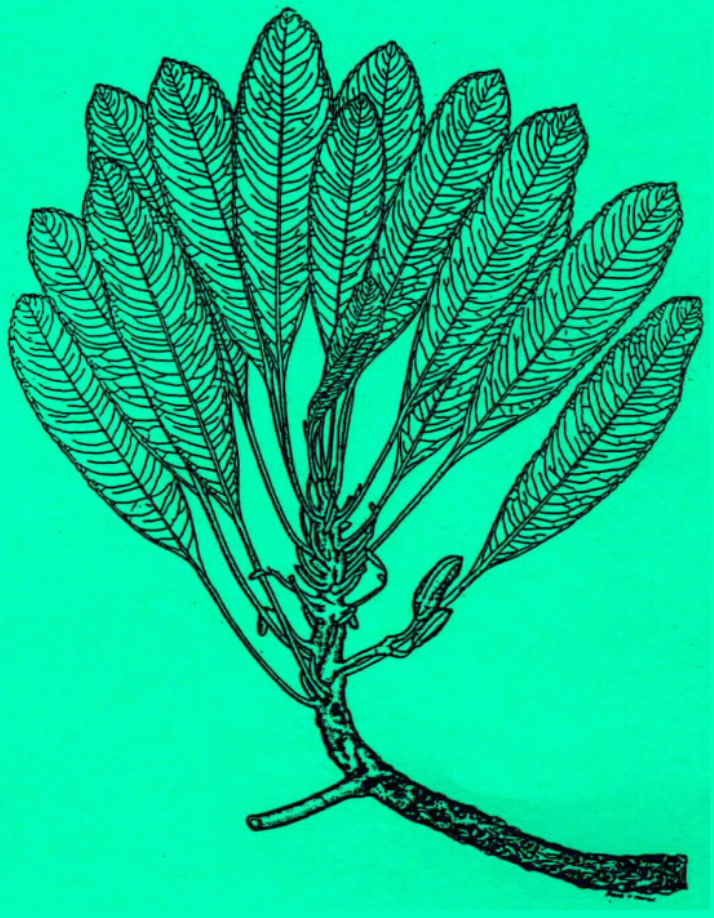
Recovery Plan for the Maui Plant Cluster (Hawaii)



US Department of the Interior
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RECOVERY PLAN FOR THE

MAUI PLANT CLUSTER

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EXECUTIVE SUMMARY

Current Species Status: Twenty of the taxa addressed in this plan are federally listed as endangered and one, *Argyroxiphium sandwicense* ssp. *macrocephalum*, is listed as threatened. Numbers of known remaining populations and individuals are as follows (# of populations, # of individuals):

Acaena exigua (last seen in 1957),
Alectryon macrococcus (28, 500),
Argyroxiphium sandwicense ssp. *macrocephalum* (1, >64,000),
Bidens micrantha ssp. *kalealaha* (4, 2,000),
Clermontia oblongifolia ssp. *mauiensis* (1, 1),
Cyanea lobata (last seen in 1982),
Cyanea mceldowneyi (6, >144),
Geranium arboreum (4, 300),
Geranium multiflorum (11, <3,000),
Hedyotis coriacea (2, <20),
~~*Huperzia*~~ *mannii* (6 <300),
Lipochaeta kamolensis (2, several hundred),
Lysimachia lydgatei (3, 150-250),
Melicope adscendens (1, 16),
Melicope balloui (1, <300),
Melicope mucronulata (1, 3),
Melicope ovalis (1, >300),
Remya mauiensis (2, 9),
Scaevola coriacea (4, <340),
Schiedea haleakalensis (3, 100-200) and
Tetramolopium capillare (2-4, <200).

Distributions: All of the 21 Maui cluster taxa occur on the island of Maui. Twelve are endemic to the island of Maui. *Bidens micrantha* ssp. *kalealaha, Clermontia oblongifolia* ssp. *mauiensis* and *Cyanea lobata* were formerly found on the island of Lanai, and *Acaena exigua* was found on the island of Kauai. *Hedyotis coriacea* is also found on the island of Hawaii, and *Melicope mucronulata* is also found on the island of Molokai. *Huperzia mannii* was formerly found on Kauai and is still extant on Hawaii. *Scaevola coriacea* formerly occurred on Kauai, Oahu, Lanai, Hawaii and Niihau; and *Alectryon macrococcus* is also extant on Kauai, Oahu and Molokai.

