad-scale method such as aerial dispersal of rodenticide), and/or the use of rodent barriers. Intensive rodent control over a period prior to and during fruit production is recommended for at least one season or until a good production season occurs, in order to have a viable crop of seeds for collection and *ex situ* propagation. Rats are a serious threat to *Euphorbia haeleeleana* and *Sesbania tomentosa*, and a potential threat to *Cyanea grimesiana* ssp. *grimesiana*, *Flueggea neowawraea*, and *Hibiscus brackenridgei*. *Sesbania tomentosa* is also threatened by mice.

145. Propagate and maintain genetic stock *ex situ*.

Although cultivation of these plants is not a substitute for their preservation in the wild, cultivated populations of each Multi-island plant taxon should be maintained as pools of genetic resources for reintroduction to appropriate sites and to safeguard against losses of genetic material due to catastrophe in wild populations. Additionally, the existence of cultivated plants may reduce any demand for field-collected specimens of these rare taxa by providing a propagated source of those taxa for which there might be a horticultural and/or research demand.

As broad a complement as possible of the existing genetic stock for each taxon should be preserved. For each identifiable population (either from extant sites or traceable, pure, cultivated material), genetic material should be collected from as many individuals as feasible. Collection methods and quantities of materials collected should be devised to have minimal impact on wild populations. All collected materials should be labeled accurately as to exact origin, collection date, etc.

Seeds of each taxon should be collected and entrusted to seed banks for long-term storage using the best available techniques for preservation. Seeds in long-term storage should be periodically tested for viability and re-collected as necessary.

146. Ensure availability of pollination vectors.

Based on research findings, measures should be established to ensure that pollination vectors remain available to the Multi-island plants. If it is discovered that pollination vectors for certain taxa are missing, necessary measures should be taken to compensate for these. This will be especially important for the three species of *Schiedea* and for *Sesbania tomentosa*.

147. Protect areas from human disturbance.

The Multi-island plants should be protected as much as possible from hikers, vehicles, and other possibilities of direct human disturbance. This protection effort will involve public awareness and education regarding the Multi-island plants, and native habitats in general, and should be done in conjunction with public education for other listed taxa. Education efforts are currently underway to ensure military training exercises avoid sensitive areas.

Signs designating sensitive environmental areas and/or research areas should be placed near sites where human contact may occur. "Kapu/No Trespassing" signs should prohibit entry to these areas. However, such signs may not be necessary for some populations in remote areas and/or areas not frequently visited, or where signs may attract undue attention to these populations, thereby exposing them to vandalism. The decision regarding sign placement should be based on the circumstances surrounding each population.

Where possible, access to roads and/or trails that pass through habitat of the Multi-island plants should be allowed only for necessary management activities (e.g., fire control, hunting, monitoring, etc.). Care should be taken at any time during road or trail maintenance in or near habitat of the endangered taxa to avoid practices that would cause opening of canopies, excessive erosion, or other damage to the Multi-island plants or their habitats. If hiking is permitted in management areas, hikers should be informed of the presence of sensitive environments and precautions that should be taken to avoid disturbance of such areas (e.g., cleaning of boots and clothing, the importance of staying on existing trails). All such activities should be closely monitored by the appropriate conservation agency or private landowner.

Human disturbance is a threat to *Hibiscus brackenridgei* ssp. *brackenridgei* in the Puu Anahulu region, *Panicum niihauense* at Polihale State Park, *Platanthera holochila* in all locations, and *Sesbania tomentosa* at Kaena Point, and a possible threat to individuals of other Multi-island plants growing close to roads and/or trails.

148. Control insects, slugs, snails, and/or disease, if necessary.

Insects, slugs, snails, and/or disease are known threats to several of the Multi-island plants, and potential threats to all. Based upon the results of research task #36, control measures should be implemented within the management units for these taxa.

149. Control all other identified threats.

The need for control of other threats may become apparent as more is learned about the Multi-island plants. New threats may also arise with further changes to natural habitats in Hawaii, such as introduction of new alien species. As new threats arise, management actions to reduce and/or eliminate their effects on the Multi-island plants should be implemented.

2. Expand existing wild populations.

The Multi-island plants may expand naturally after management eliminates current threats. However, in certain instances, wild populations may need to be augmented in order to reach down/delisting objectives. Suitable sites for population augmentation should be selected after careful evaluation of the threat of introducing detrimental organisms into the wild populations. Augmentation efforts should always be well-documented as to lineage and methods.

21. Select populations for expansion.

The need for expansion of current populations should be evaluated, and specific plans should be created for the augmentation of wild populations that need to be enhanced.

22. Prepare sites and plant.

Plans should describe the plant material to be used and the most appropriate methods. Each selected site must be prepared and protected appropriately, including the building of exclosures and controlling alien species within.

After sites are protected, *ex situ*-propagated material should be added to existing wild populations in quantities and times deemed appropriate based on population and growth studies. Normally, in order to maintain the integrity of the wild population's gene pool, the *ex situ* propagated material should be from the same site. The *ex situ* materials must be free from pests, diseases, and pathogens that might be introduced to the wild. Cultivated plants may have been grown in the presence of other pathogen-carrying plants, and wild populations may have lower resistance to such pathogens than plants that have been nurtured under garden conditions. Care should be taken regarding the matching of soils if transplanting already-started plants due to differences in water retention around the root areas (i.e., if surrounding soil is more absorptive, the soil directly around the roots could become overly dry and weaken or kill the newly transplanted specimen).

Augmented populations should be monitored carefully (see Task #4), and ongoing maintenance of each site should begin after initial preparation and planting.

3. Conduct essential research.

Research must be conducted into aspects of the life history, habitat, pollinators, reproductive biology, symbionts, seed viability, optimum requirements for growth, requirements for population viability, and control of threats for each of the Multi-island plants to better understand what is needed for perpetuation of these plants. Such additional knowledge would allow more appropriate management and assessment techniques to be developed, and is needed in order to determine meaningful parameters for definition of specific recovery criteria for each taxon.

31. Collect diagnostic data on crucial associated ecosystem components.

Composition of flora and invertebrate, bird, and other fauna populations within each management area should be established to attempt to gain an understanding of any relationships between these organisms and the Multi-island plants.

32. Map alien vegetation.

Periodic mapping of alien vegetation is recommended using various techniques, including direct ground observations as well as aerial color and/or infrared photographs. Aerial techniques have these advantages: (1) they do not directly invade the sensitive habitat of the endangered plants and (2) monitoring of large inaccessible areas is feasible. Mapping would allow changes in distributions and abundance of alien plants to be followed so that appropriate management actions may be taken.

33. Study various aspects of growth.

Aspects of the growth of each taxon need to be studied, including growth and mortality of seedlings, growth of mature plants (including seasonal changes), optimum conditions and limiting factors, seasonal differences in temperature and light needs, water sources and requirements, and soil and nutrient requirements.

34. Study reproductive viability.

Factors affecting the reproductive viability of each of the Multi-island plants need to be investigated, including seed viability, breeding systems (including self-compatibility), pollination vectors, and preferred conditions for flowering and seed set. This will allow development of the best management strategy for each taxon.

35. Determine parameters of viable populations.

Definitions of viable populations need to be established. This is needed to more precisely determine criteria for consideration of downlisting or delisting. These definitions should include the following: minimum numbers of individuals and populations needed for long-term survival, demographics, longevity, minimum range needed for long-term survival, genetic relationships/susceptibility to inbreeding depression, and dispersal potential.

36. Determine effects of insects, slugs, snails, and/or diseases and develop control methods, as needed.

The black twig borer seriously threatens *Flueggea neowawraea*. Effective control methods for this and other harmful insects and disease must be developed. The black twig borer is also a serious pest of a number of economically important plants in Hawaii. A number of parasitoids have been introduced for its control by the Hawaii Department of Agriculture (DOA), but none has become established. The DOA is considering further research on biological control of this beetle. The research will need to proceed diligently, as there are a number of rare native scolytids in Hawaii which are closely related to the black twig borer (P. Conant, personal communication 1997; J. Nakatani, *in litt.* 1996). Predation by introduced slugs and snails is a serious threat to *Schiedea hookeri* and *S. nuttallii* (S. Weller, personal communication 1997). Effective control methods for these harmful alien invertebrates must be developed.

37. Identify and test potential biocontrol agents for host specificity and efficacy of control.

Many of the most significant weeds are widespread over large areas of land. For such weeds, manual and chemical control may be inefficient and ineffective due to time, cost, and logistics involved. Several of the weeds discussed in this plan have known natural enemies that have not yet been funded for evaluation as potential biological control agents in Hawaii. Examples are Christmas berry, strawberry guava, Koster's curse, and lantana (M. Isherwood, personal communication 1998). Potential biological control agents for these species as well as other particularly invasive weeds such as *Ardisia elliptica* should be identified and research conducted on their efficacy at controlling the target weed as well as their host specificity.

38. Evaluate results and use in future management.

The results of the above studies should be evaluated and incorporated into the management process and used in the development of recovery objectives.

4. Develop and implement detailed monitoring plans for all species.

All populations of the Multi-island plants should be monitored to ensure that current information is available for each. A detailed monitoring plan should be designed and implemented for each taxon. Permanent plots should be set up for each population, and individuals mapped by size class, in order to establish baseline information regarding population size, local distribution patterns, and threats. As new populations are discovered or established, they should be added to the monitoring program.

When appropriate, individual plants may also be carefully tagged for monitoring purposes. Data collection should include quantities and locations of all extant plants as well as any other relevant observations regarding phenology, habitat, or threats. Plots should be set up to allow point- and/or line-intercept monitoring methods as appropriate for each situation. Information such as changes in numbers of plants by size class, changes in vigor of individual plants, and changes or disturbances to the environment should be noted as appropriate and recorded.

5. Reestablish wild populations within historic range.

If necessary to meet recovery objectives, populations should be reestablished in areas where they are known or are believed to have occurred historically, particularly if genetically uncontaminated, cultivated materials exist that are known to have originated from the historical site. The goal of reintroduction is to permanently reestablish viable populations of these taxa in stable and secure conditions.

51. Investigate feasibility and desirability of reintroduction.

For each taxon, appropriateness of reintroduction into wild situations should be assessed. Genetic purity of populations is a prime concern, as is the possibility of introducing pathogens to natural areas. Reintroduction efforts should always be well documented as to lineage and methods.

52. Develop and implement specific plans for reestablishment.

Each reestablishment effort should be guided by a specific plan. The plan should identify reestablishment sites, plant materials, and methods to be used. The plan should specify methods to ensure that selected materials are free from pests, diseases, and pathogens that might be introduced to the new or nearby wild populations. This aspect is particularly critical since cultivated plants may have been grown in the presence of other pathogen-carrying plants, and nearby wild populations may have lower resistance to such introductions. If the reestablishment sites are outside the management units already established, they should be protected as discussed above (Task #1).

Each site must be prepared appropriately, including construction of exclosures and control of alien species therein, as necessary. The selected material should then be planted. If already-started plants are being set out, care should be taken to match pot soils to those of the site, to minimize differences in water retention around the root areas (i.e., if surrounding soil in the transplant area is more absorptive than the soil used to start the plant, the roots could be overly dried and the newly transplanted specimen could be weakened or could die).

Newly established populations should be monitored carefully (see Task #4) and maintenance should begin soon after initial preparation and planting.

6. Validate recovery objectives.

The scientific validity of the recovery objectives should be reviewed and revised as appropriate as more information becomes available.

61. Determine number of populations and individuals needed for long-term survival.

For each of the Multi-island plants, the number of populations and the number of individuals needed for long-term survival should be determined.

62. Refine/revise downlisting and delisting criteria.

Based on scientific information gathered during recovery efforts (e.g., data on viable population sizes, longevity, etc.), recovery criteria for each of the Multi-island plants should be revised. Until this additional information is available, the criteria presented in this recovery plan should be used as the bases for downlisting and delisting.

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IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated cost for the Multi-island plants recovery program, as set forth in this recovery plan. It is a guide for meeting the objectives discussed in Part II of this Plan. This schedule indicates task priority, task numbers, task descriptions, durations of tasks, the organizations involved and/or responsible for committing funds, and lastly, estimated costs. When more than one organization is listed as the responsible party, an asterisk is used to identify the lead entity.

The actions identified in the Implementation Schedule, when accomplished, should protect habitat for the taxa, stabilize the existing populations, and increase the population sizes and numbers. Monetary needs for all parties involved are identified to reach this point, whenever feasible.

Priorities in Column 1 of the following Implementation Schedule are assigned as follows:

Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.

Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to provide for full recovery of the species.

Key to Acronyms Used in the Implementation Schedule:

BOT	—	Various Botanical Gardens (e.g., National Tropical Botanical Garden, Lyon Arboretum, Waimea Botanical Garden, etc.)
BRD	—	Biological Resources Division, U.S. Geological Survey
C	—	Task will need to be performed continuously or repeatedly
DLNR	—	Hawaii Department of Land and Natural Resources
DOD	—	U.S. Department of Defense
FWS-PIE	—	U.S. Fish & Wildlife Service, Pacific Islands Ecoregion, Honolulu, Hawaii
HDOA	—	Hawaii Department of Agriculture
NPS	—	National Park Service
O	—	Task is ongoing
OTHER	—	Various private landowners
TBD	—	Funding or timing of the task has not been determined
TNCH	—	The Nature Conservancy of Hawaii
*	—	Party with lead responsibility

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE MULTI-ISLAND PLANTS

Priority #	Task #	Task Description	Duration (Yrs)	Responsible Party	Total cost, 1999-2013	Cost estimates, by fiscal year, in thousands of dollars. 1999	2000	2001	2002	2003
1	11	Identify and map all extant wild populations	5	DLNR*	525.0	105	105	105	105	105
				FWS-PIE	50.0	10	10	10	10	10
				DOD	125.0	25	25	25	25	25
				NPS	50.0	10	10	10	10	10
				TNCH	90.0	18	18	18	18	18
1	12	Delineate management units	3	FWS-PIE*	15.0	–	5	5	5	–
				DLNR	12.0	–	4	4	4	–
				TNCH	TBD	–	–	–	–	–
1	13	Ensure long-term protection of habitat	O	DLNR*	150.0	10	10	10	10	10
				NPS	45.0	3	3	3	3	3
				DOD	120.0	8	8	8	8	8
				OTHER	120.0	8	8	8	8	8
				TNCH	90.0	6	6	6	6	6
				FWS-PIE	75.0	5	5	5	5	5
1	1411	Construct and maintain fencing, wherever possible	C	DLNR*	2,717.0	–	–	209	209	209
				DOD	3,250.0	–	–	250	250	250
				NPS	1,300.0	–	–	100	100	100
				TNCH	2,379.0	–	–	183	183	183
				OTHER	TBD	TBD	–	–	–	–
				FWS-PIE	1,300.0	–	–	100	100	100

Priority #	Task #	Task Description	Duration (Yrs)	Responsible Party	Total cost, 1999-2013	Cost estimates, by fiscal year, in thousands of dollars. 1999	2000	2001	2002	2003
1	142	Conduct alien plant control	O	DLNR*	3,135.0	209	209	209	209	209
				DOD	1,860.0	124	124	124	124	124
				NPS	600.0	40	40	40	40	40
				TNCH	1,365.0	91	91	91	91	91
				OTHER	TBD	TBD	-	-	-	-
				FWS-PIE	300.0	20	20	20	20	20
1	143	Provide necessary fire protection	C	DLNR*	1,176.0	-	84	84	84	84
				DOD	1,050.0	-	75	75	75	75
				TNCH	770.0	-	55	55	55	55
				NPS	280.0	-	20	20	20	20
				FWS-PIE	140.0	-	10	10	10	10
1	144	Control rodents, if necessary	TBD	DLNR*	TBD	TBD	-	-	-	-
				FWS-PIE	TBD	TBD	-	-	-	-
				TNCH	TBD	TBD	-	-	-	-
				NPS	TBD	TBD	-	-	-	-
				DOD	TBD	TBD	-	-	-	-
1	145	Propagate and maintain genetic stock of each taxon *ex situ*	O	DLNR*	2,505.0	167	167	167	167	167
				FWS-PIE	150.0	10	10	10	10	10
				DOD	555.0	37	37	37	37	37
				BOT	495.0	33	33	33	33	33
				NPS	225.0	15	15	15	15	15

Priority #	Task #	Task Description	Duration (Yrs)	Responsible Party	Total cost, 1999-2013	Cost estimates, by fiscal year, in thousands of dollars. 1999	2000	2001	2002	2003
1	146	Ensure availability of pollination vectors	C	DLNR*	492.0	–	–	–	41	41
				FWS-PIE	120.0	–	–	–	10	10
				DOD	300.0	–	–	–	25	25
				NPS	120.0	–	–	–	10	10
1	147	Protect areas from human disturbance	O	DOD	375.0	25	25	25	25	25
				DLNR*	615.0	41	41	41	41	41
				NPS	150.0	10	10	10	10	10
				TNCH	270.0	18	18	18	18	18
				OTHER	195.0	13	13	13	13	13
				FWS-PIE	75.0	5	5	5	5	5
1	148	Control insects and/or disease, if necessary	TBD	DLNR*	TBD	TBD	–	–	–	–
				DOD	TBD	TBD	–	–	–	–
				NPS	TBD	TBD	–	–	–	–
				TNCH	TBD	TBD	–	–	–	–
				FWS-PIE	TBD	TBD	–	–	–	–
1	149	Control all other identified threats	TBD	DLNR*	TBD	TBD	–	–	–	–
				DOD	TBD	TBD	–	–	–	–
				NPS	TBD	TBD	–	–	–	–
				TNCH	TBD	TBD	–	–	–	–
				OTHER	TBD	TBD	–	–	–	–
				FWS-PIE	TBD	TBD	–	–	–	–

Priority #	Task #	Task Description	Duration (Yrs)	Responsible Party	Total cost, 1999-2013	Cost estimates, by fiscal year, in thousands of dollars. 1999	2000	2001	2002	2003
2	1412	Evaluate the potential for eradication programs for control of ungulates	3	DLNR*	30.0	-	10	10	10	-
				OTHER	TBD	TBD	-	-	-	-
				FWS-PIE	15.0	-	5	5	5	-
NEED 1 (Protect habitat and control threats) cost subtotals					**30,416.0**	**1,093**	**1,361**	**2,290**	**2,371**	**2,361**
2	21	Select populations for expansion	2	DLNR*	8.0	-	-	-	4	4
				OTHER	10.0	-	-	-	5	5
				TNCH	4.0	-	-	-	2	2
				FWS-PIE	4.0	-	-	-	2	2
2	22	Prepare sites and plant	TBD	DLNR*	TBD	-	-	-	-	TBD
				TNCH	TBD	-	-	-		TBD
				OTHER	TBD	-	-	-	-	TBD
				FWS-PIE	TBD					TBD
NEED 2 (Expand existing wild populations) cost subtotals					**26.0**	**0**	**0**	**0**	**13**	**13**
2	31	Collect diagnostic data on crucial associated ecosystem components	5	BRD*	325.0	65	65	65	65	65
				DLNR	100.0	20	20	20	20	20
2	32	Map alien vegetation	O	BRD*	645.0	43	43	43	43	43
				DLNR	300.0	20	20	20	20	20
				FWS-PIE	150.0	10	10	10	10	10

Priority #	Task #	Task Description	Duration (Yrs)	Responsible Party	Total cost, 1999-2013	Cost estimates, by fiscal year, in thousands of dollars. 1999	2000	2001	2002	2003
2	33	Study various aspects of growth	5	BRD*	215.0	43	43	43	43	43
				DLNR	100.0	20	20	20	20	20
				FWS-PIE	50.0	10	10	10	10	10
2	34	Study reproductive viability	5	BRD*	215.0	43	43	43	43	43
				DLN	100.0	20	20	20	20	20
				FWS-PIE	50.0	10	10	10	10	10
2	35	Determine parameters of viable populations	5	FWS-PIE*	100.0	20	20	20	20	20
				BRD	110.0	22	22	22	22	22
2	36	Determine effects of insects and/or diseases, and develop control methods, as needed	TBD	DLNR*	TBD	TBD	–	–	–	–
				FWS-PIE	TBD	TBD	–	–	–	–
				BRD	TBD	TBD	–	–	–	–
2	37	Identify and test potential biocontrol agents for host specificity and efficacy of control	TBD	HDOA	TBD	TBD	–	–	–	–
2	38	Evaluate results and use in future management	O	DLNR*	60.0	4	4	4	4	4
				FWS-PIE	30.0	2	2	2	2	2
NEED 3 (Conduct essential research) cost subtotals					**2,550.0**	**352**	**352**	**352**	**352**	**352**

Priority #	Task #	Task Description	Duration (Yrs)	Responsible Party	Total cost, 1999-2013	Cost estimates, by fiscal year, in thousands of dollars. 1999	2000	2001	2002	2003
3	4	Develop and implement long-term monitoring programs for all species	C	DLNR*	240.0	–	–	–	20	20
				NPS	60.0	–	–	–	5	5
				DOD	144.0	–	–	–	12	12
				BOT	132.0	–	–	–	11	11
				TNCH	108.0	–	–	–	9	9
				FWS-PIE	60.0	–	–	–	5	5
NEED 4 (Develop and maintain monitoring plans) cost subtotals					**744.0**	**0**	**0**	**0**	**62**	**62**
3	51	Investigate feasibility and desirability of reintroduction	2	FWS-PIE*	10.0	–	–	–	–	–
				DLNR	20.0	–	–	–	–	–
				BRD	TBD	–	–	–	–	–
3	52	Develop and implement specific plans for reestablishment	TBD	FWS-PIE*	TBD	TBD	–	–	–	–
				DLNR	TBD	TBD	–	–	–	–
				BRD	TBD	TBD	–	–	–	–
				TNCH	TBD	TBD	–	–	–	–
				OTHER	TBD	TBD	–	–	–	–
NEED 5 (Reestablish wild populations within the historic range) cost subtotals					**30.0**	**0**	**0**	**0**	**0**	**5,453**

Priority #	Task #	Task Description	Duration (Yrs)	Responsible Party	Total cost, 1999-2013	Cost estimates, by fiscal year, in thousands of dollars. 1999	2000	2001	2002	2003
3	61	Determine number of populations and individuals needed for long-term survival	2	FWS-PIE*	10.0	-	-	-	-	-
				DLNR	20.0	-	-	-	-	-
				BRD	22.0	-	-	-	-	-
3	62	Refine/revise downlisting and delisting criteria	2	FWS-PIE*	10.0	-	-	-	-	-
				DLNR	20.0	-	-	-	-	-
				BRD	22.0	-	-	-	-	-
NEED 6 (Validate recovery criteria) cost subtotals					**134.0**	**0**	**0**	**0**	**0**	**0**
TOTAL ESTIMATED COST					**33,900.0**	**1,285**	**1,498**	**2,247**	**2,392**	**2,382**

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Director of Science and Stewardship
The Nature Conservancy of Hawaii
1116 Smith Street, Suite 201
Honolulu, HI 97817

TNC Preserves
Ms. Heather Cole
The Nature Conservancy of Hawaii
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Kamuela, HI 96743

Director, Oahu and Lanai Preserves
The Nature Conservancy of Hawaii
1116 Smith Street, Suite 201
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Mr. Ed Misaki**
Director, Molokai Preserves
The Nature Conservancy of Hawaii
P.O. Box 220
Kualapuu, HI 96757

Barrie Morgan**
The Nature Conservancy of Hawaii
1116 Smith St., Suite 201
Honolulu, HI 96817

Mr. Mark White
Director, Maui Preserves
The Nature Conservancy of Hawaii
P.O. Box 1716
81 Makawao Ave., Suite 203A
Makawao, Maui 96768

Appropriate Landowners/Managers

Natural Resources Development
Alexander and Baldwin, Inc.
822 Bishop Street
Honolulu, HI 96813

Amfac/JMB Hawaii Inc.
700 Bishop Street
Honolulu, HI 96813

James W. Austin Trust
P.O. Box 3467
Honolulu, Hawaii 96801

Trustees
Kamehameha Schools Bishop Estate
Bernice P. Bishop Estate
P.O. Box 3466
Honolulu, HI 96801

C. Brewer and Company, Limited
827 Fort Street
Honolulu, HI 96813

Administrator of Agriculture
Campbell Estate
1001 Kamokila Blvd.
Kapolei, HI 96707

Castle & Cooke
Land Company
P.O. Box 898900
Mililani, HI 96789-8900

Deseret Holding Corporation
55-510 Kamehameha Highway
Laie, HI 96762

Dole Food Co., Inc.
P.O. Box 2990
Honolulu, HI 96802

East Maui Irrigation et al.
P.O. Box H
Paia, HI 96779

Gay and Robinson
P.O. Box 117
Makaweli, HI 96769

Grove Farm Co., Inc.
P.O. Box 2069
Lihue, HI 96766

Manager
Haleakala Ranch
Makawao, HI 96768

Paul C. Hudson Trust, et al.
P. O. Box 16205
Baltimore, MD 21210

Jani Corp.
333 Queen Street 700
Honolulu, HI 96813

Kapua Ventures
745 Grier Drive
Las Vegas, NV 89119

Kawela Plantation Development
Association
P.O. Box G
Kaunakakai, HI 96748

Kealakekua Development Corporation
Box 399
Captain Cook, HI 96704

Kualoa Ranch, Inc.
1000 Bishop Street, Suite 810
Honolulu, HI 96813

Lihue Plantation Co., Ltd.
2970 Kele Street
Lihue, HI 96766

Frank Jahrling, Trustee
Liliuokalani Trust
P.O. Box 3200
Honolulu, HI 96847

MacFarms of Hawaii, Inc.
S.R. Box 25
Captain Cook, HI 96704

Maui Land & Pineapple Co., Inc.
P.O. Box 187
Kahului, HI 96733-6687

McBryde Sugar Company, Inc.
P.O. Box 8
Eleele, HI 96705

McCandless Properties
P.O. Box 497
Honolulu, HI 96809

Minami Group Inc.
45-610 Kionaole Road
Kaneohe, Hawaii 96744

Molokai Ranch, Ltd.
55 Merchant St.
Suite 2020
Box 96
Honolulu, HI 96813

Richard Smart Trust
Parker Ranch
P.O. Box 458
Kamuela, HI 96753

Mr. William Hyde Rice Ltd.
P.O. Box 1391
Lihue, HI 96766

Ulupalakua Ranch Inc.
P.O. Box 901
Kula, HI 96790

Wailuku Agribusiness Co., Inc.
255 E. Waiko Rd
Wailuku, HI 96793

Zions Securities Corporation
55-510 Kamehameha Highway
Laie, HI 96762

(*) - Persons and Agencies who provided information necessary for the development of the Plan

(**) - Personal communication received

APPENDIX B

Line Drawings of Plants

Illustration Acknowledgments

Drawing B2 (*Achyranthes mutica*):

H. St. John, *Pacific Science* 33:333-350, 1979 [1980]. Reproduced by permission of University of Hawaii Press, Honolulu, Hawaii.