Habitat Requirements and Limiting Factors: The 21 taxa included in this recovery plan grow in a variety of vegetation communities (forests, shrubland, and volcanic cliffs), elevation zones (coastal to high cliff faces), and moisture regimes (dry to wet). These taxa and their habitats have been variously affected or are currently threatened by one or more of the following: trampling, predation, and habitat destruction by introduced animals; habitat degradation and competition for space, light, water, and nutrients by naturalized, alien vegetation; habitat loss from fires; alien insects; disease; small number of individuals and populations; and loss of pollinators. A few of these taxa may have been subjected to over collection and are subject to trampling by human beings along trails. Because of the small number of extant individuals and severely restricted distributions, populations of these taxa are subject to an increased likelihood of extinction from stochastic events.

Recovery Objectives: Delist all taxa. Interim downlisting and delisting objectives are provided.

Recovery Criteria:

• Interim Objectives for the 20 Endangered Taxa

The interim objective is to stabilize all existing populations of the Maui taxa. 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 Maui and, if possible, at least one other island 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 and a minimum of 50 mature individuals per population for short-lived perennials.

• Downlisting Objectives for the 20 Endangered Taxa

For downlisting, a total of five to seven populations of each taxon should be documented on Maui and at least one other island 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 a minimum of 100 mature individuals per population for long-lived perennials, and a minimum of 300 mature individuals per population for short-lived perennials. Each population should persist at this level for a minimum of five consecutive years before downlisting is considered.

• Delisting Objective for the 20 Endangered Taxa

For delisting, a total of 8 to 10 populations of each taxon should be documented on Maui and at least one other island where they now occur or occurred historically. Each population 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 and a minimum of 300 mature individuals per population for short-lived perennials. Each population should persist at this level for a minimum of five consecutive years.

• Delisting Objective for *Argyroxiphium sandwicense* ssp. *macrocephalum*

Delisting of this taxon would be appropriate if the threat to its pollinators from the alien Argentine ant is controlled through management action, no other threat of comparable magnitude arises during that time, and the single population continues to exceed 50,000 individuals.

Actions Needed:

1. Protect current populations, manage threats and monitor.
2. Conduct research essential to conservation of the species.
3. Expand current populations.
4. Establish new populations as needed to reach recovery objectives.
5. Validate and revise recovery objectives.

Total Estimated Cost of Recovery: $80,019,000

Date of Recovery: To be determined once more is known about the biology and population dynamics of the Maui cluster taxa.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

A. Brief Overview

This recovery plan deals with 20 endangered and one threatened taxa that occur or occurred on the island of Maui, Hawaii (Figure 1) and in some cases on other islands as well. *Acaena exigua* (liliwai), *Alectryon macrococcus* (mahoe), *Bidens micrantha* ssp. *kalealaha* (kookoolau), *Clermontia oblongifolia* ssp. *mauiensis* (oha wai), *Cyanea lobata* (haha), *Cyanea mceldowneyi* (haha), *Geranium multiflorum* (nohoanu), *Hedyotis coriacea* (kioele), *Huperzia mannii* (wawaeiole), *Lipochaeta kamolensis* (nehe), *Lysimachia lydgatei* (no common name [NCN]), *Melicope mucronulata* (alani), and *Schiedea haleakalensis* (NCN) were listed as endangered and *Argyroxiphium sandwicense* ssp. *macrocephalum* (Haleakala silversword, ahinahina) was listed as threatened on May 15, 1992 (USFWS 1992a). *Geranium arboreum* (nohoanu), *Melicope adscendens* (alani), *Melicope balloui* (alani), *Melicope ovalis* (alani), *Remya mauiensis* (NCN), *Scaevola coriacea* (dwarf naupaka) and *Tetramolopium capillare* (NCN) were listed as endangered in a total of five listing actions between May 1986 and December 1994 (USFWS 1986; USFWS 1991; USFWS 1992b; USFWS 1994a; USFWS 1994b).