Drawings B3 through B14, and B16 through B23:

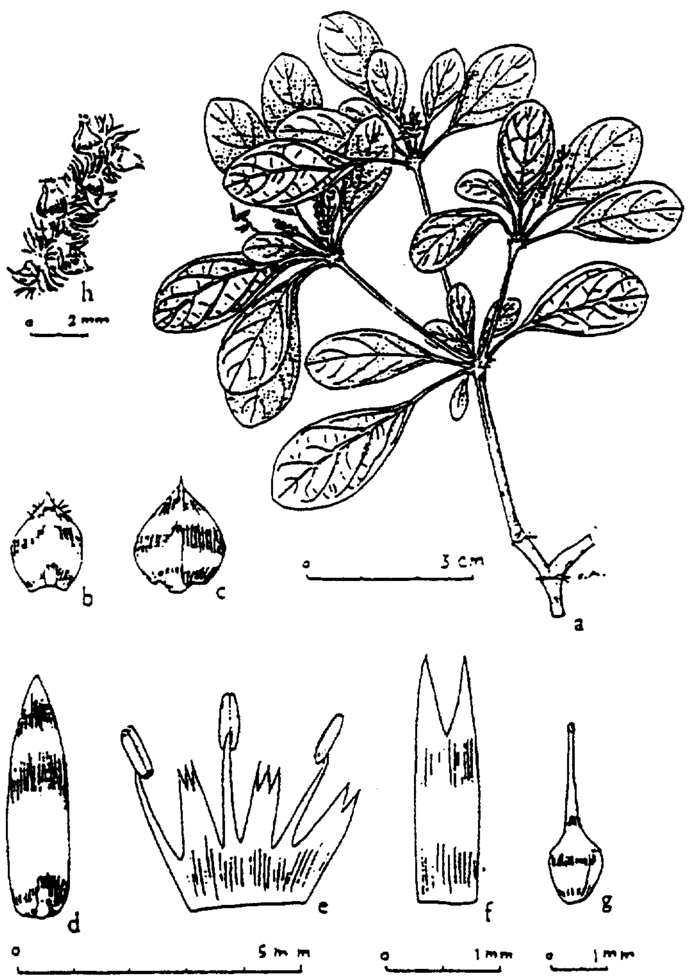
W. L. Wagner, D. R. Herbst, and S. H. Sohmer, *Manual of the Flowering Plants of Hawaii*, University of Hawaii Press and Bishop Museum Press, Honolulu, Hawaii, 1990. Reproduced by permission of Bishop Museum, Honolulu, Hawaii.

Drawing B15 (*Neraudia sericea*):

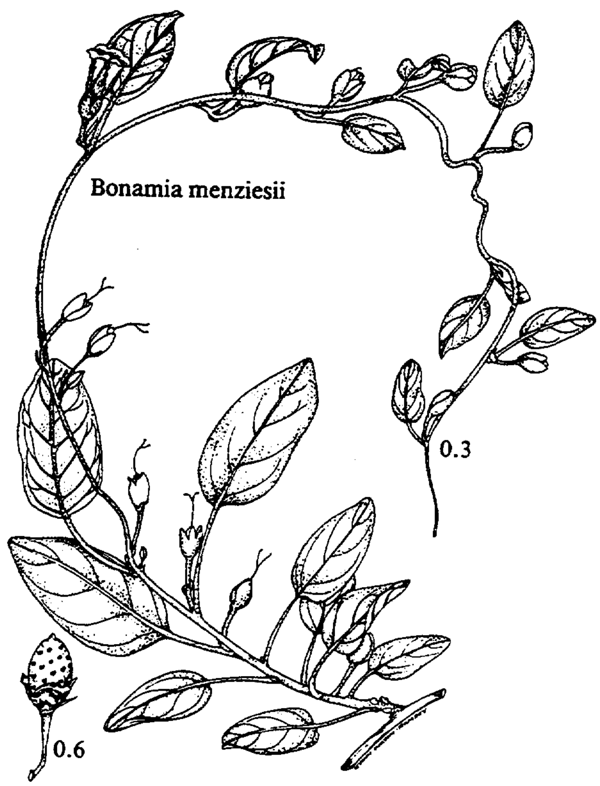
R.S. Cowan, *Pacific Science* 3:231-270, 1949. Reproduced by permission of University of Hawaii Press, Honolulu, Hawaii.

No line drawings were available for the following plants:

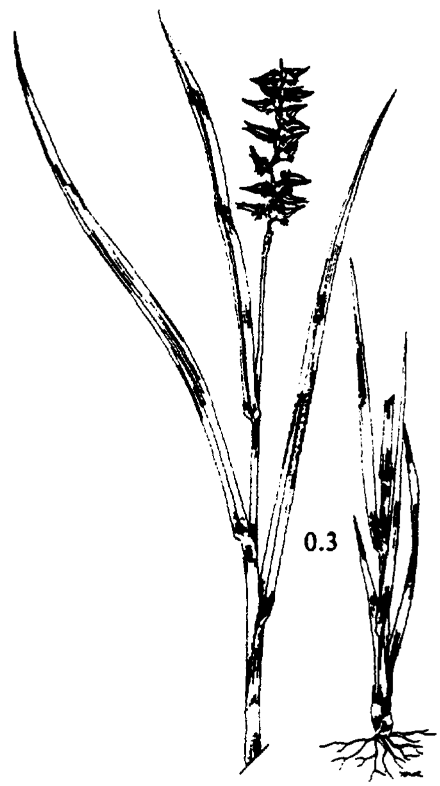
Adenophorus periens
Diellia erecta
Panicum niihauense
Schiedea hookeri
Schiedea nuttallii



Line drawing of *Achyranthes mutica* from St. John (1979).



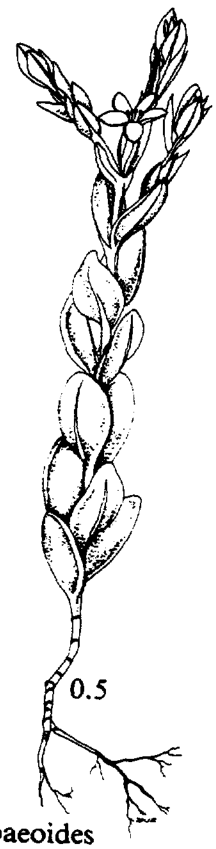
Line drawing of *Bonamia menziesii* from Wagner *et al.* (1990).



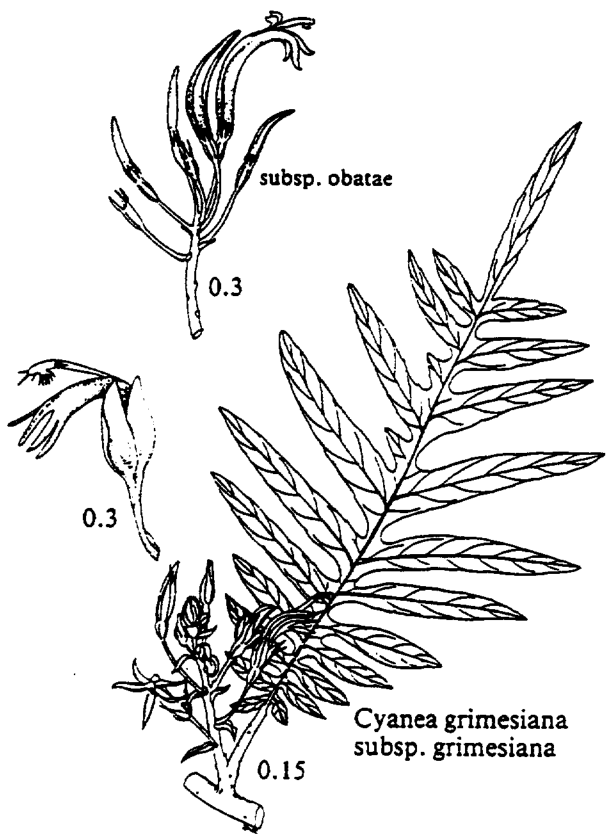
Cenchrus agrimonioides var. agrimonioides

Line drawing of *Cenchrus agrimonioides* var. *agrimonioides* from Wagner *et al.* (1990)

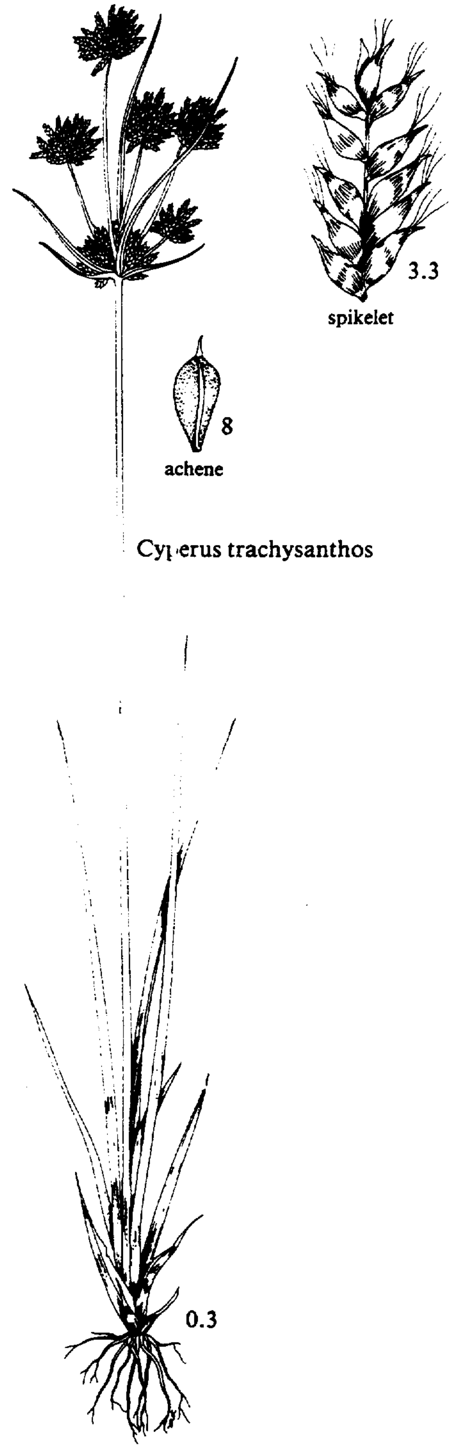
Line drawing of *Cenchrus agrimonioides* var. *laysanensis* from Degener and Whitney (1937)



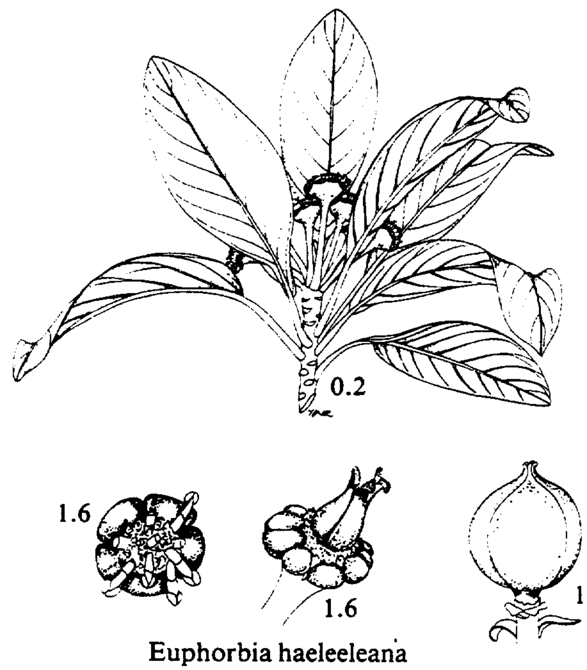
Line drawing of *Centaurium sebaeoides* from Wagner *et al.* (1990).



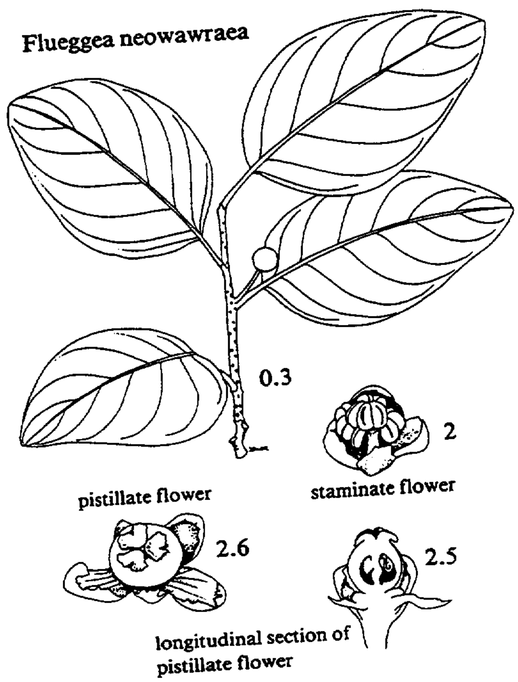
Line drawing of *Cyanea grimesiana* ssp. *grimesiana* from Wagner *et al.* (1990).



Line drawing of *Cyperus trachysanthos* from Wagner *et al.* (1990)



Line drawing of *Euphorbia haeleeleana* from Wagner *et al.* (1990).



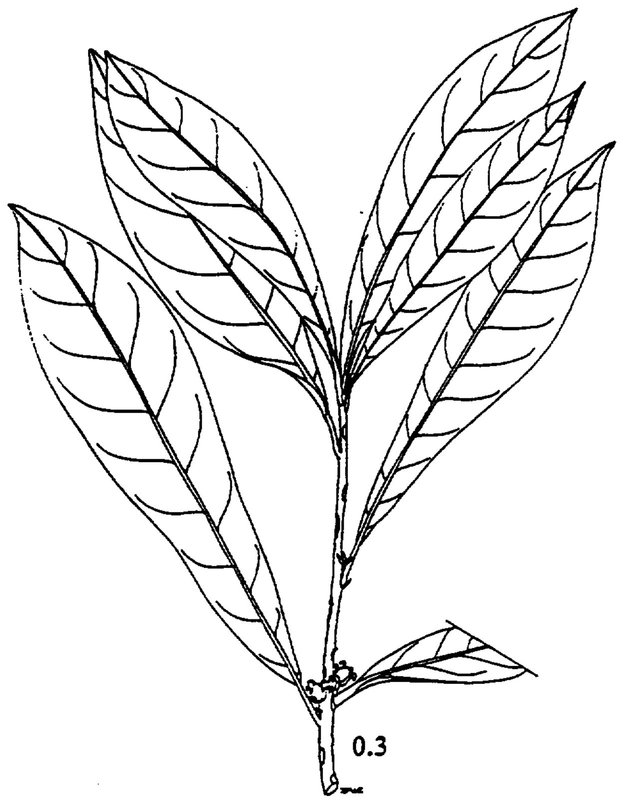
Line drawing of *Flueggea neowawraea* from Wagner *et al.* (1990).

Hibiscus brackenridgei subsp. brackenridgei

Line drawing of *Hibiscus brackenridgei* ssp. *brackenridgei* from Wagner et al. (1990).

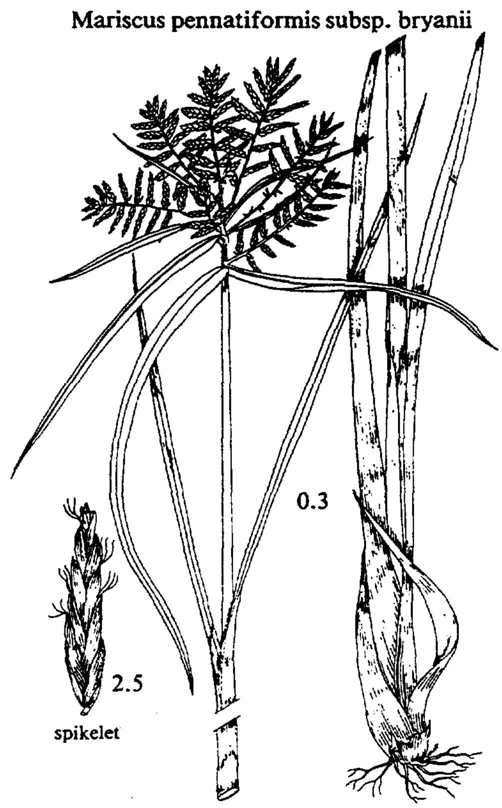
Isodendrion laurifolium

Line drawing of *Isodendrion laurifolium* from Wagner *et al.* (1990).

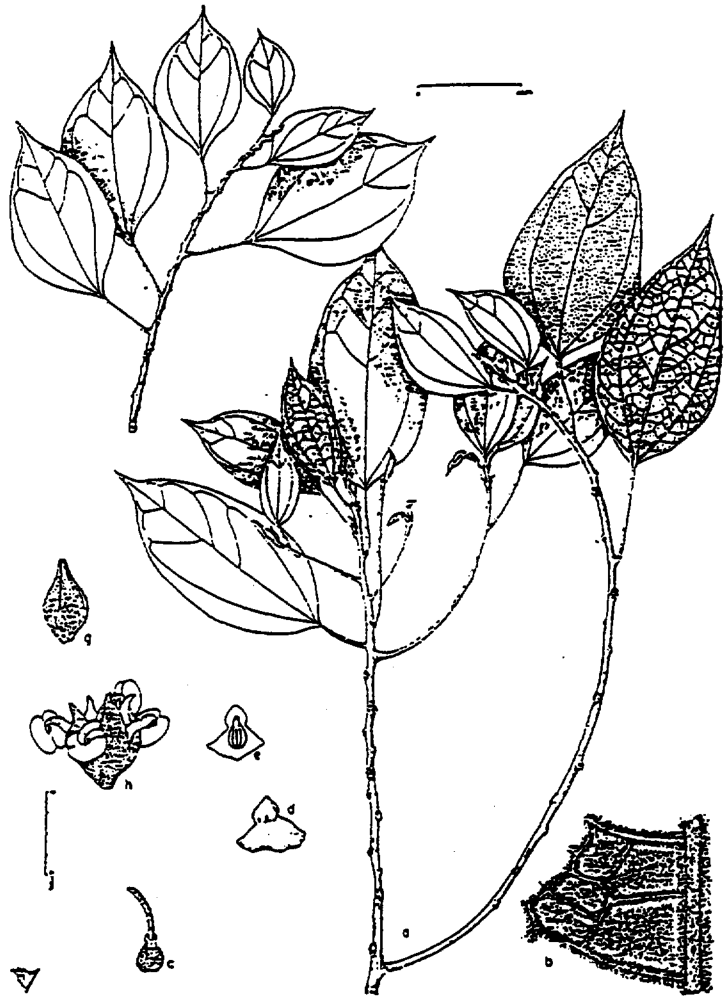


Isodendrion longifolium

Line drawing of *Isodendrion longifolium* from Wagner *et al.* (1990).



Line drawing of *Mariscus pennatiformis* ssp. *bryanii* from Wagner *et al.* (1990).



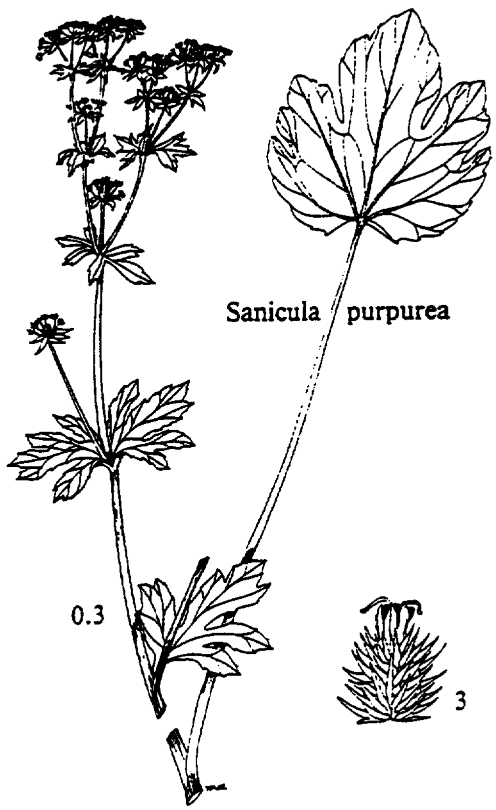
Line drawing of *Neraudia sericea* from Cowan (1945).

Line drawing of *Phyllostegia parviflora* var. *parviflora* from Wagner *et al.* (1990).

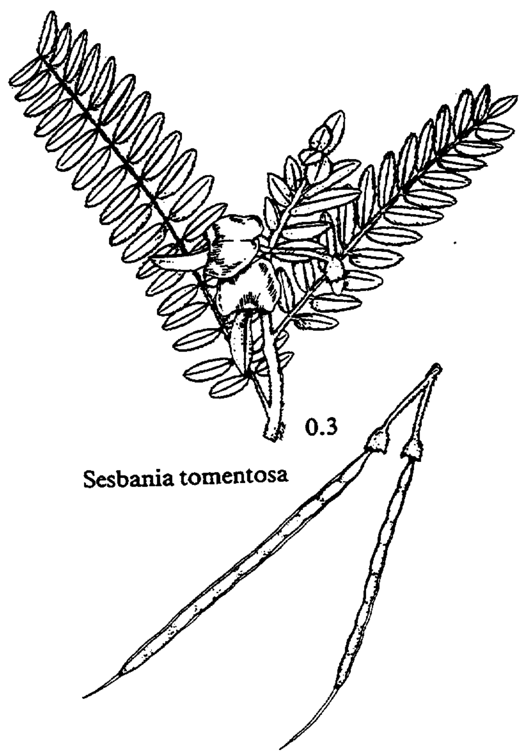
Plantago princeps var. laxiflora

Line drawing of *Plantago princeps* var. *laxiflora* from Wagner *et al.* (1990).

Line drawing of *Platanthera holochila* from Wagner *et al.* (1990).