These taxa (hereafter referred to as the "Maui cluster taxa") are scattered throughout Maui in diverse ecosystems. Twelve are endemic to the island of Maui. *Bidens micrantha* ssp. *kalealaha, Clermontia oblongifolia* and *Cyanea lobata* were formerly found on the island of Lanai, and *Acaena exigua* was found on the island of Kauai. *Hedyotis coriacea* is also found on the island of Hawaii, and *Melicope mucronulata* is found on the island of Molokai. *Huperzia mannii* was formerly found on Kauai and is still extant on Hawaii. *Scaevola coriacea* formerly occurred on Kauai, Oahu, Lanai, Hawaii and Niihau and *Alectryon macrococcus* is also extant on Kauai, Oahu and Molokai.

The Maui cluster taxa and their habitats have been adversely affected in various degrees by one or more of the following: trampling, grazing, and habitat destruction by introduced ungulates; habitat degradation and competition for space, light, water, and nutrients by alien vegetation; habitat loss from fires; insects and disease; predation by rodents and slugs; and loss of pollinators. A few of these taxa may have been subjected to overcollection, primarily for scientific or horticultural purposes, and are subject to trampling by human beings along trails. Because of the depauperate number of extant individuals and severely restricted distributions, populations of these taxa are subject to an increased likelihood of extinction from stochastic (chance) events.

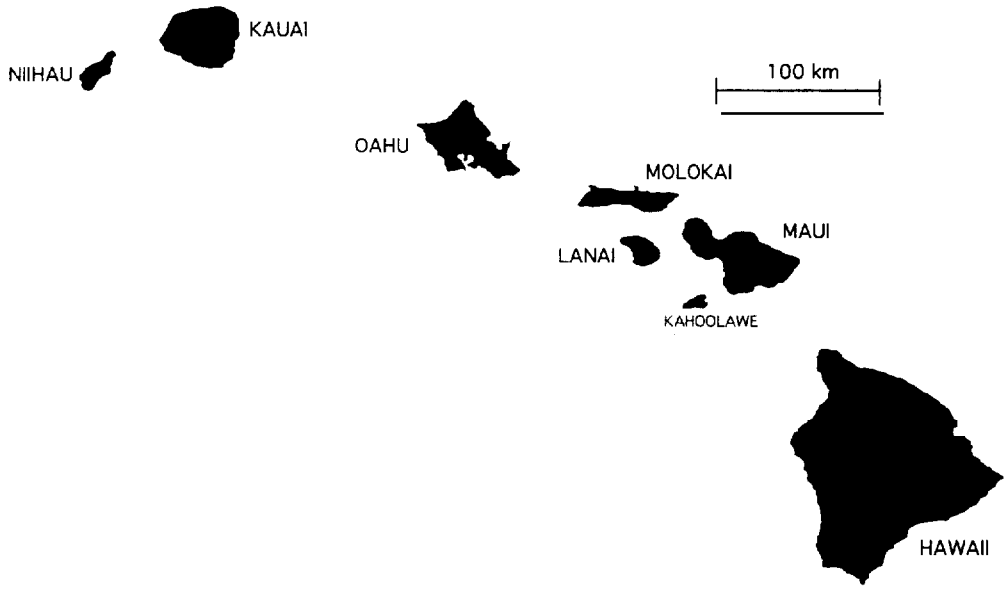

Figure 1. Map of the main Hawaiian Islands.

The land that supports the Maui cluster taxa is owned by the State of Hawaii (including land classified as Natural Area Reserve (NAR), Forest Reserve, State Park, Hawaiian Home Lands (HHL) and Plant Sanctuary lands), the City and County of Honolulu, the Federal government, and various private parties. Much of the Federal land occupied by these taxa is owned and managed by the National Park Service as Haleakala National Park. Other Federal lands supporting these taxa are controlled by the U.S. Army and U.S. Navy.