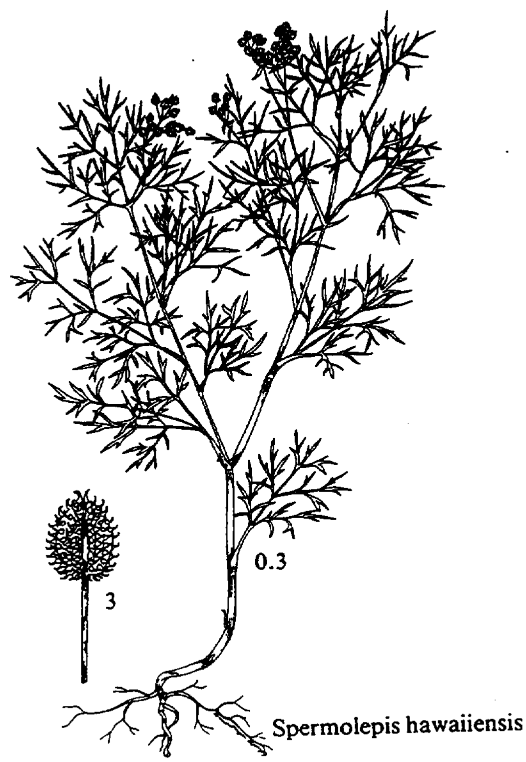
Line drawing of *Sanicula purpurea* from Wagner *et al.* (1990).



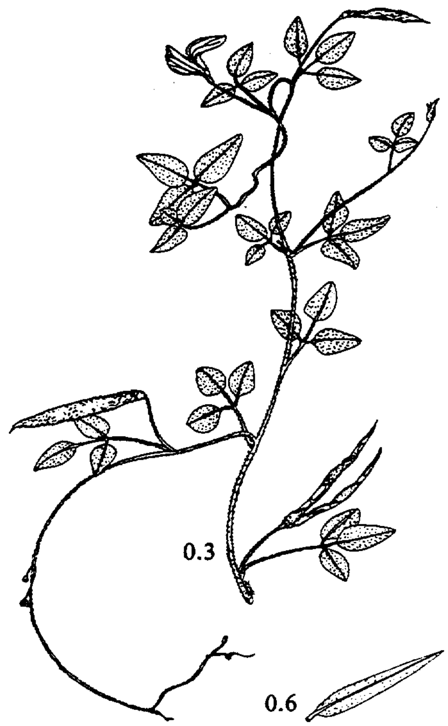
Line drawing of *Sesbania tomentosa* from Wagner *et al.* (1990).

Solanum incompletum

Line drawing of *Solanum incompletum* from Wagner *et al.* (1990).



Line drawing of *Spermolepis hawaiiensis* from Wagner *et al.* (1990).



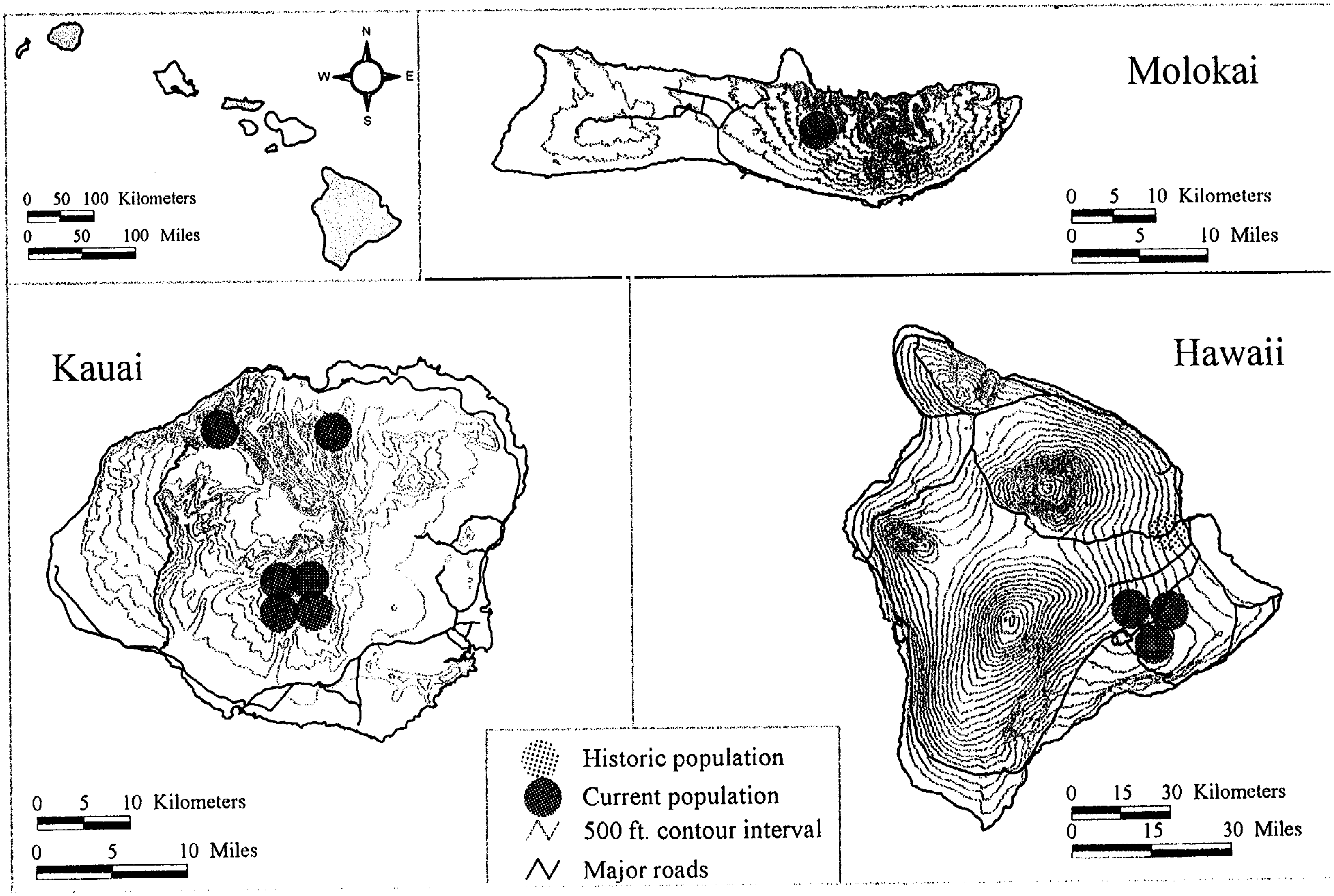
Vigna o-wahuensis

Line drawing of *Vigna o-wahuensis* from Wagner *et al.* (1990).

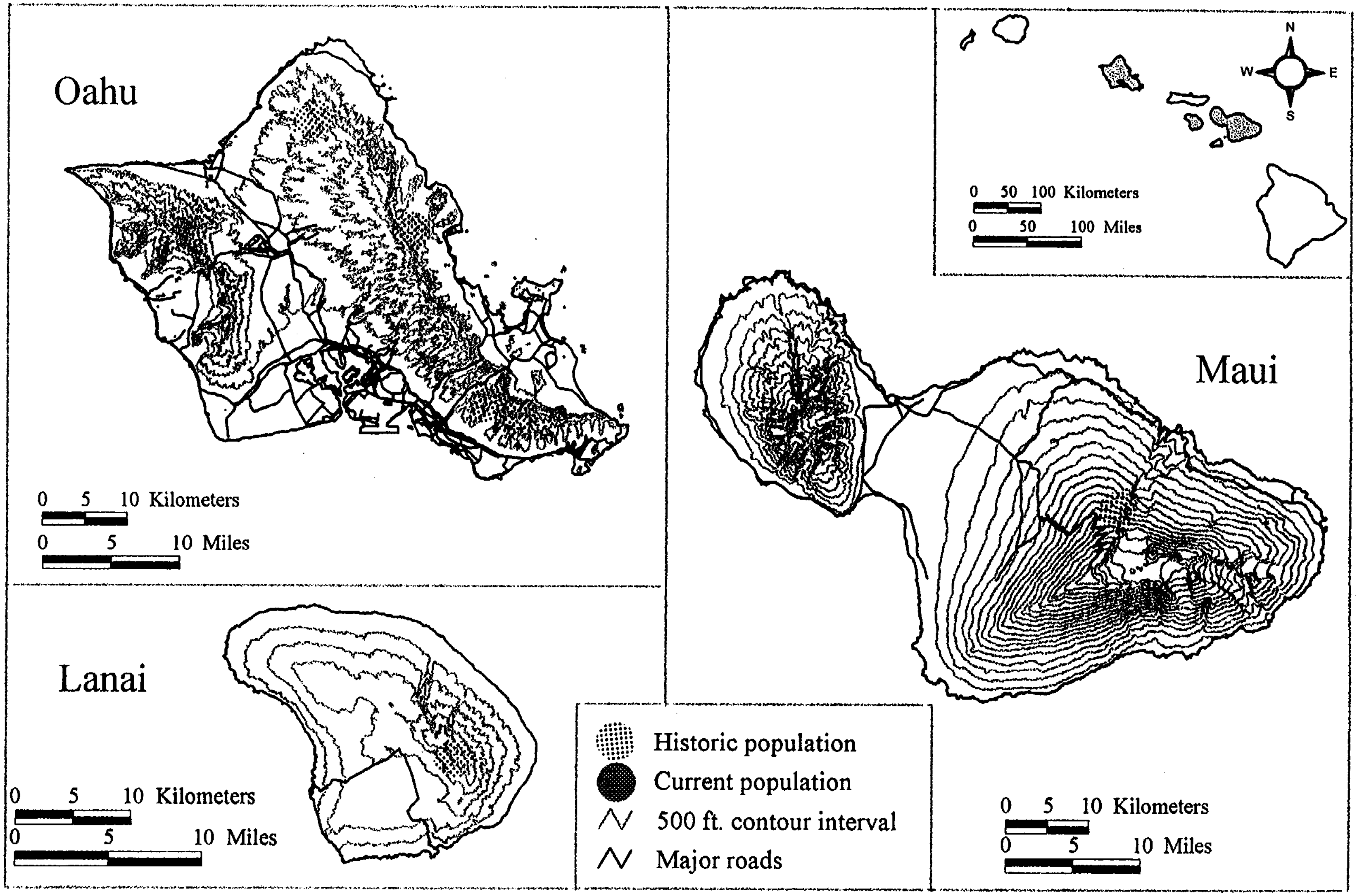
APPENDIX C

Historic and Current Distribution Maps

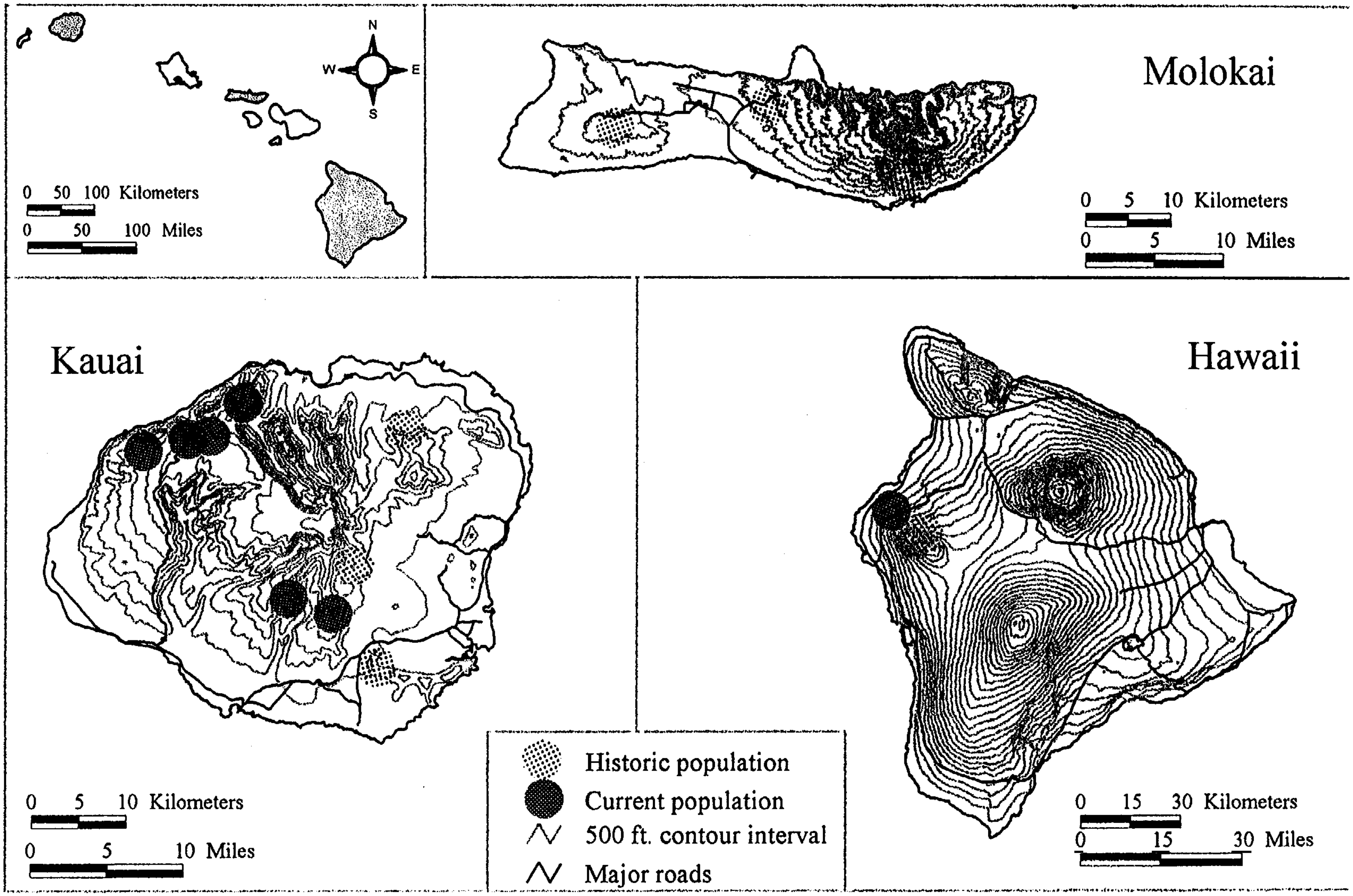
Historic distributions are estimates based on the best available information.



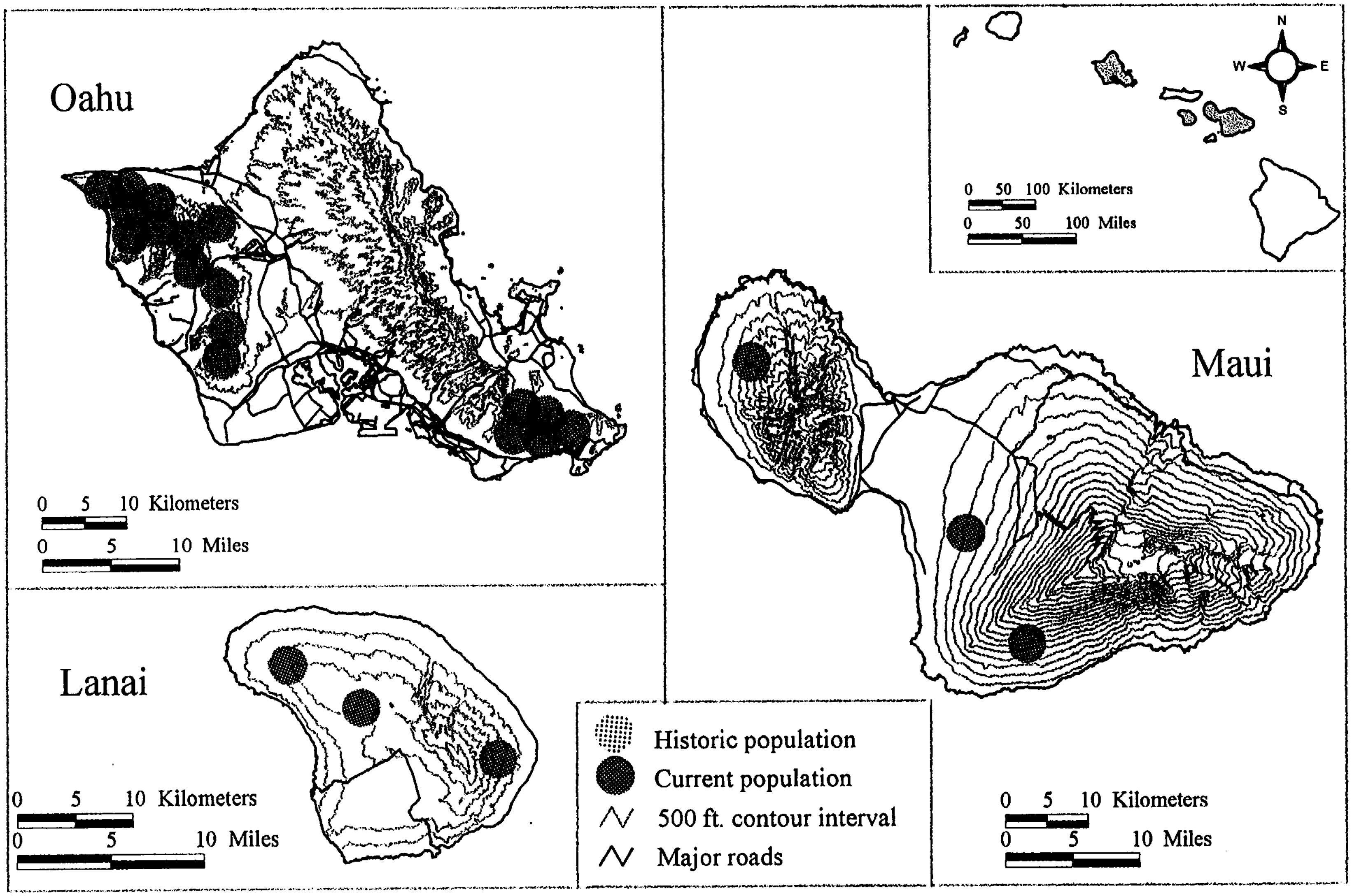
Current range and historical occurrences of *Adenophorus periens* (1 of 2).



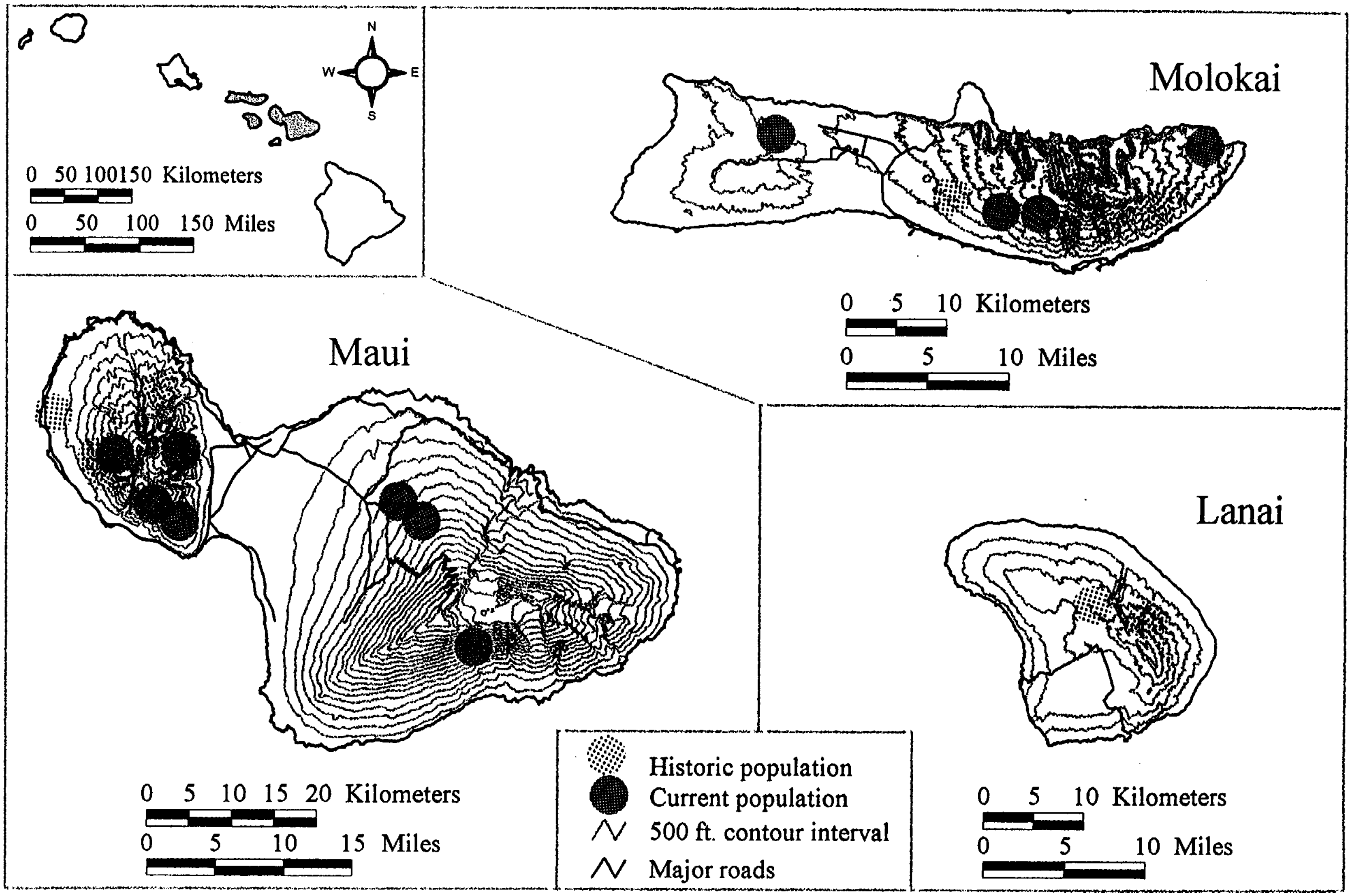
Current range and historical occurrences of *Adenophorus periens* (2 of 2).



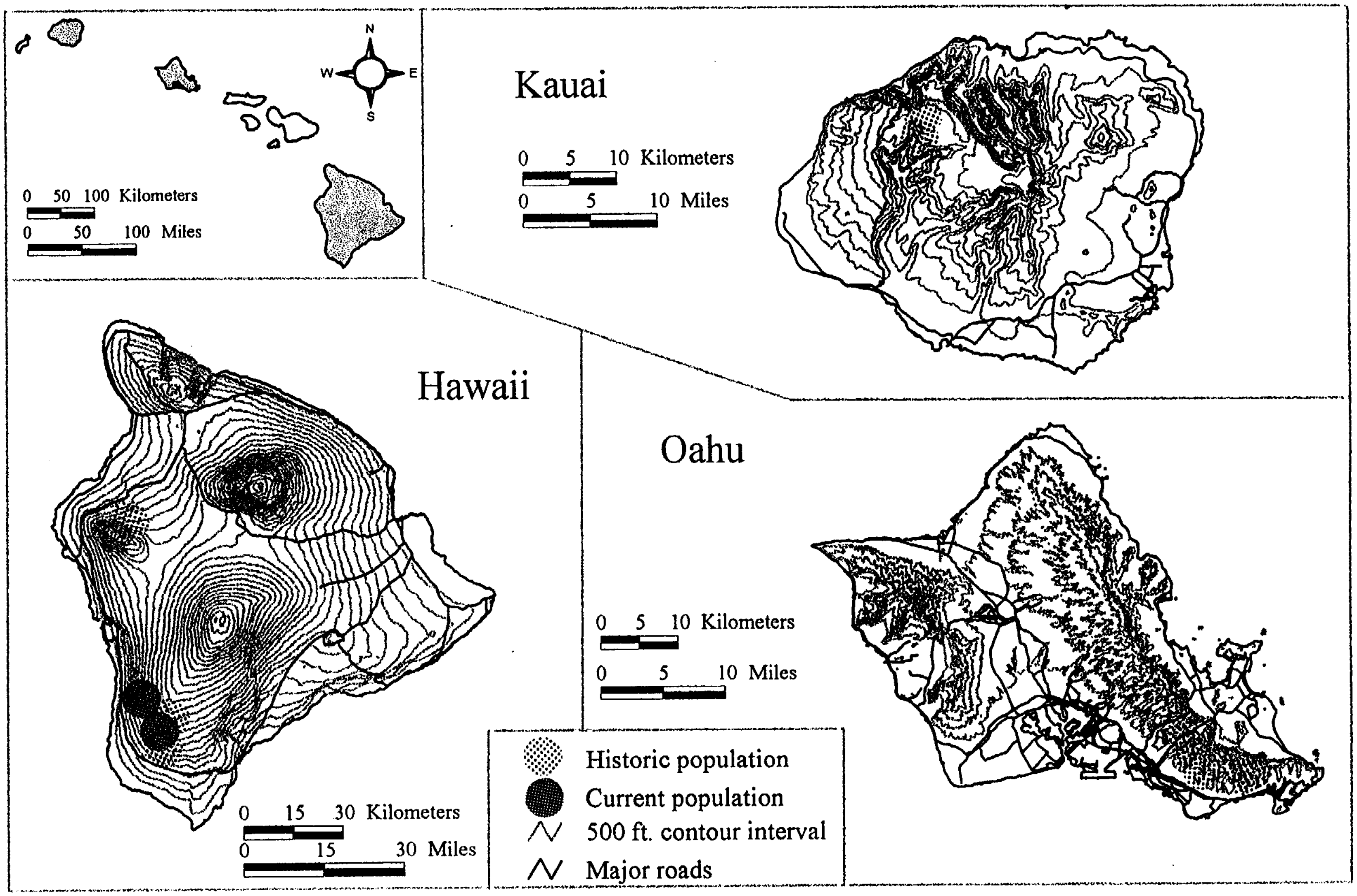
Current range and historical occurrences of *Bonamia menziesii* (1 of 2).



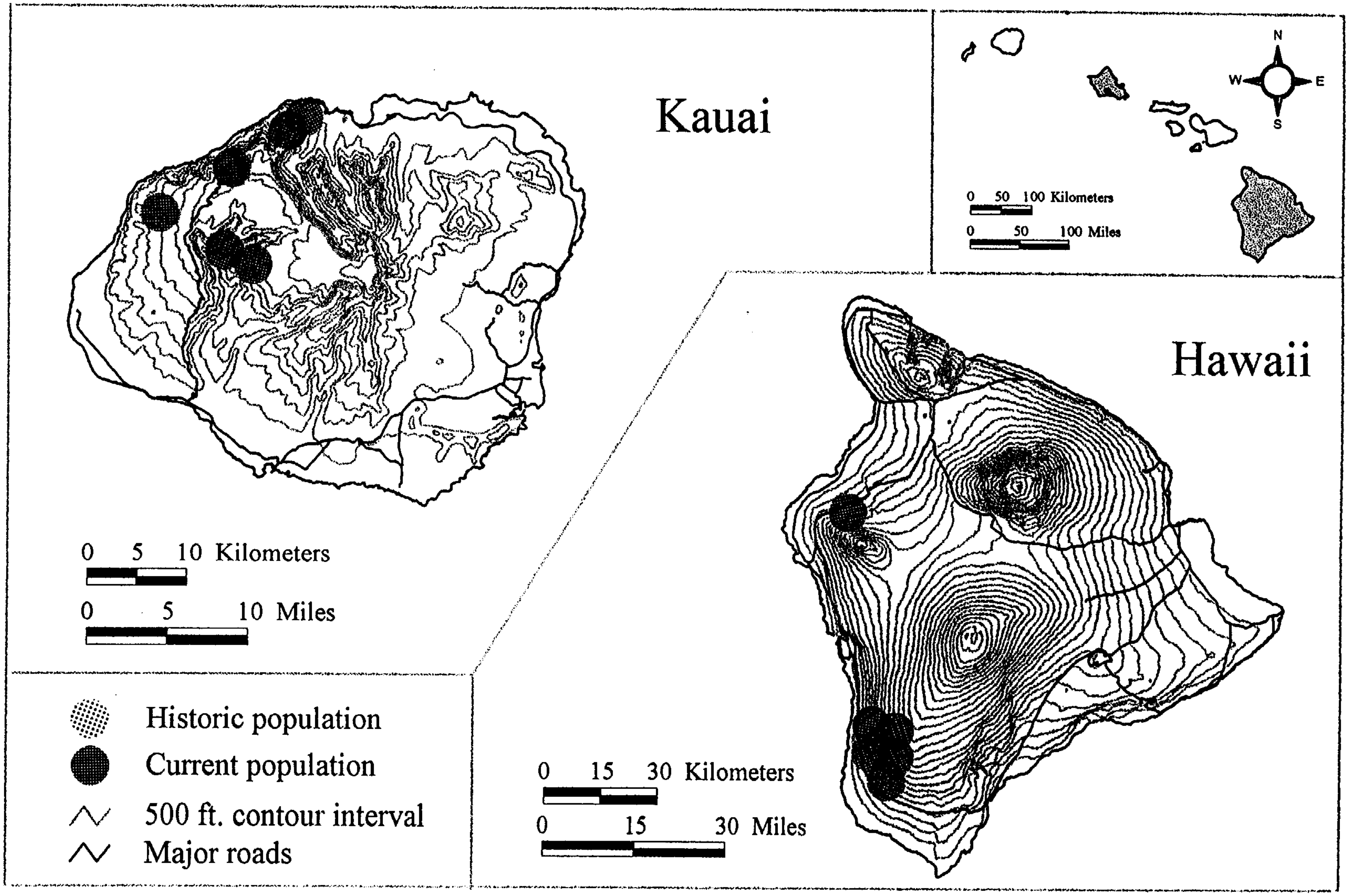
Current range and historical occurrences of *Bonamia menziesii* (2 of 2).



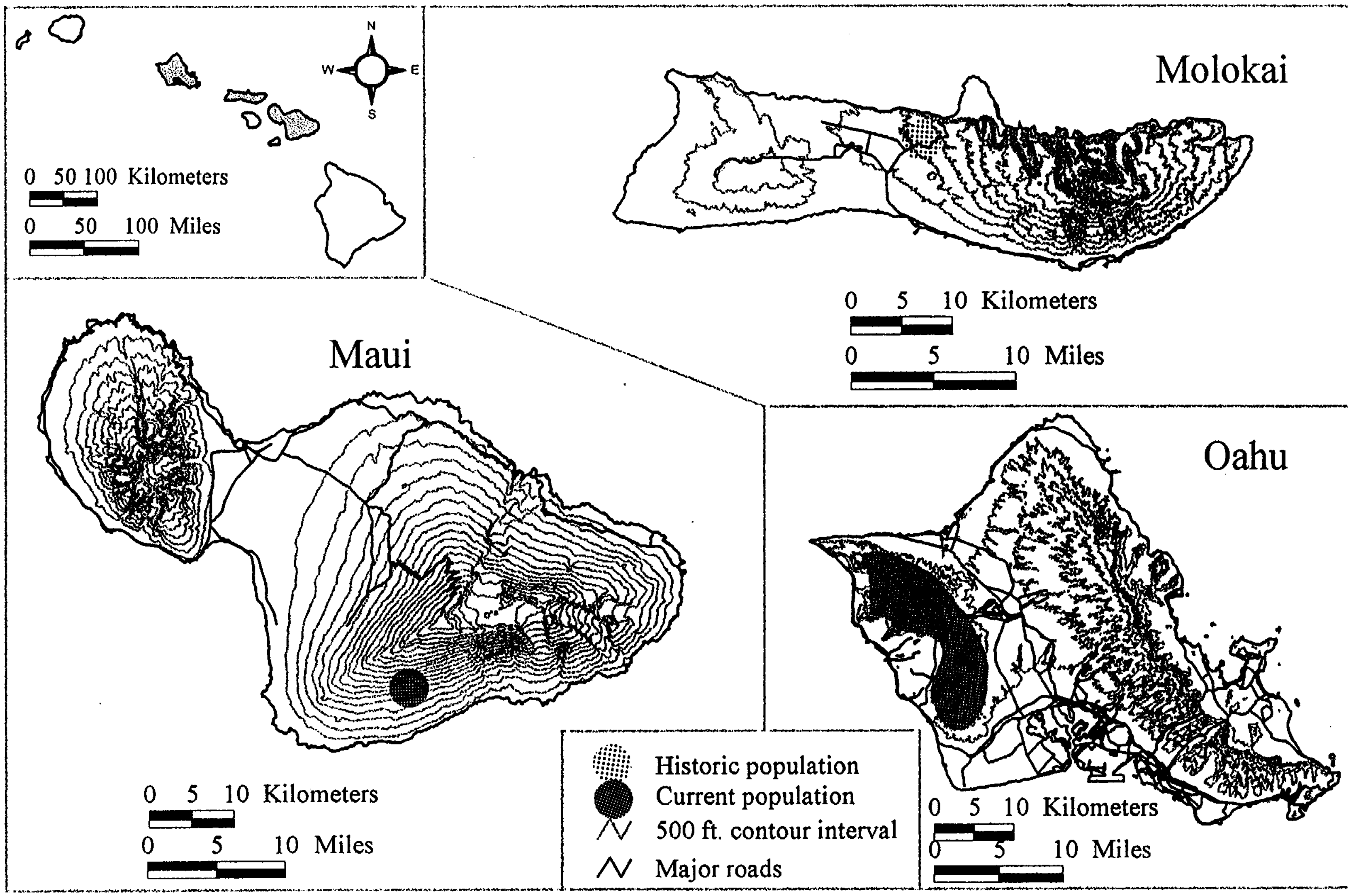
Current range and historical occurrences of *Diellia erecta* (1 of 2).



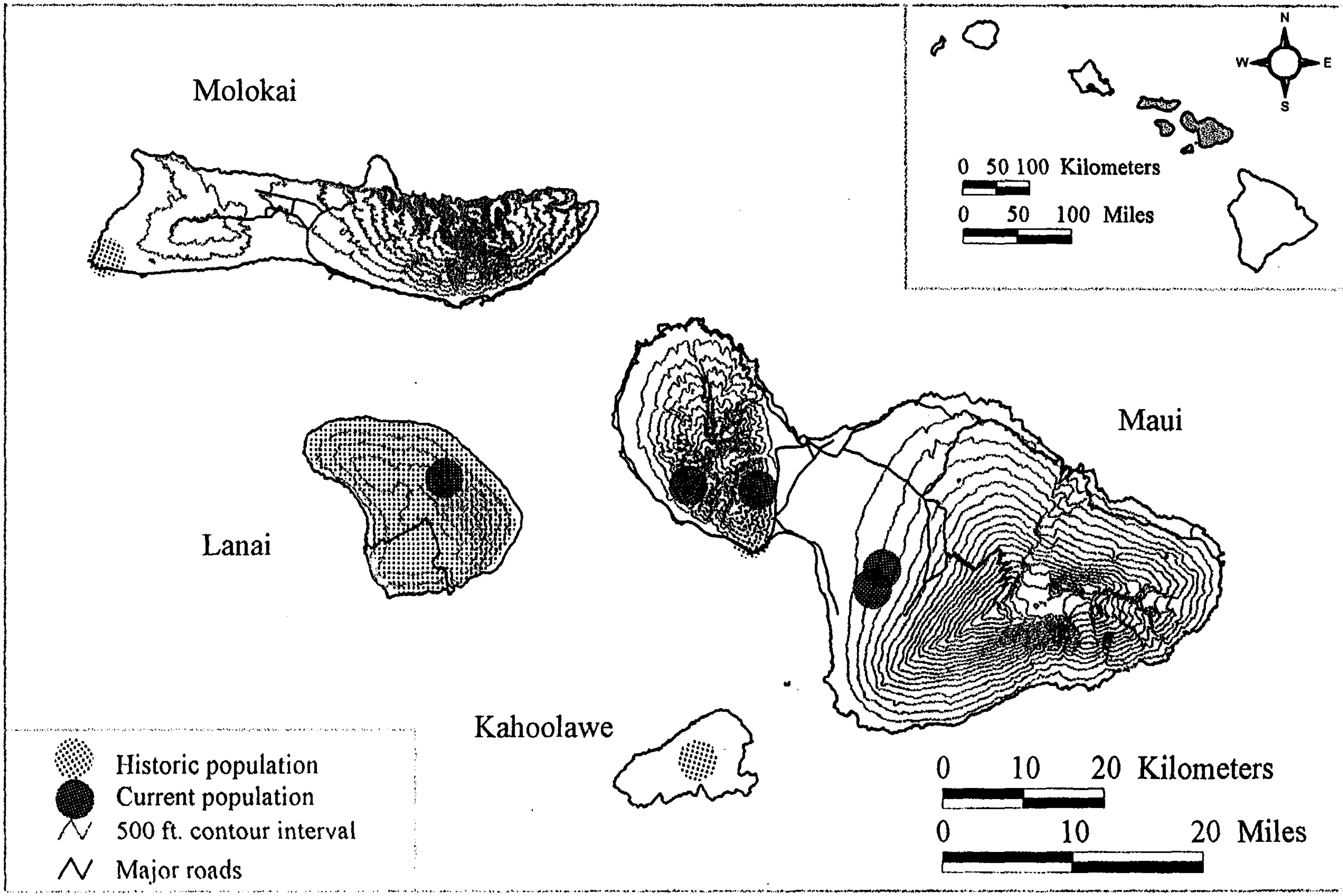
Current range and historical occurrences of *Diellia erecta* (2 of 2).



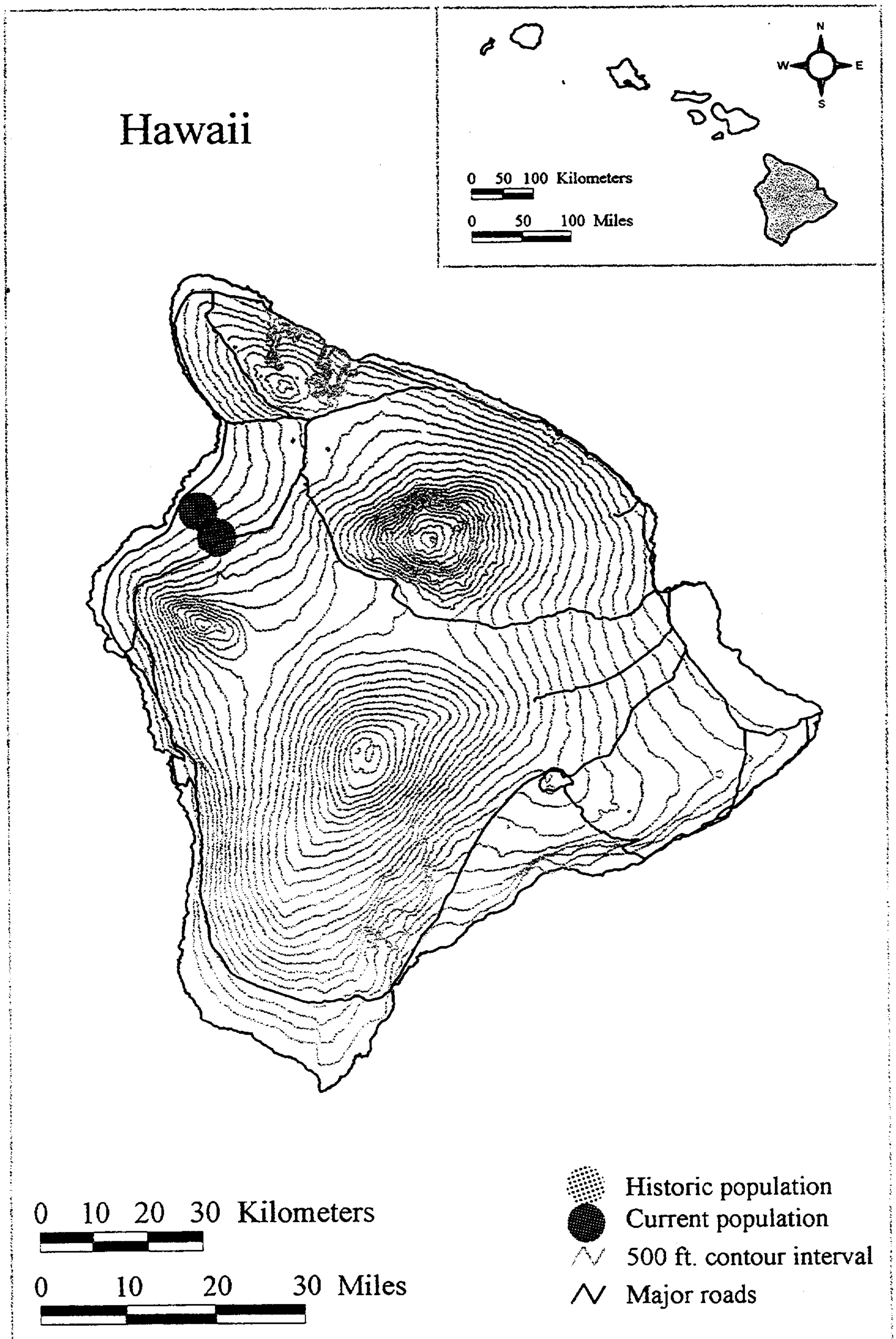
Current range and historical occurrences of *Flueggea neowawraea* (1 of 2).



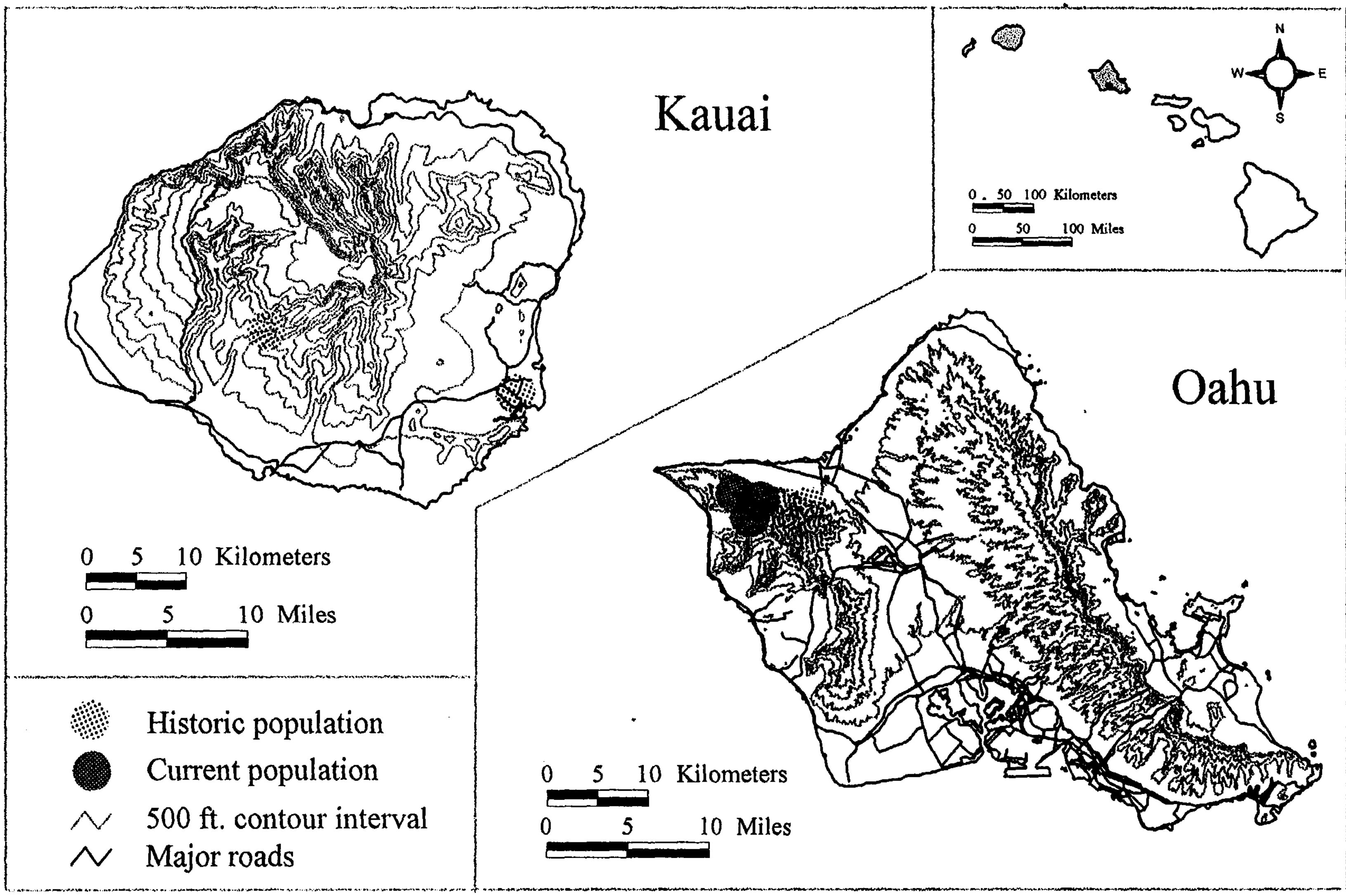
Current range and historical occurrences of *Flueggea neowawraea* (2 of 2).



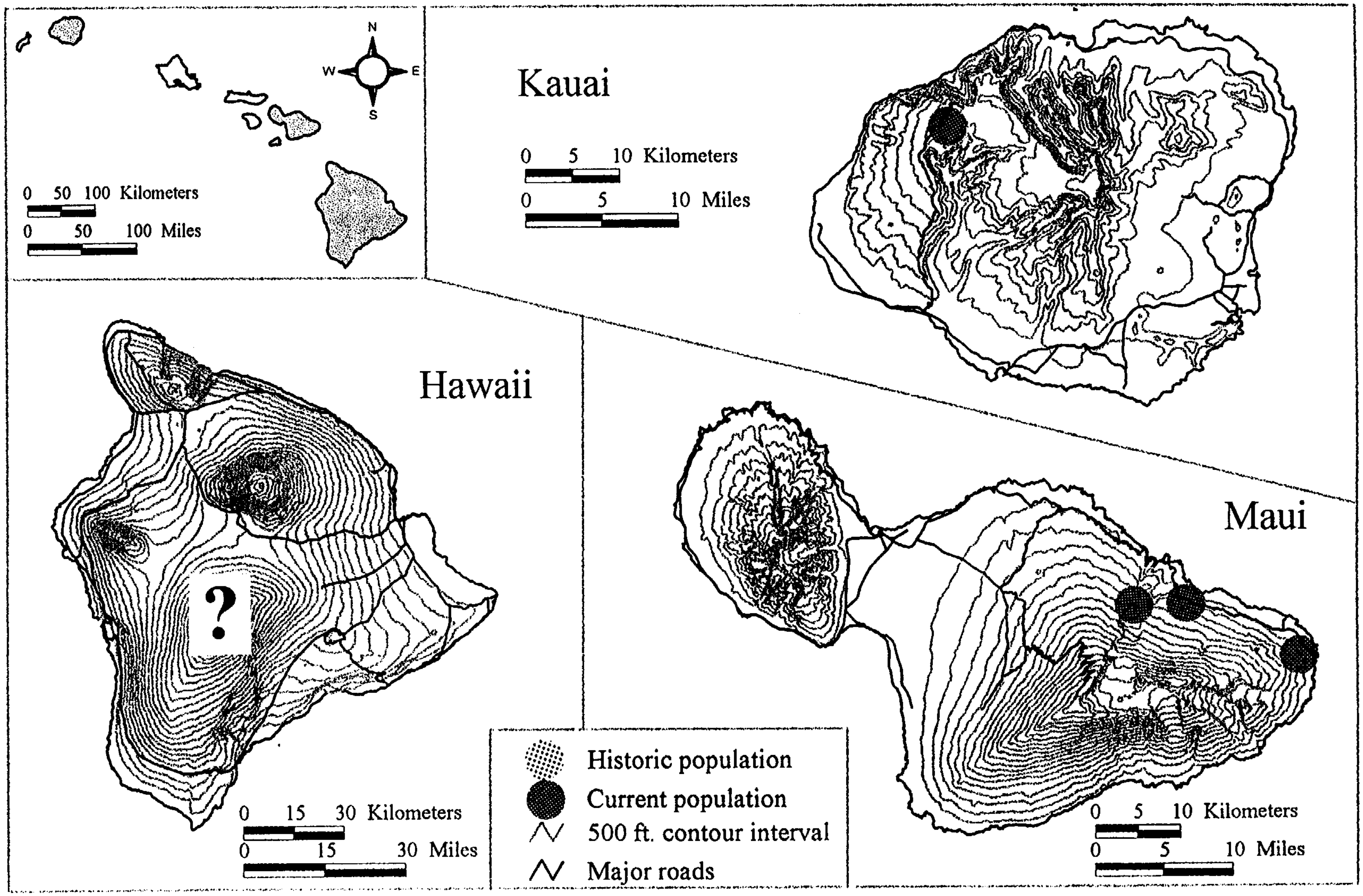
Current range and historical occurrences of *Hibiscus brackenridgei* ssp. *brackenridgei* (1 of 2).



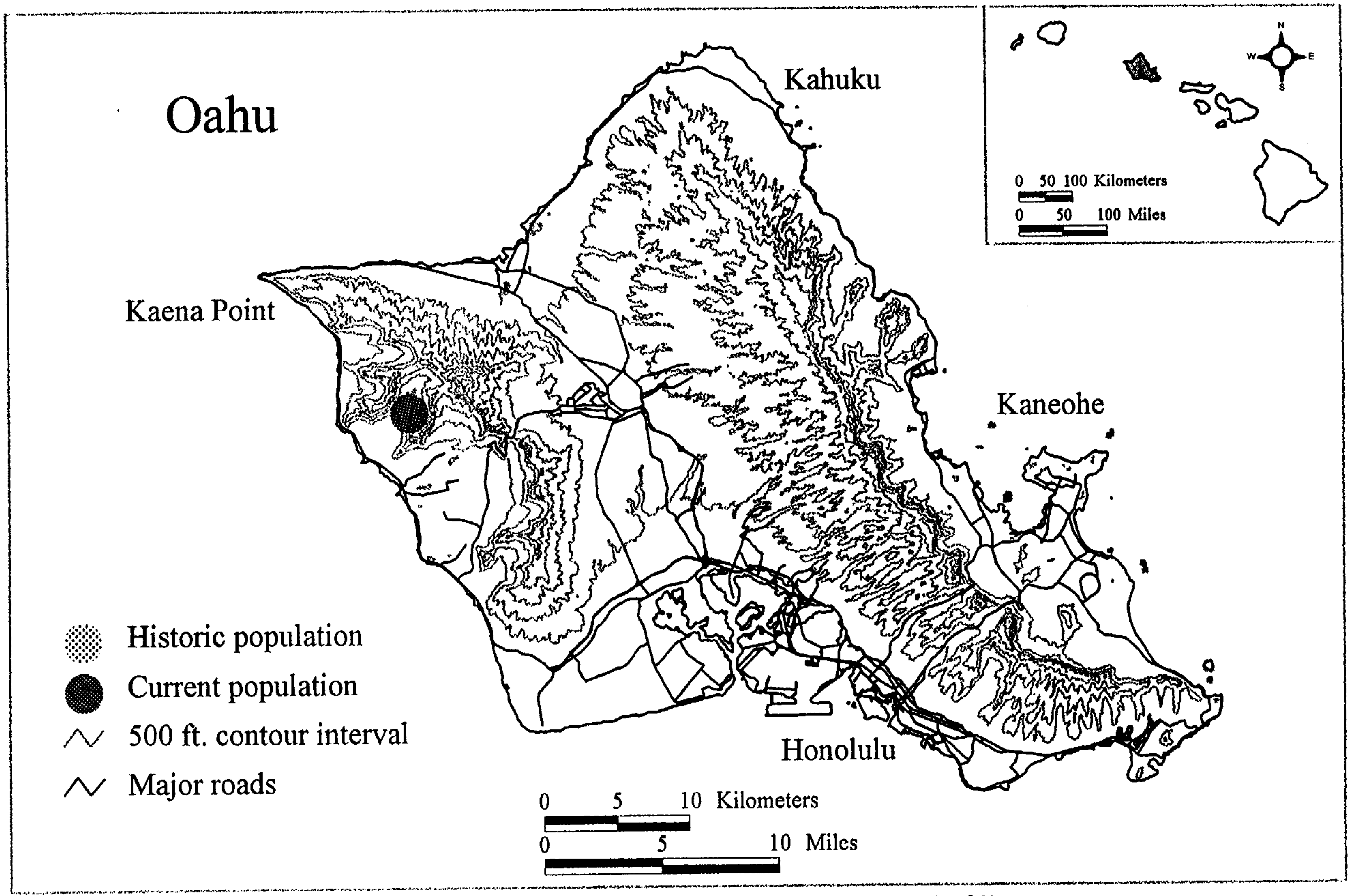
Current range and historical occurrences of *Hibiscus brackenridgei* ssp. *brackenridgei* (2 of 2).



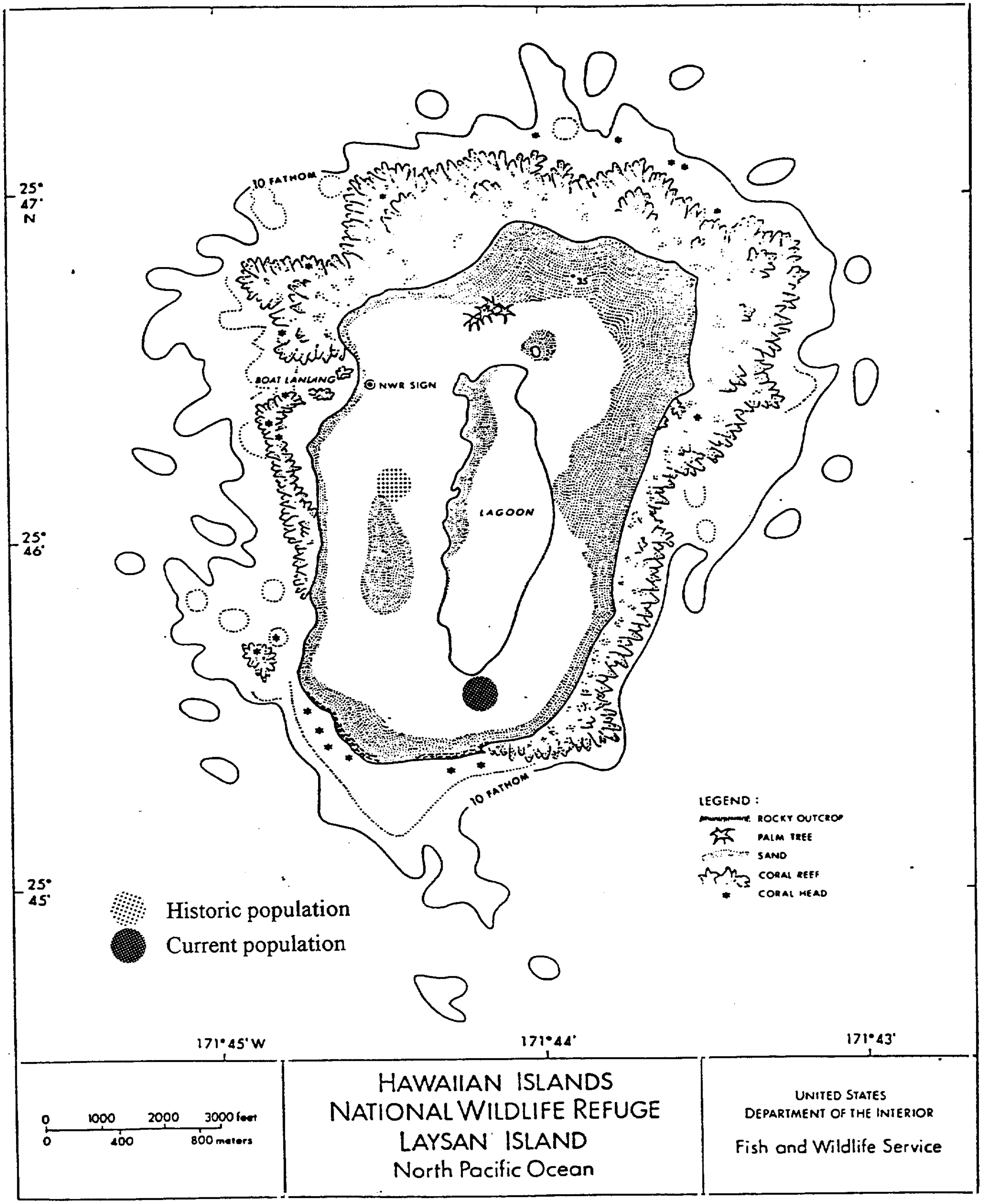
Current range and historical occurrences of *Hibiscus brackenridgei* ssp. *mokuleianus*.



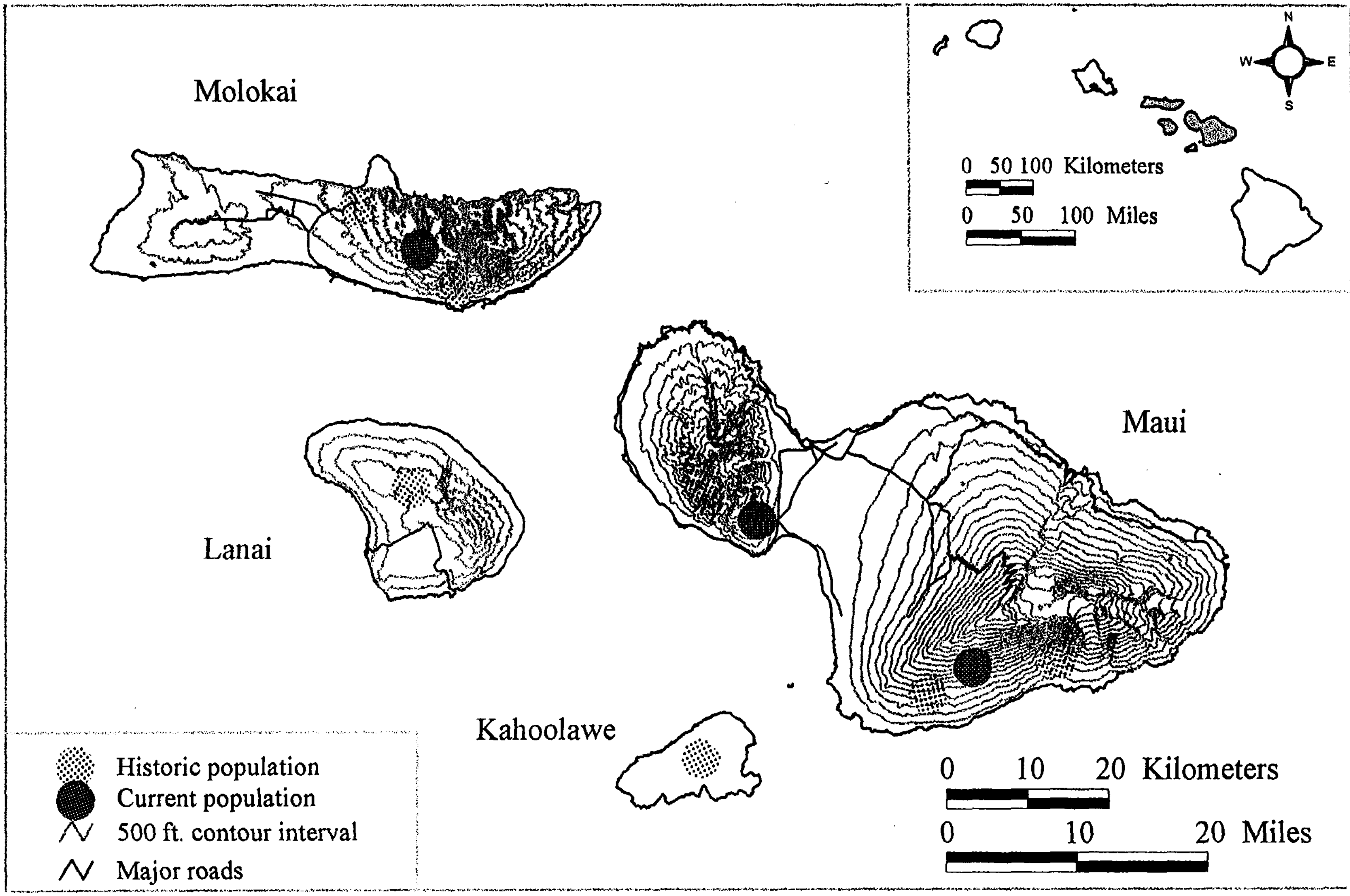
Current range and historical occurrences of *Mariscus pennatiformis* ssp. *pennatiformis* (1 of 2).



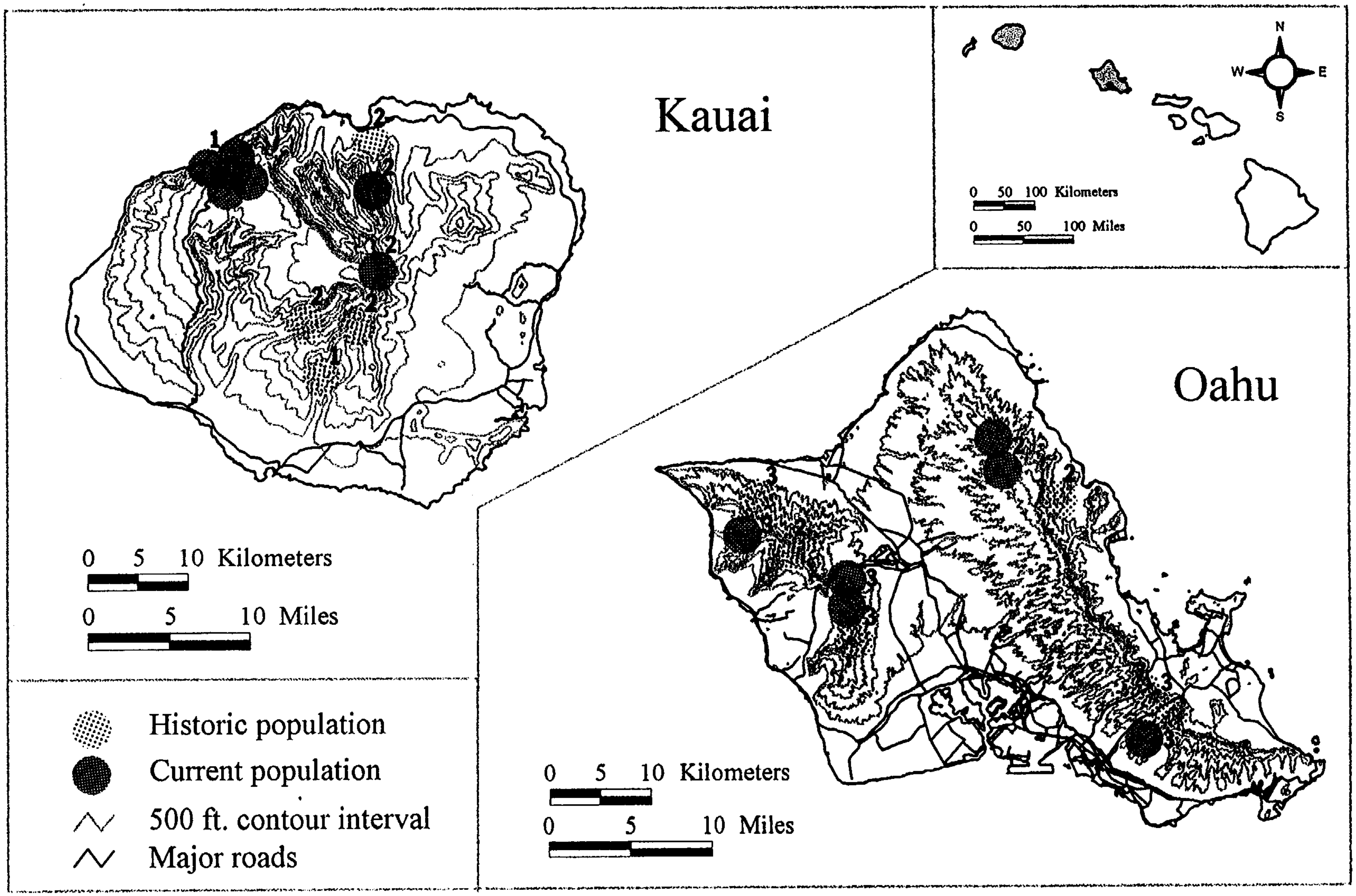
Current range and historical occurrences of *Mariscus pennatiformis* ssp. *pennatiformis* (2 of 2).



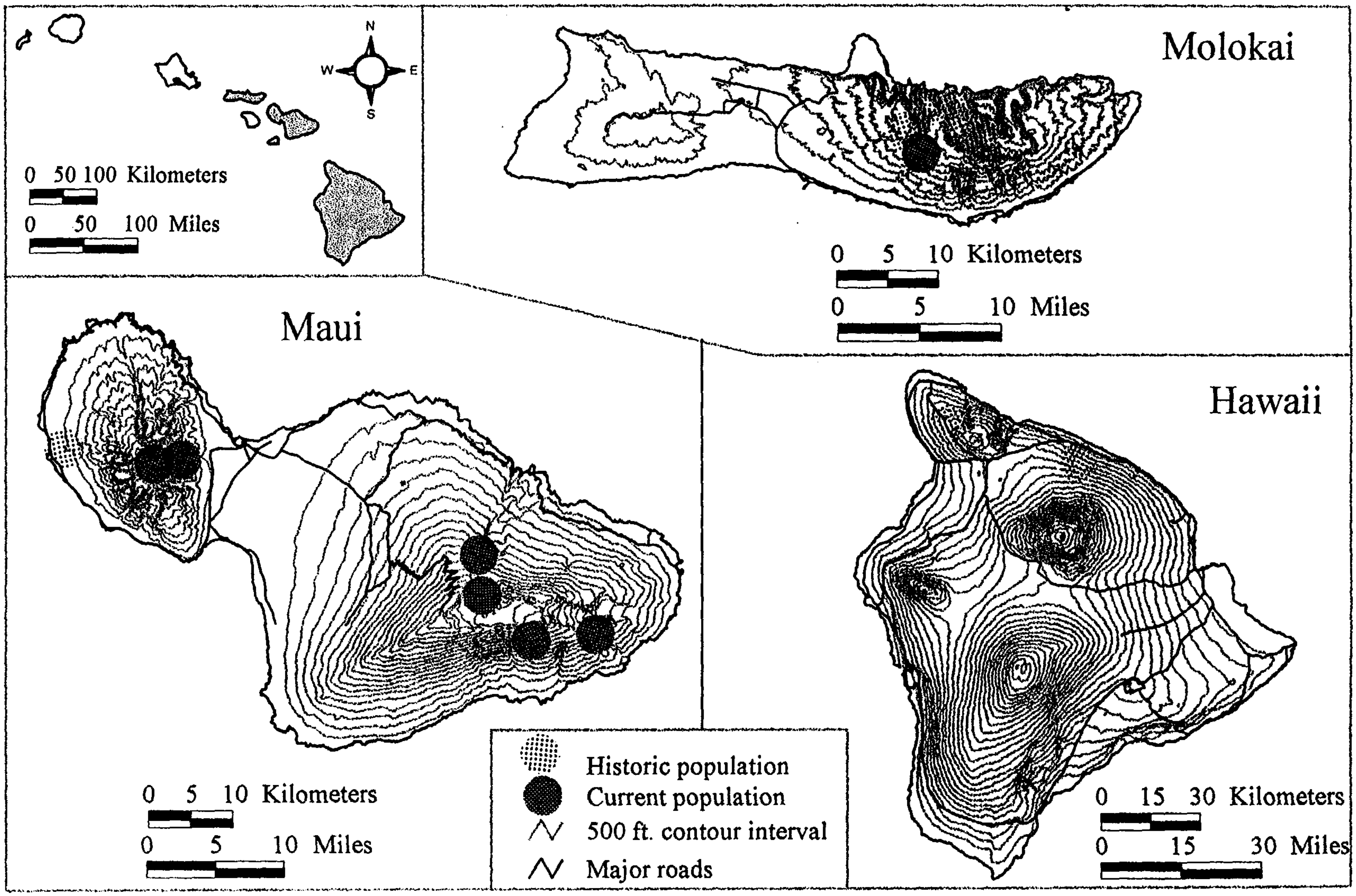
Current range and historical occurrences of *Mariscus pennatiformis* ssp. *bryanii*.



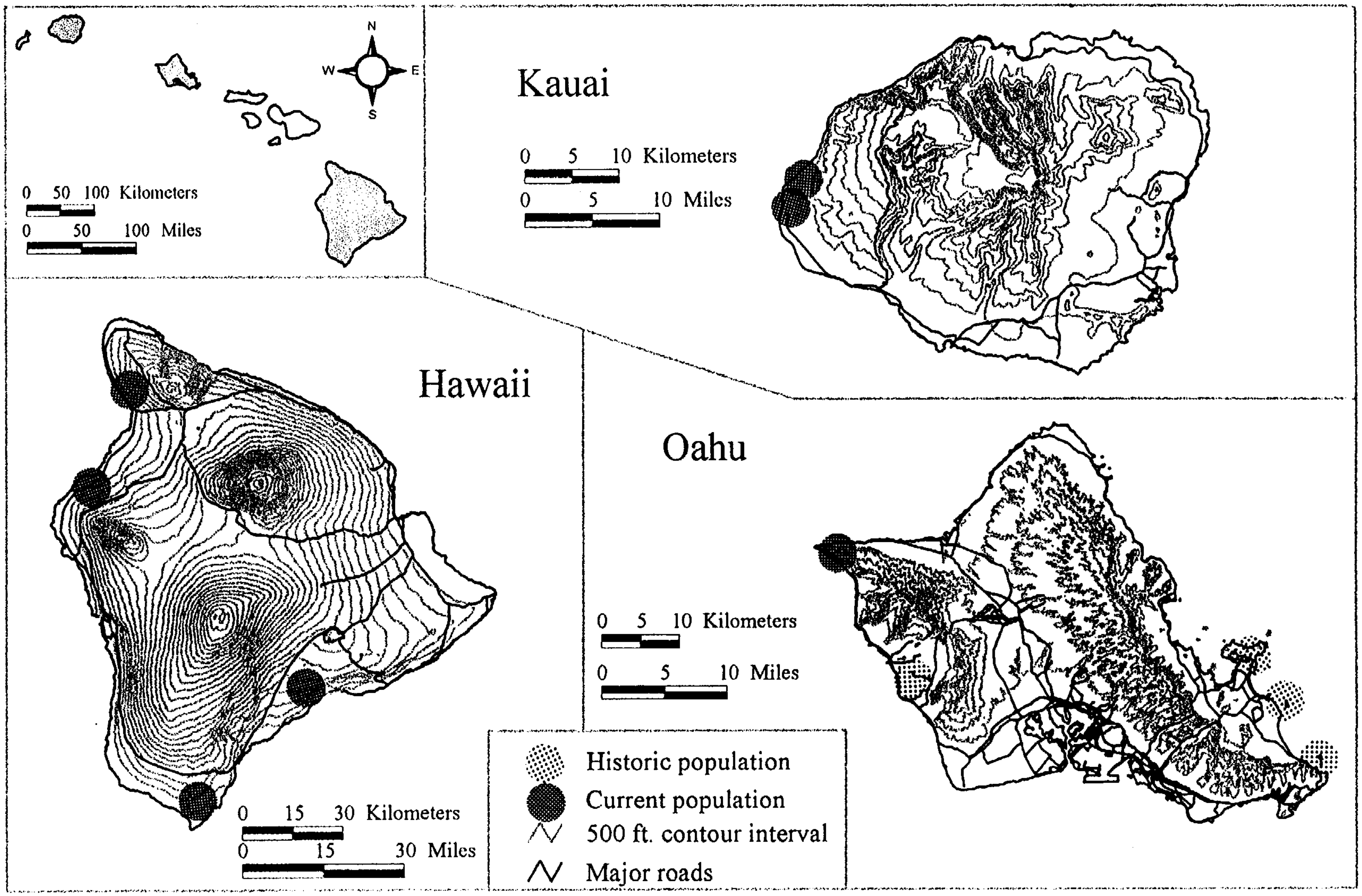
Current range and historical occurrences of *Neraudia sericea*.



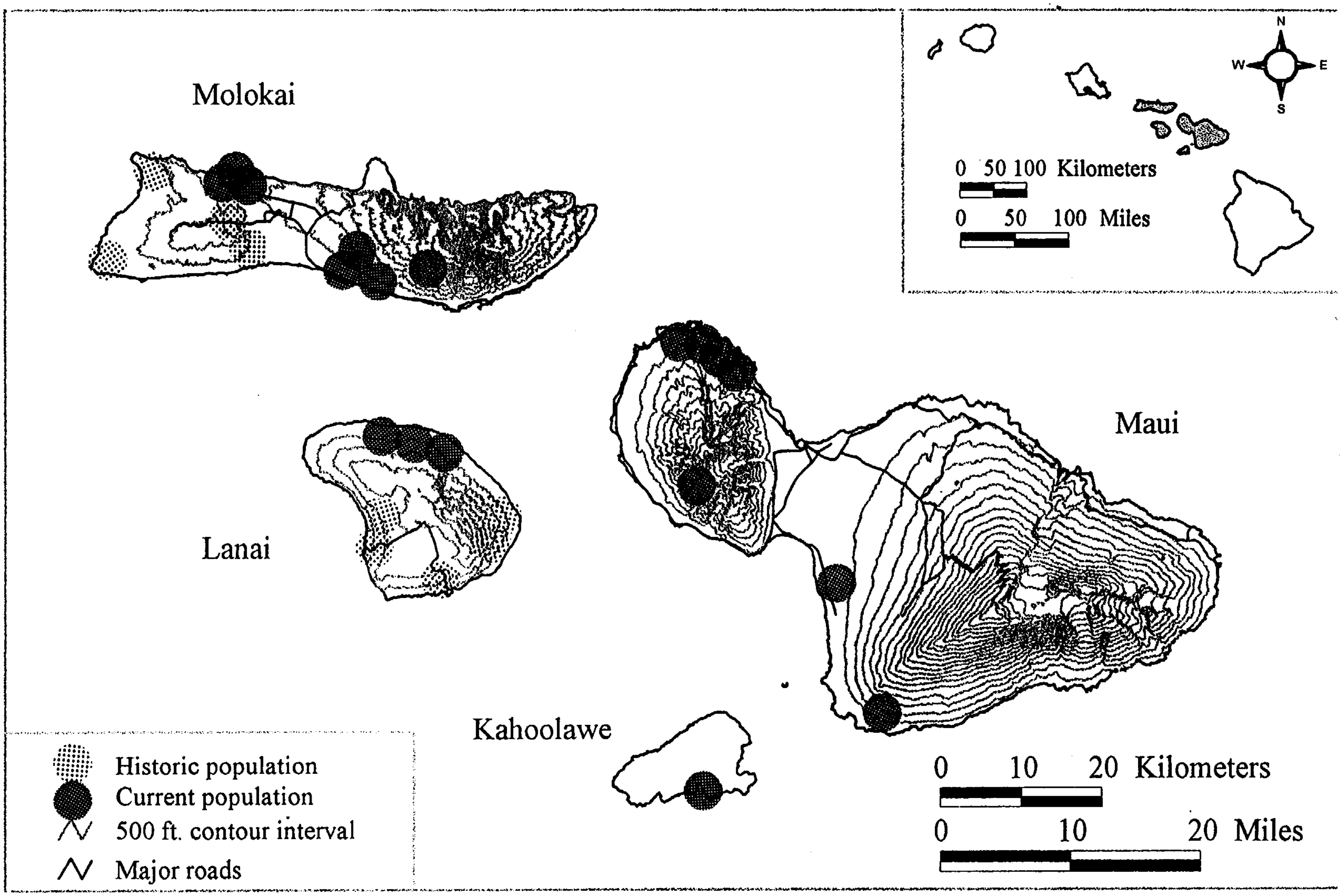
Current range and historical occurrences of *Plantago princeps* var. *anomala* (1), var. *longibracteata* (2), and var. *princeps* (3).



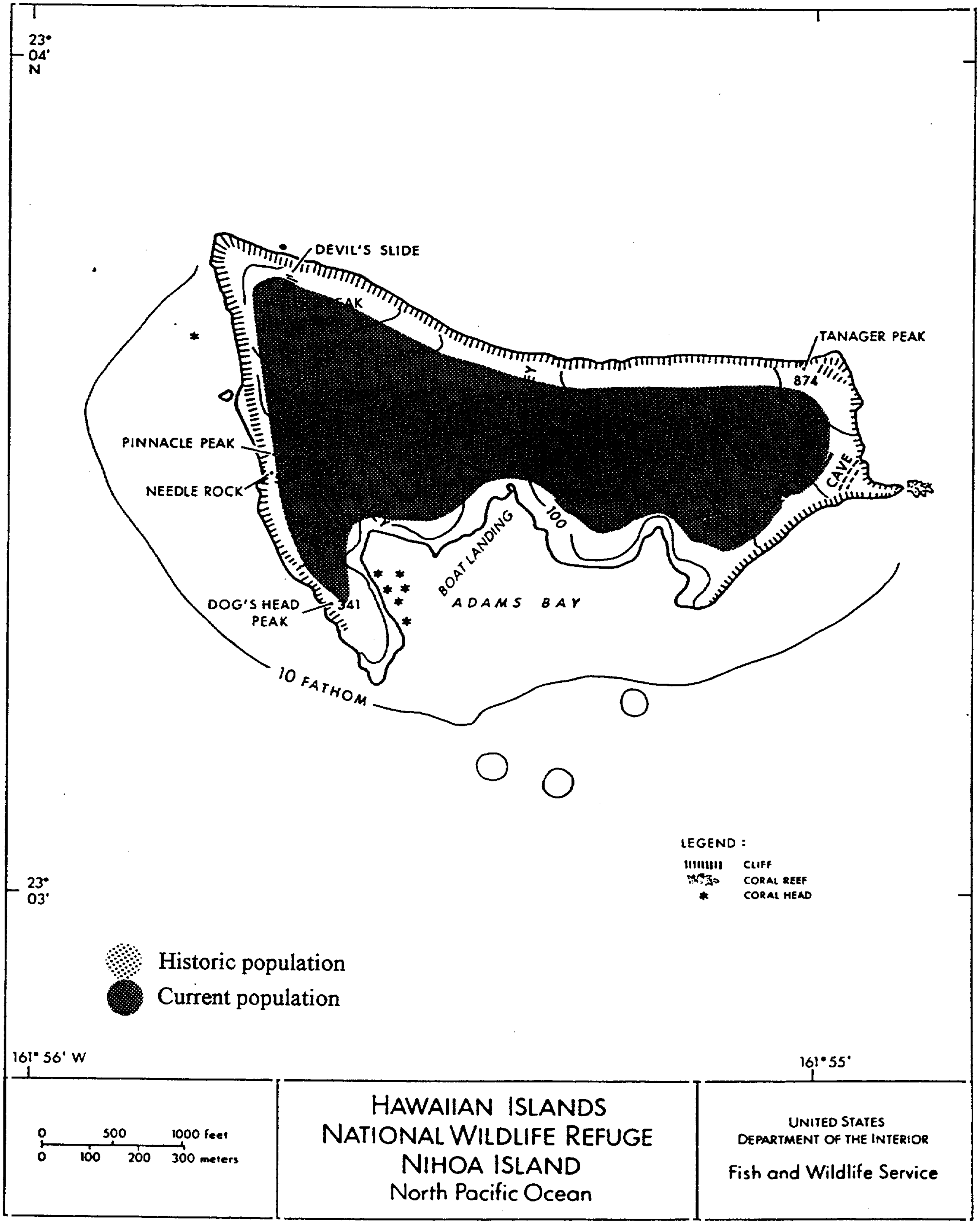
Current range and historical occurrences of *Plantago princeps* var. *laxiflora*.



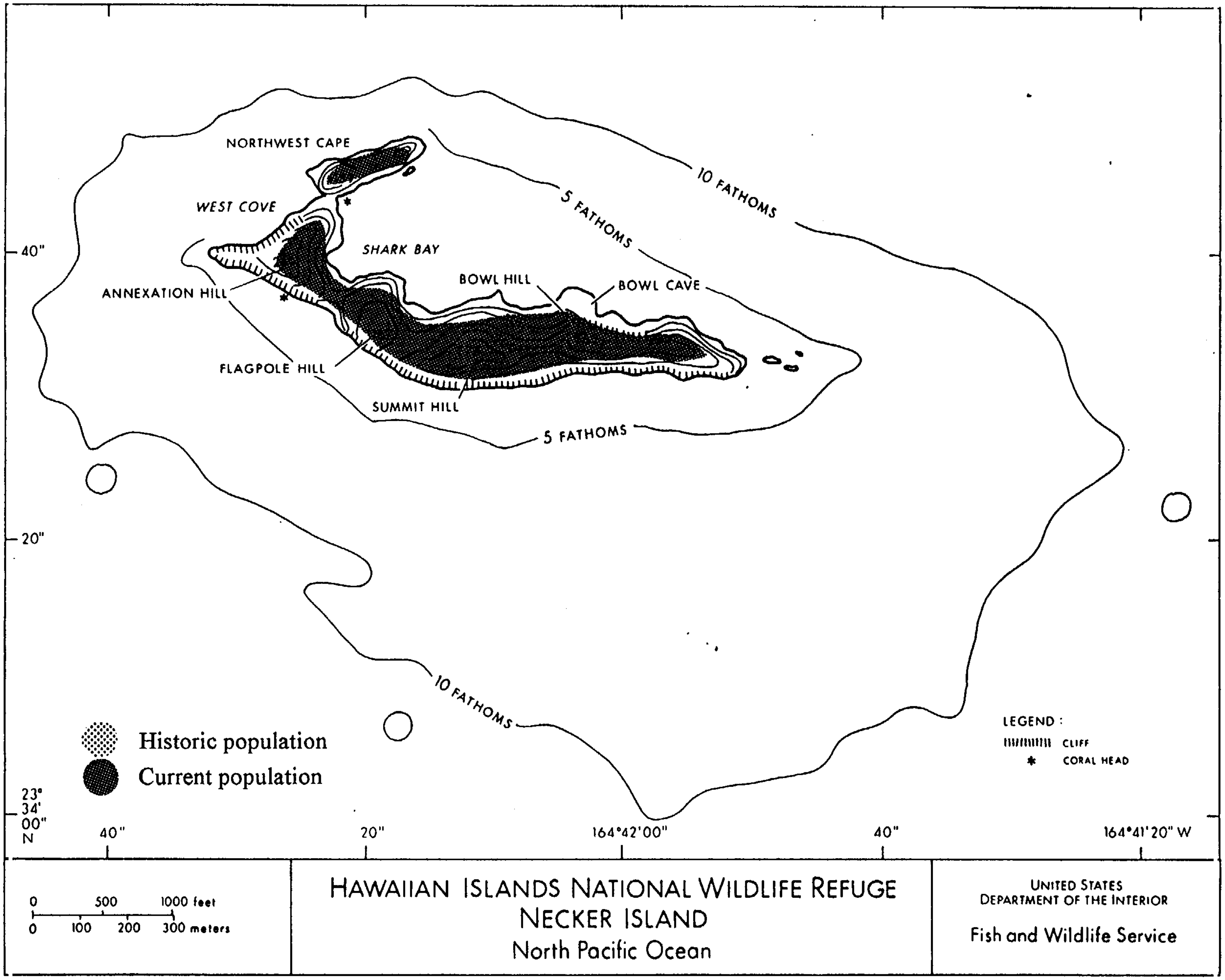
Current range and historic occurrences of *Sesbania tomentosa* (1 of 4).



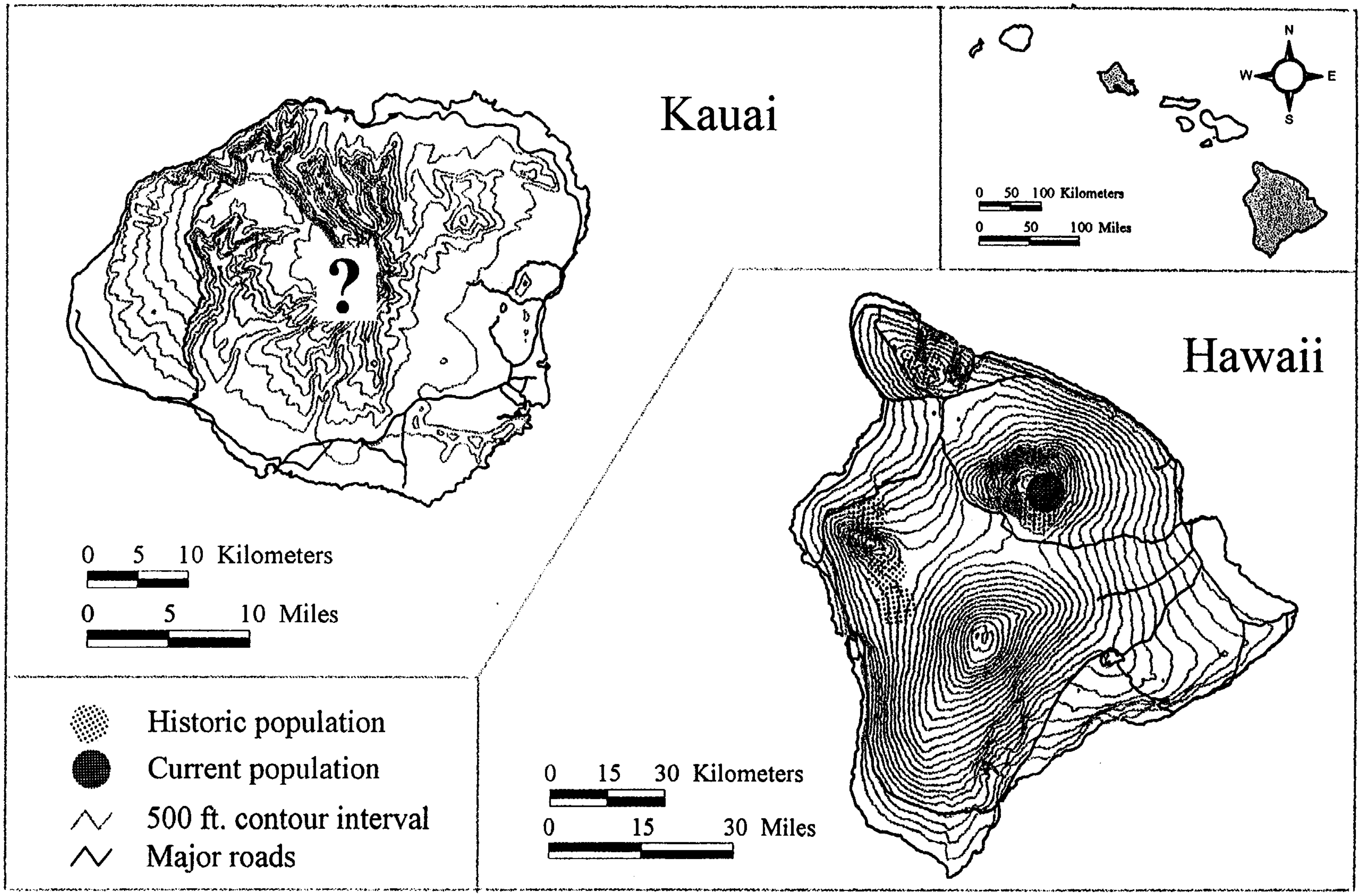
Current range and historical occurrences of *Sesbania tomentosa* (2 of 4).



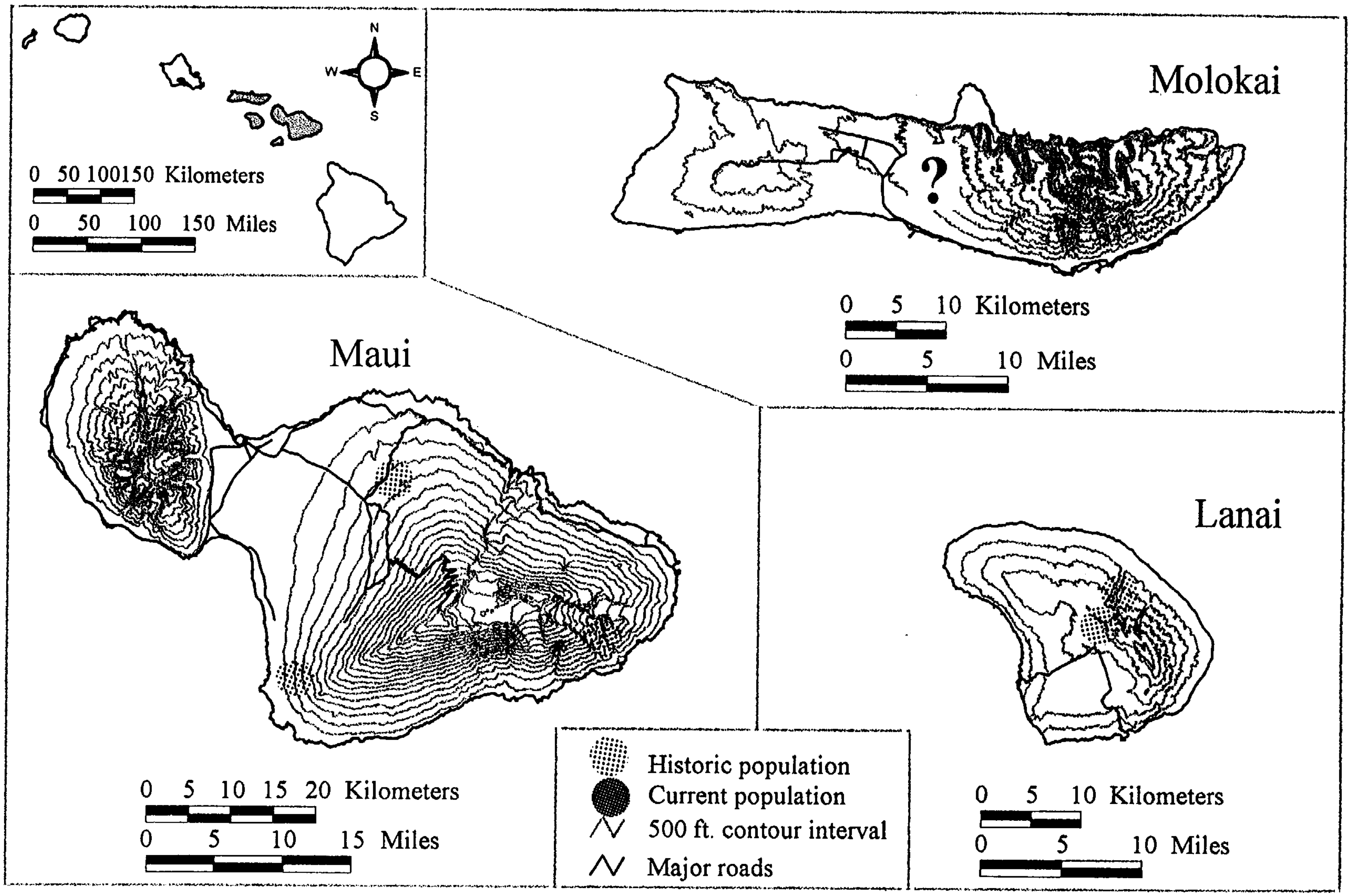
Current range and historical occurrences of *Sesbania tomentosa* (3 of 4).



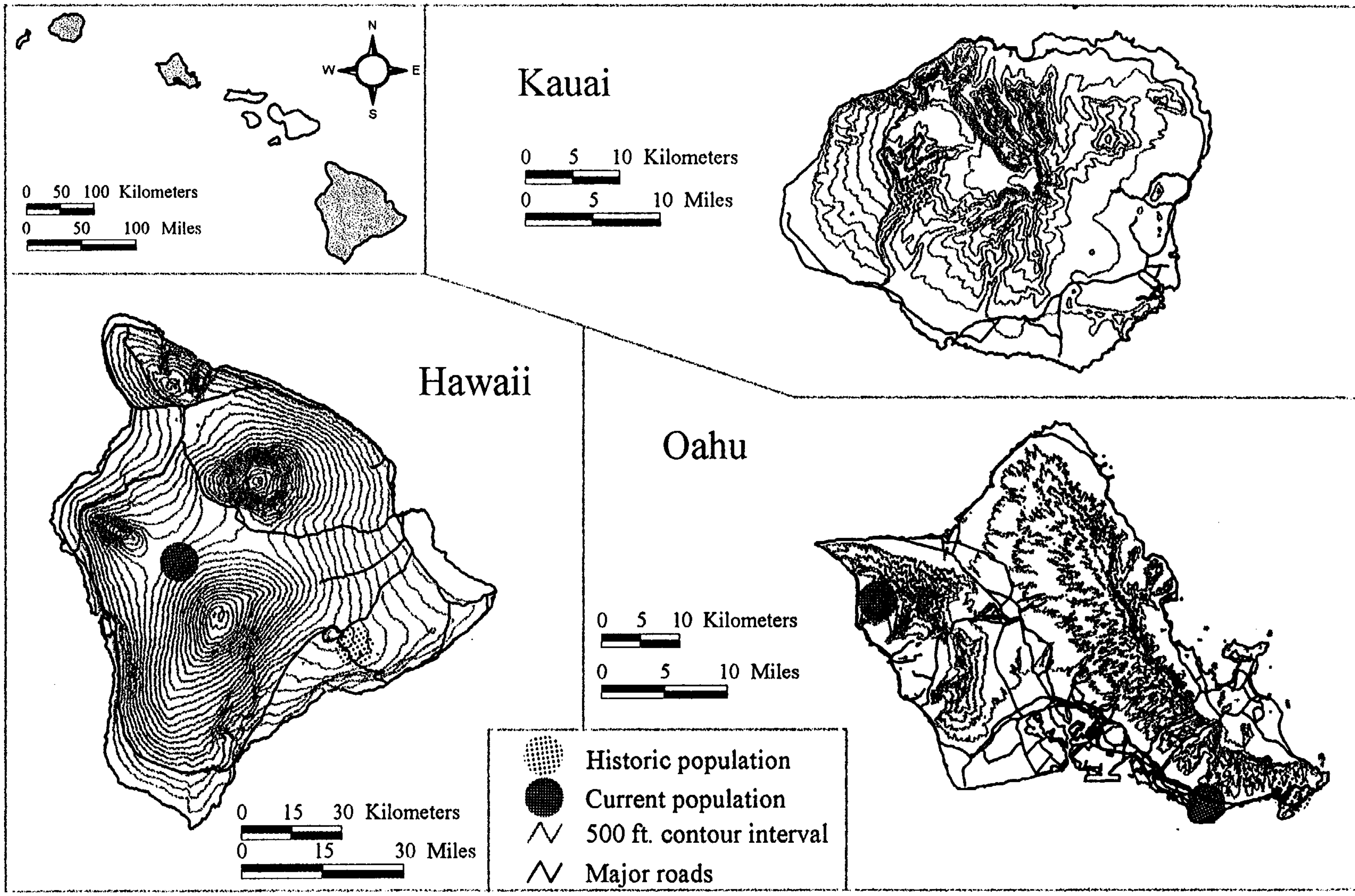
Current range and historical occurrences of *Sesbania tomentosa* (4 of 4).



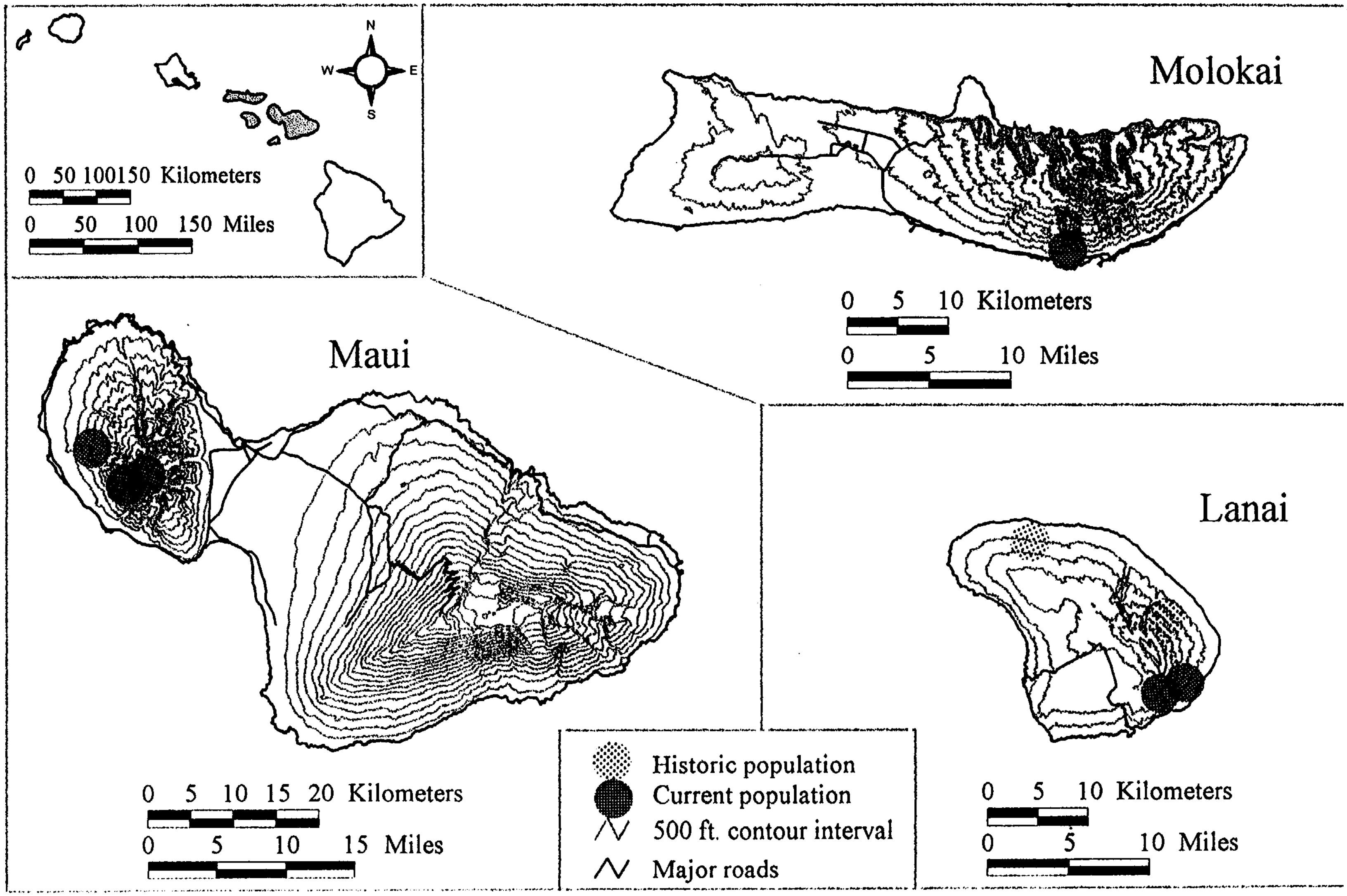
Current range and historical occurrences of *Solanum incompletum* (1 of 2).



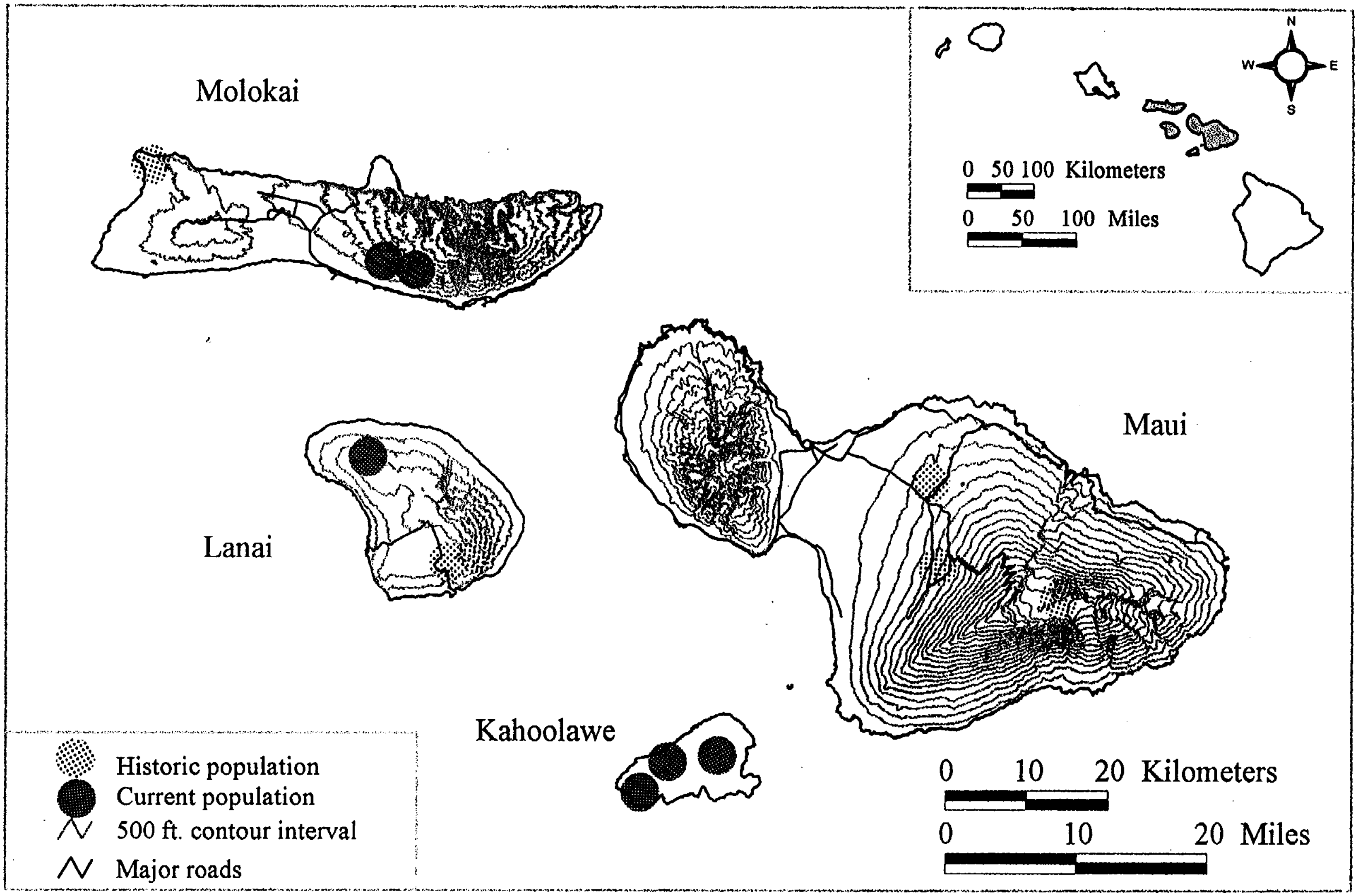
Current range and historical occurrences of *Solanum incompletum* (2 of 2).



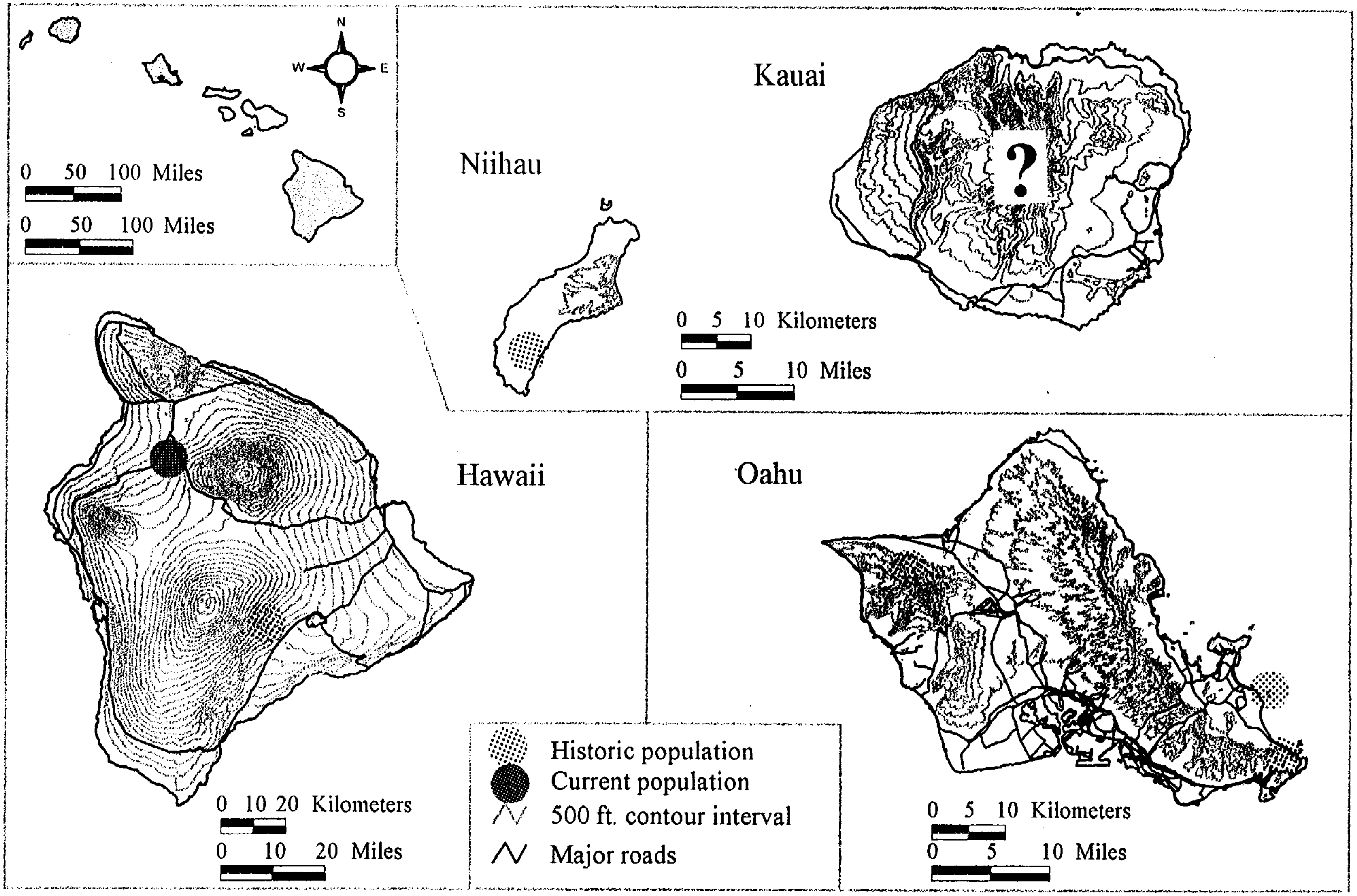
Current range and historical occurrences of *Spermolepis hawaiiensis* (1 of 2).



Current range and historical occurrences of *Spermolepis hawaiiensis* (2 of 2).



Current range and historical occurrences of *Vigna o-wahuensis* (1 of 2).



Current range and historical occurrences of *Vigna o-wahuensis* (2 of 2).

APPENDIX D

Summary of Landownership/Management

City and County of Honolulu: *Cenchrus agrimonioides* var. *agrimonioides, Centaurium sebaeoides, Isodendrion laurifolium*, and *Schiedea hookeri.*

Department of Defense: *Bonamia menziesii, Cenchrus agrimonioides* var. *agrimonioides, Cyanea grimesiana* ssp. *grimesiana, Cyperus trachysanthos, Euphorbia haeleeleana, Flueggea neowawraea, Hibiscus brackenridgei, Isodendrion laurifolium, Phyllostegia parviflora, Plantago princeps* var. *princeps, Sanicula purpurea, Schiedea hookeri, Schiedea nuttallii, Sesbania tomentosa, Solanum incompletum,* and *Spermolepis hawaiiensis.*

National Park Service: *Adenophorus periens, Plantago princeps* var. *laxiflora*, and *Sesbania tomentosa.*

U.S. Fish and Wildlife Service: *Mariscus pennatiformis* ssp. *bryanii* and *Sesbania tomentosa.*

State of Hawaii: *Adenophorus periens, Bonamia menziesii, Cenchrus agrimonioide* var. *agrimonioides, Centaurium sebaeoides, Cyanea grimesiana* ssp. *grimesiana, Cyperus trachysanthos, Diellia erecta, Euphorbia haeleeleana, Flueggea neowawraea, Hibiscus brackenridgei, Isodendrion laurifolium, Isodendrion longifolium, Mariscus pennatiformis* var. *pennatiformis, Neraudia sericea, Panicum niihauense, Plantago princeps, Platanthera holochila, Sanicula purpurea, Schiedea hookeri, Schiedea nuttallii, Sesbania tomentosa, Solanum incompletum, Spermolepis hawaiiensis*, and *Vigna o-wahuensis.*

Private Landowners: *Achyranthes mutica, Adenophorus periens, Bonamia menziesii, Cenchrus agrimonioides, Centaurium sebaeoides, Cyanea grimesiana, Cyperus* *trachysanthos, Diellia erecta, Euphorbia haeleeleana, Flueggea neowawraea, Hibiscus brackenridgei, Isodendrion longifolium, Neraudia sericea, Phyllostegia parviflora, Plantago princeps, Platanthera holochila, Sanicula purpurea, Schiedea hookeri, Schiedea nuttallii, Sesbania tomentosa, Spermolepis* hawaiiensis, andVigna *o-wahuensis*

APPENDIX E

Recovery Priority System

The Recovery Priority System uses the criteria of (1) degree of threat, (2) recovery potential and (3) taxonomy (level of genetic distinctiveness). By applying these criteria, all listed species are assigned a species priority number of 1 through 18. A fourth factor, conflict, is a supplementary element in determining what actions are to be implemented for recovery of a species. In addition, the fourth factor gives priority, within each category, to those species that are or may be in conflict with construction or development projects. Thus, the species retains its numerical rank and acquires the letter designation of "C," indicating conflict (1C-18C).

A detailed discussion of the Recovery Priority System can be found in FR Vol. 48, No. 221, Pg. 51985 of the issue Tuesday, November 15, 1983.

Recovery Priority Table in Federal Register Vol. 48, No. 221, Pg 51985, Tuesday, November 15, 1983.

Degree of Threat	Recovery Potential	Taxonomy	Priority	Conflict
High	High	Monotypic genus	1	1C 1
	High	Species	2	2C 2
	High	Subspecies	3	3C 3
	Low	Monotypic genus	4	4C 4
	Low	Species	5	5C 5
	Low	Subspecies	6	6C 6
Moderate	High	Monotypic genus	7	7C 7
	High	Species	8	8C 8
	High	Subspecies	9	9C 9
	Low	Monotypic genus	10	10C 10
	Low	Species	11	11C 11
	Low	Subspecies	12	12C 12
Low	High	Monotypic genus	13	13C 13
	High	Species	14	14C 14
	High	Subspecies	15	15C 15
	Low	Monotypic genus	16	16C 16
	Low	Species	17	17C 17
	Low	Subspecies	18	18C 18

APPENDIX F

Habitat Potentially Important for the Recovery of Hawaiian Plants

Introduction

In 1992, the Hawaii State Department of Land and Natural Resources, the U.S. Fish and Wildlife Service, and The Nature Conservancy of Hawaii issued a joint publication entitled "Hawaii's Extinction Crisis: A Call to Action." These organizations proposed a ten-point action plan to reverse the decline of Hawaiian species. The first of these recommended actions was to protect and manage potentially important habitat (defined as the area or areas on which conservation actions may be necessary for the successful recovery and maintenance of rare species). This recommendation was based on the realization that the long-term survival of the majority of Hawaii's native plants and animals depends upon the management of large, intact natural areas.

The lack of mapped habitat was also seen by the Hawaii and Pacific Plant Recovery Coordinating Committee (Committee) as a significant impediment to the recovery of endangered Hawaiian plants. In 1994, the Committee initiated an effort to identify and map habitat believed to be "essential" for the recovery of Hawaii's 282 endangered and threatened plant species (Table 1). The Committee's effort to map habitat (hereafter called "important habitat") was driven by three practical concerns:

- That conservation agencies and land managers currently lack information on the relative value of Hawaii's remaining natural areas and as a result, habitat that may be crucial to endangered species recovery is being lost without an understanding of its importance.
- That habitat restoration, mitigation, and reintroduction efforts may not always be focused on areas which contribute to the long-term survival and recovery of the species.
- Many Hawaiian species have been reduced to small relict populations or are found only in cultivation. Because the primary threats to Hawaiian plants (e.g., alien

species) are difficult to control, the Committee expects that many species will continue to decline or be extirpated in the wild. Consequently, a failure to protect and restore unoccupied habitat may preclude future recovery opportunities for these species.

The overall goal of the Committee's effort is to identify habitat areas that, if properly managed, may allow the recovery of Hawaii's endangered and threatened plants.

These areas are a recovery planning tool to focus conservation efforts on the areas that may be most important to the conservation of Hawaii's listed species and other plant species of concern. These mapped areas receive no protection under the Endangered Species Act or any other Federal legislation. The Committee's mapping of habitat is distinct from critical habitat, a regulatory designation defined by section 4 of the Endangered Species Act. The Act requires that Federal agencies refrain from authorizing, funding, or carrying out activities likely to adversely modify or destroy critical habitat. The process for designating critical habitat takes into account the economic and other impacts of the designation, and provides opportunities for public comment.

Table F-1. Endangered and Threatened Hawaiian Plants.

	Number of Species*	Percentage of Flora
Native Plant Species	1,304	—
Endemic Species	1,160	89
Endangered Species	272	21
Threatened Species	10	1
Proposed Species	10	1
Candidate Species	42	3
Species of Concern	252	19

*Current as of 9/97

Habitat in the Hawaiian Archipelago

The Committee identified areas of important habitat on most of the islands in the Hawaiian chain. Protection, management, and restoration of these areas may provide habitat for the vast majority of listed Hawaiian species and for many unlisted Species of Concern as well.

The Committee did not attempt to delineate these habitat areas to include all extant sites of listed species nor all areas with high-quality native habitat. Out of the 3,825 mapped locations for listed species, 2,638 are thought to still be extant. Of these extant sites, 2,398 or 91 percent are included within an important habitat. Another 2,737 locations for Species of Concern were also reviewed to see how well these habitat areas might provide for their habitat needs.

Similarly, approximately 40 percent of Hawaii's total area may still be in predominantly native vegetation, but most of this habitat is at higher elevations.

Important habitat areas account for only 21 percent of the State, but these areas are not located solely in high quality habitat. Many important habitat areas are heavily degraded and will require intensive management.

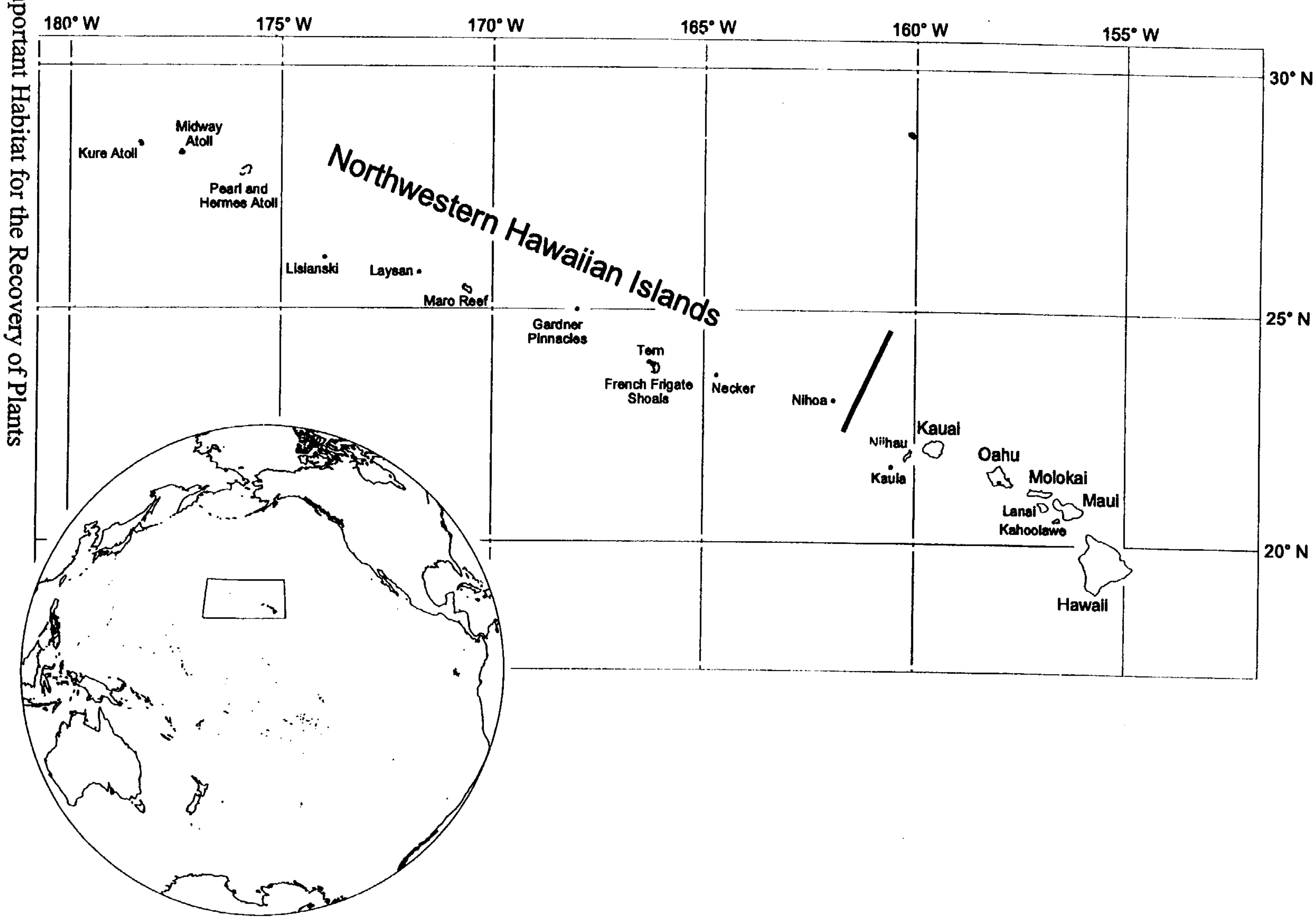
A detailed discussion of the Committee's delineation of these areas can be found in the Committee's report to the U.S. Fish and Wildlife Service, "Habitat Essential to the Recovery of Hawaiian Plants" (1998).

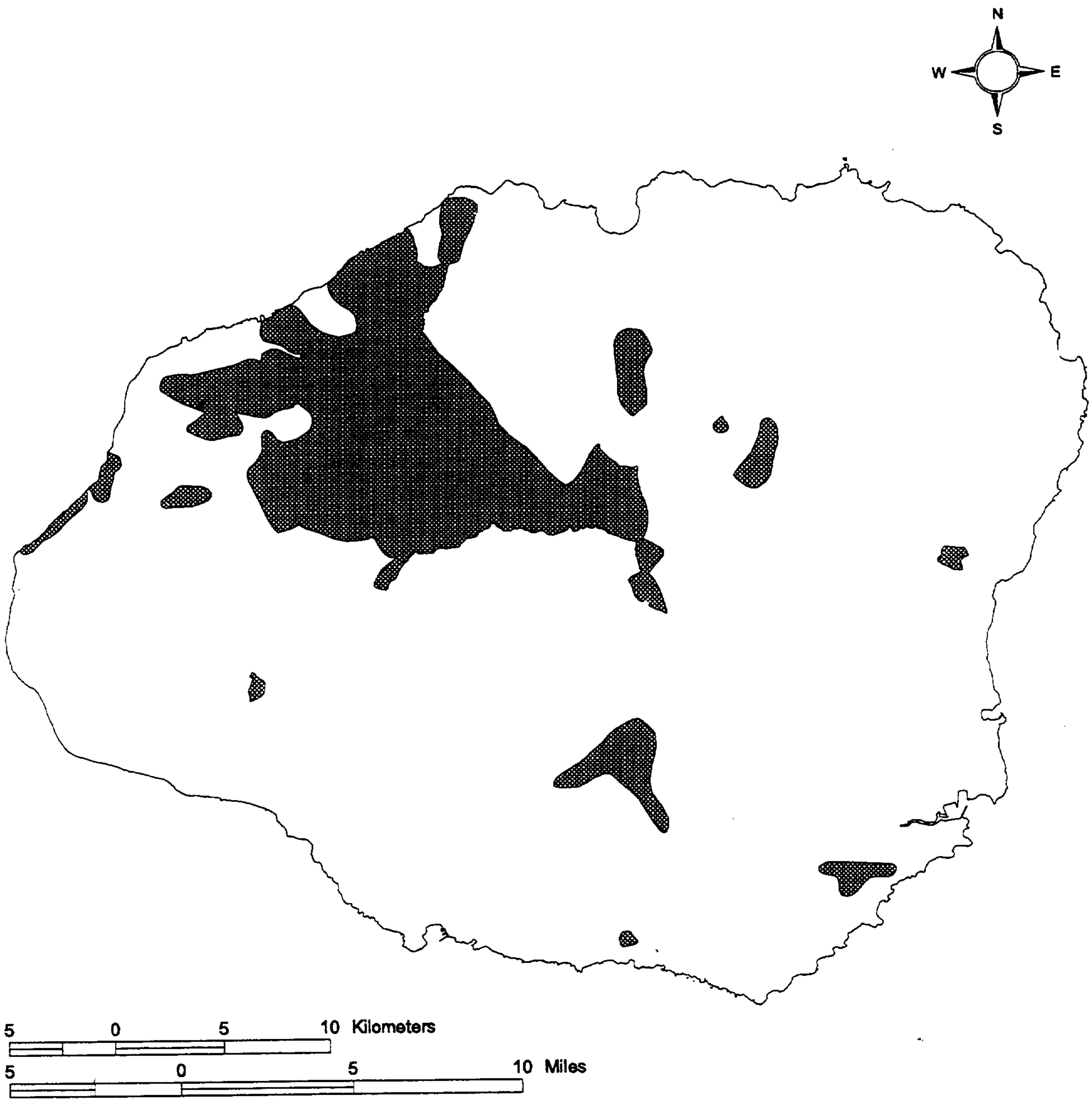
Inadequately Surveyed Areas

The Committee recognized a number of areas where the current state of knowledge is insufficient to assess their importance for the recovery of listed species. These areas are poorly-surveyed, and surveys are needed before their importance can be determined. These areas are likely to have at least some habitat which could contribute to conserving listed species that are currently poorly addressed by areas of important habitat. Many of these areas are also likely to contain species new to science or currently thought to be extinct. While these areas were not included as important habitat areas, and thus are not shown on the maps in this Recovery Plan, they are delineated in the Committee's report to the U.S. Fish and Wildlife Service, "Habitat Essential to the Recovery of Hawaiian Plants" (1998).

Important habitat areas for the recovery of Hawaiian plants are found in the following pages. The Committee decided that Niihau was too poorly surveyed to determine its value to endangered species recovery. All of the islands of the Northwest Hawaiian Islands, with the exception of Midway, were evaluated for mapping.

Important Habitat for the Recovery of Plants
Protected under the U.S. Endangered Species Act— Northwest Hawaiian Islands



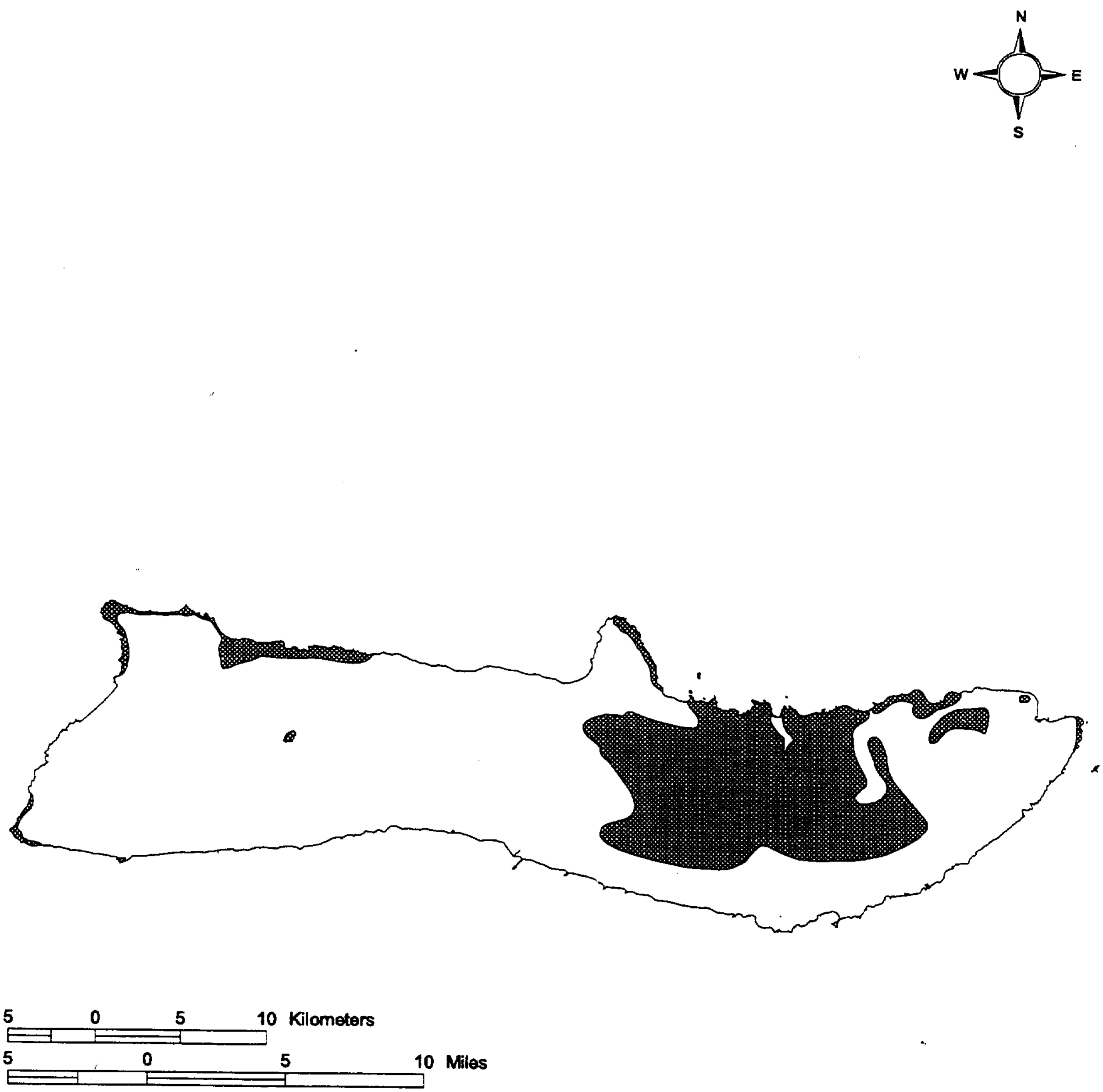


Hawaii and Pacific Plant Recovery Coordinating Committee
December 1997

Important Habitat for the Recovery of Plants Protected under the U.S. Endangered Species Act— Island of Kauai

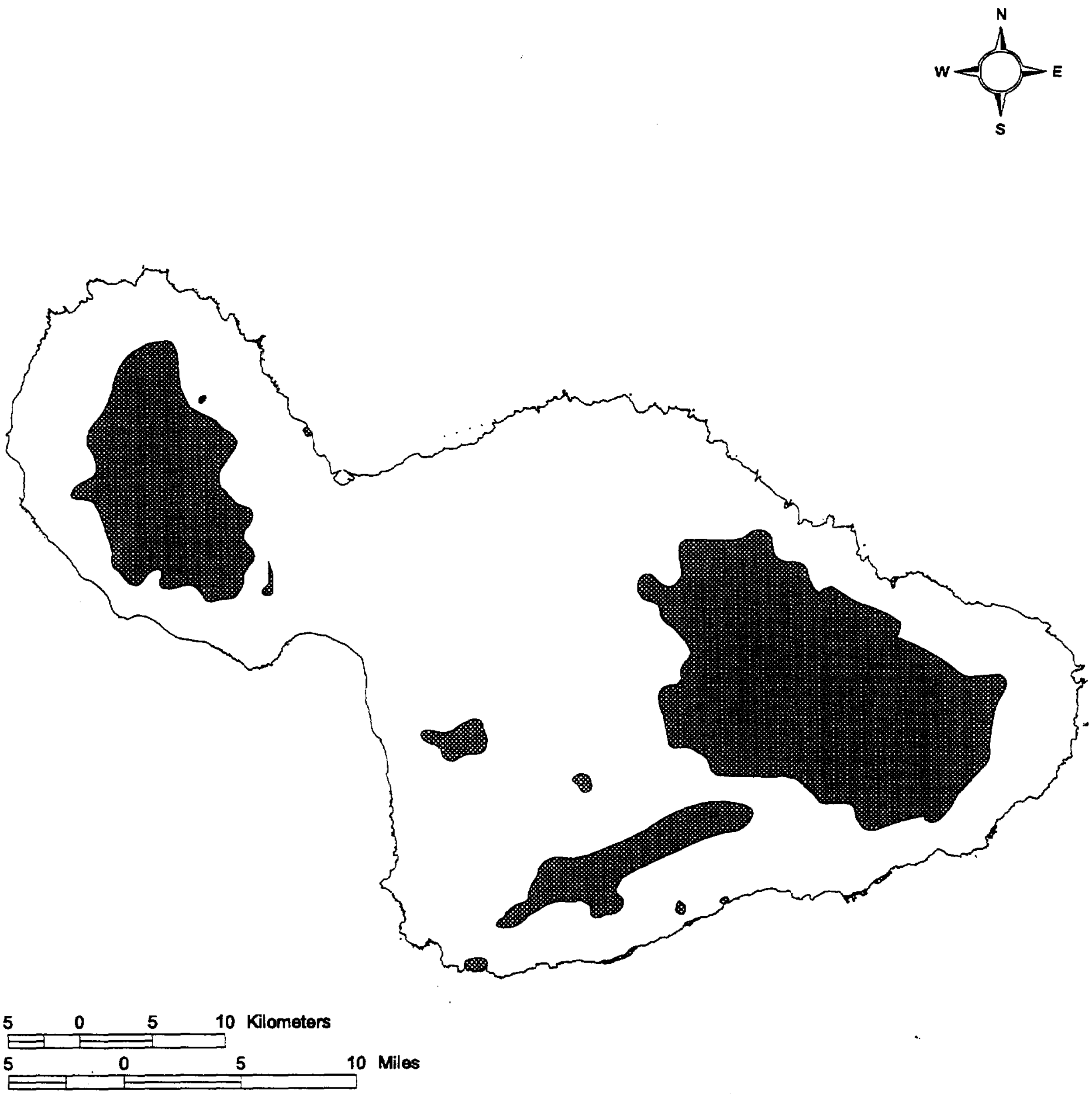
Hawaii and Pacific Plant Recovery Coordinating Committee
December 1997

Important Habitat for the Recovery of Plants Protected under the U.S. Endangered Species Act— Island of Oahu



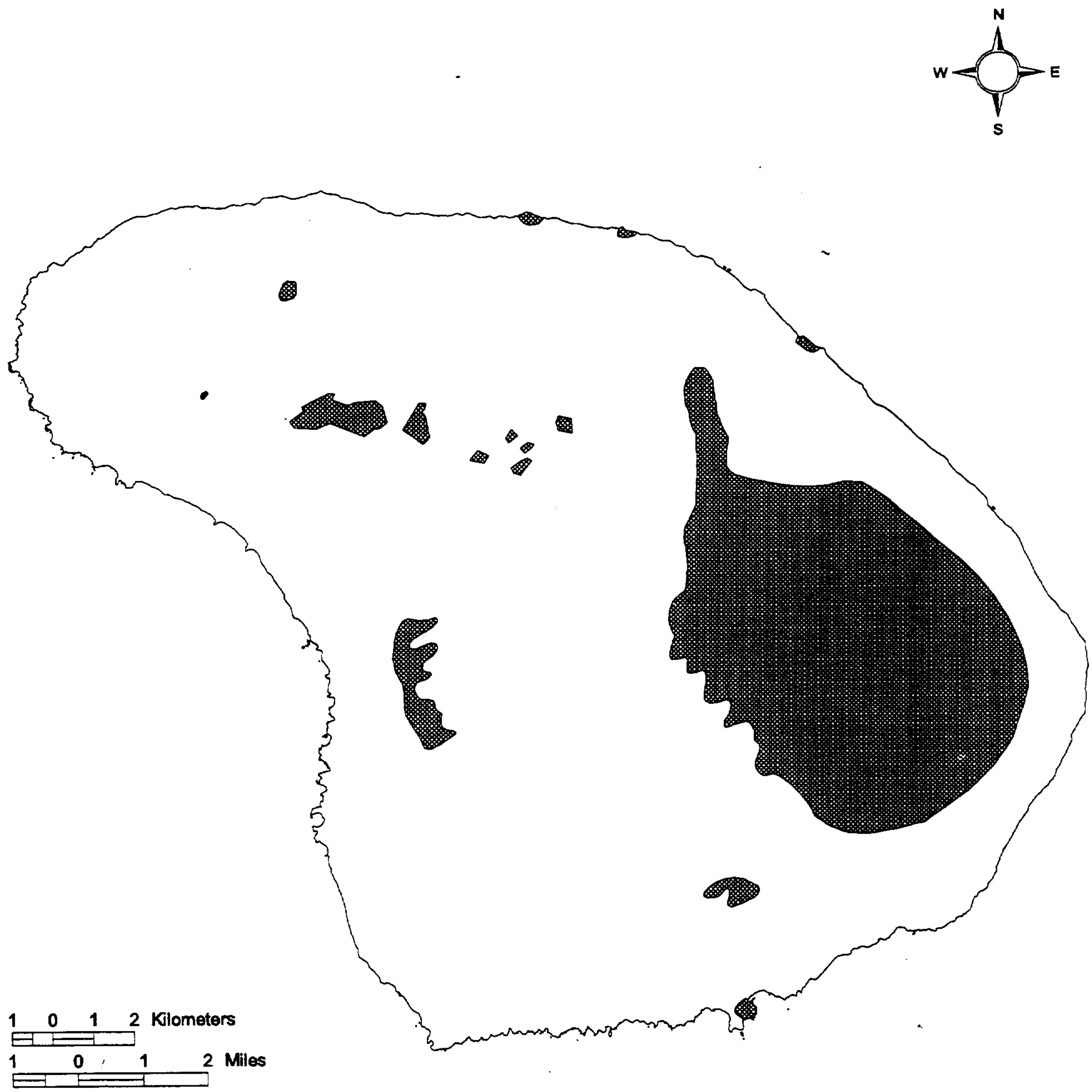
Hawaii and Pacific Plant Recovery Coordinating Committee
December 1997

Important Habitat for the Recovery of Plants Protected under the U.S. Endangered Species Act— Island of Molokai



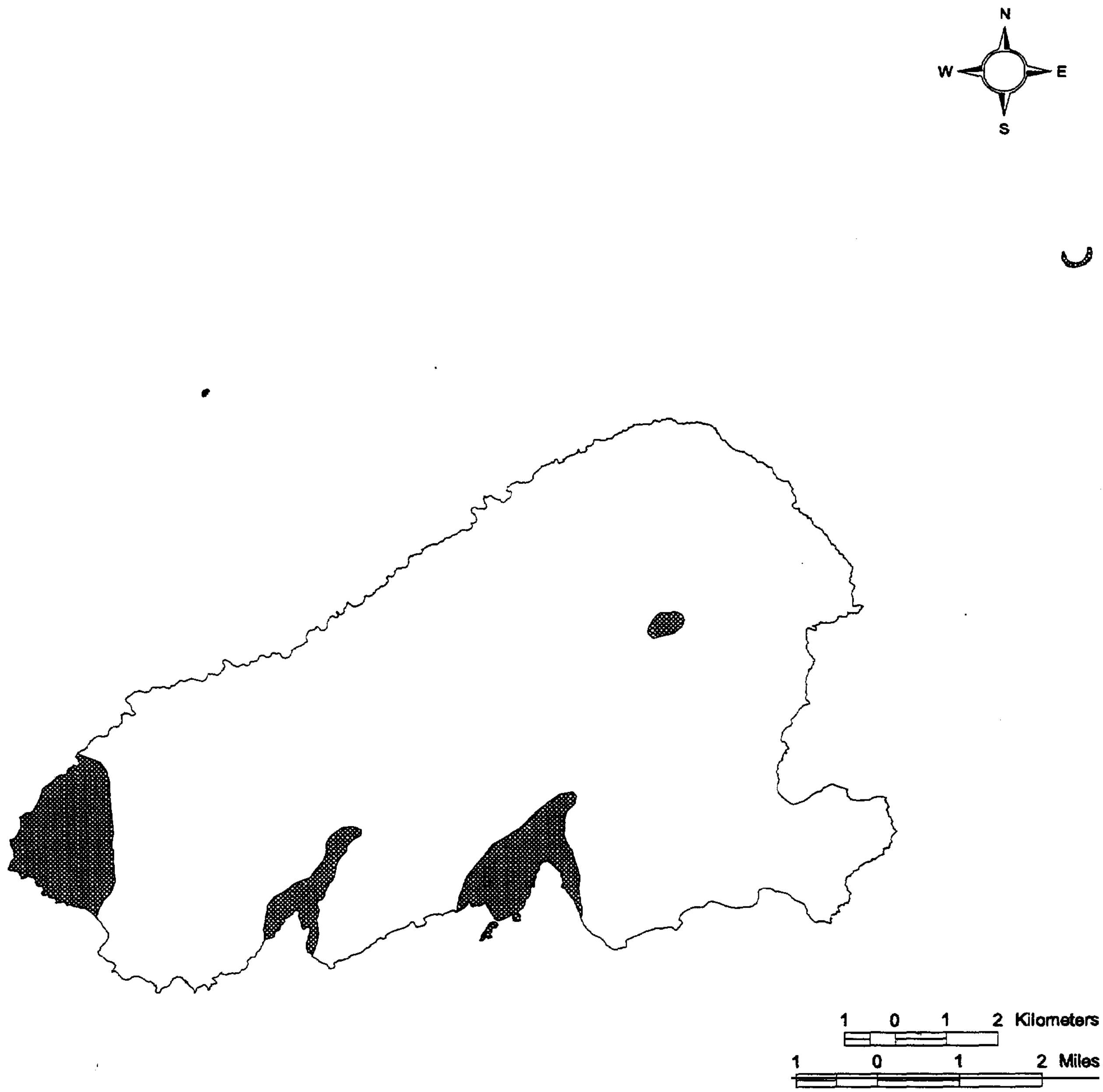
Hawaii and Pacific Plant Recovery Coordinating Committee
December 1997

Important Habitat for the Recovery of Plants Protected under the U.S. Endangered Species Act— Island of Maui



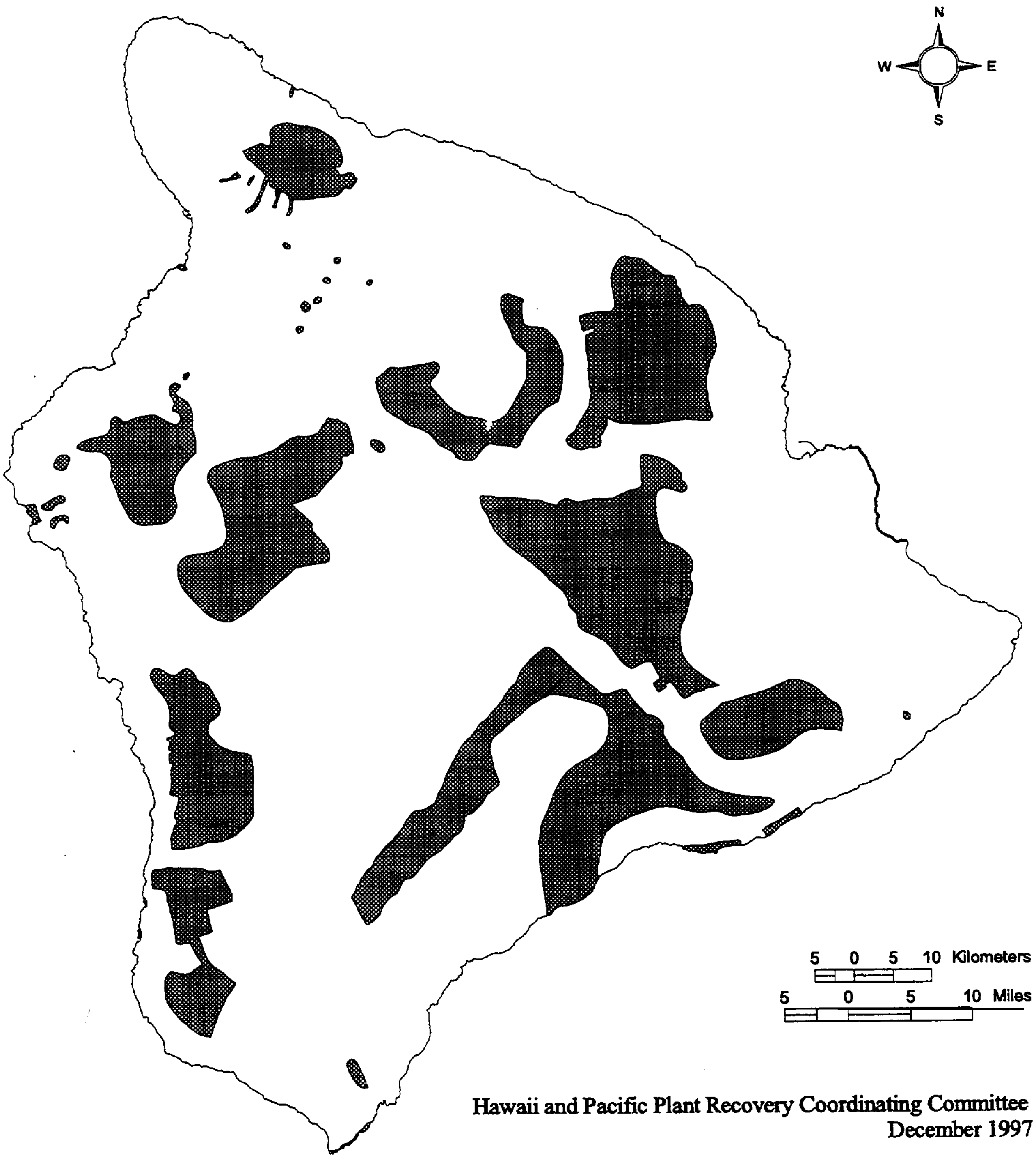
Hawaii and Pacific Plant Recovery Coordinating Committee
December 1997

Important Habitat for the Recovery of Plants Protected under the U.S. Endangered Species Act— Island of Lanai



Hawaii and Pacific Plant Recovery Coordinating Committee
December 1997

Important Habitat for the Recovery of Plants Protected under the U.S. Endangered Species Act— Island of Kahoolawe



Important Habitat for the Recovery of Plants Protected under the U.S. Endangered Species Act— Island of Hawaii

APPENDIX G

Summary of Comments

The U.S. Fish and Wildlife Service received comments on the Draft Recovery Plan for Multi-Island Plants from the Department of the Army; the State of Hawaii, Department of Land and Natural Resources, Division of Forestry and Wildlife; the State of Hawaii, Department of Agriculture; the City and County of Honolulu; the Big Island Native Plant Society; and two private individuals. Many of the editorial and organizational comments provided have been incorporated in the text of this document. Additional comments are addressed specifically below.

Comment: This recovery plan suggests fencing as the first step in ungulate control. The plan should reflect that fencing is not the only, or necessarily the best, ungulate control option . . . and is not always an option because of funding limitations.

Service Response: The Service recognizes the limitations of fencing as a recovery strategy and acknowledges the use and efficacy of other ungulate control methods. Further discussion can be found in the Stepdown Outline and Narrative.

Comment: Although we do not expect your agency to be able to identify candidate pests for biocontrol, we suggest that you at least mention that biocontrol can have a part in the conservation effort.

Service Response: The Service agrees that due to the widespread nature of many weeds and the time, cost, and logistics of weed control, use of biocontrol agents to control alien plants should be considered. The Service supports the use of biocontrol provided adequate testing is conducted for the host specificity using native plants. This is necessary to ensure that native plants, including endangered species, are not adversely impacted by the release of biocontrol agents. We have included a synopsis of biocontrol efforts to date for each alien species in the section entitled "Overall Reasons for Decline and Current Threats, Aliens Plants," page 19. Biological control is also considered in the Stepdown Outline and Narrative.

Comment: The use of immunocontraceptives is a better way to control wildlife populations. With [this method] available, can't we now control the wildlife population without the dangers inherent in hunting, hunters wounding but not cleanly killing animals, and without the cruelty of poisoning and snaring?

Service Response: The Service is supportive of proven, cost-effective, methods for control of feral ungulates in order to preserve native, threatened, and endangered biota. Immunocontraceptives can be effective for feral ungulate control, but only in rare instances. In order to be effective, the drugs must be delivered repeatedly throughout the animal's life. Many of the areas that the Service and its partners target for ungulate control are very remote. The likelihood of encountering the same animal multiple times though its life cycle in many of these areas is very low. Also, long-term drug redelivery may not be cost effective.

Comment: *In situ* control of threats should be suggested as a management technique for certain species.

Service Response: *In situ* control of threats is recommended in the "Needed Recovery Actions" section for each of the Multi-island species. For example, construction of fences to protect extant plants and their propagules from feral ungulates, alien plant control, rat control, and implementation of fire management plans.

Comment: The propagation facility on Wright Road [Volcano, Hawaii] should not be used as a zoo for any species. For recovery of any declining species, it must be allowed to survive in suitable habitat with the idea that it eventually will continue its existence without human intervention.

Service Response: The Service agrees with the sentiment that captive propagation is less than an ideal recovery strategy. However, sometimes captive propagation is the only resource left to us in order to prevent a species from going extinct.

Comment: Recovery Plans will only work, provided there are people there to do the work.

Service Response: The Service agrees with the comment and adds that the recovery of threatened and endangered species truly requires the coordinated efforts and pooled resources of private, State, and Federal entities.