Part I of this plan has been constructed in a species-by-species format, allowing the reader to find all information about a particular taxon in one section, and allowing for efficient revision to include other Maui taxa as they are listed. This format will eventually produce one large, coordinated master plan for recovery of plants on the island of Maui, including a comprehensive analysis of the threats to Maui ecosystems and species as a whole, and species-by-species enumeration of actions needed for stabilization and recovery. Taxa could then be grouped within ecosystem types, since several taxa within such ecosystem groups could sometimes be benefitted by a single recovery action. Multispecies projects, such as the one outlined in Appendix B, should be developed to make this possible.

The Maui cluster taxa can be divided into four groups, based on their status:

Group #1 -- Eight taxa very near extinction: *Acaena exigua*, *Clermontia oblongifolia* var. *mauiensis*, *Cyanea lobata*, *Hedyotis coriacea*, *Melicope adscendens*, *Melicope mucronulata*, *Remya mauiensis*, and *Tetramolopium capillare*. These taxa appear to be at, beyond, or near the point of no return in the direction of extinction. Some *(Acaena exigua*, *Cyanea lobata*) may already be extinct, since no individuals are known to exist, although careful searching over a period of years is warranted. Others (*Clermontia oblongifolia* var. *mauiensis*, *Hedyotis coriacea*, *Melicope adscendens*, *Melicope mucronulata*) have (or had when most recently surveyed) fewer than five known individuals.

Group #2 -- Four taxa that, based on current trends, are clearly declining and may be beyond the point of no return within 5-10 years without prompt action to save them: *Alectryon macrococcus*, *Cyanea mceldowneyi*, *Scaevola coriacea*, and *Schiedea haleakalensis*.

Group #3 -- Three taxa that, though by no means stabilized, appear to be hanging on with the help of positive conservation efforts underway: *Geranium arboreum*, *Huperzia mannii*, *Lipochaeta kamolensis*.

Group #4 -- Six taxa that, though rare and/or very localized, are already at least partially stabilized, largely as a result of highly effective stewardship efforts already being implemented: *Argyroxiphium*

sandwicense ssp. *macrocephalum*, *Bidens micrantha* var. *kalealaha*, *Geranium multiflorum*, *Lysimachia lydgatei*, *Melicope balloui*, and *Melicope ovalis*.

B. Overall Reasons for Decline and Current Threats

A general description of the threats facing the Maui cluster taxa is given here. Particular threats facing individual taxa are given in the species narratives in the following section and are summarized in Table 1.

The primary threats to the endangered Maui taxa are coastal development and alien animals and plants. The resident human population of the island of Maui has increased rapidly in the recent past—from 39,000 in 1970 to 95,000 in 1990. Annual tourist visitation to Maui has increased from 169,000 visitors in 1957 to over 2 million in the late-1980s (U.S. Department of the Interior, National Park Service 1994).

Rapid growth of the local population on Maui and ever-increasing commerce between Maui and other islands and continents are causing accelerated introduction of potential invaders. Since the 1970s, an average of 20 new species of alien invertebrates alone get established in the Hawaiian Islands every year (The Nature Conservancy of Hawaii (TNCH) and the Natural Resources Defense Council (NRDC) 1992). More than 8,000 species of alien plants have already been brought into Hawaii and introductions continue (Smith 1985). Fortunately, not all of them will adversely affect surviving native biota and relatively few will threaten the pristine, high-elevation native ecosystems. Increasingly, concerted efforts are being made to slow the flow of alien species through quarantine procedures, etc., but serious "leaks" still occur (TNCH and NRDC 1992). An expanded international airport at Kahului, Maui, still in the planning stages but scheduled to become a reality within the next few years, is likely to increase these "leaks."

Rapid residential development and growth in tourism on Maui since 1970 have resulted in obliteration of extensive coastal and other low-elevation habitats, some of which still harbored native species. Most notable among the habitats affected are the sand hills of Wailuku. Alien animals and plants have been responsible for drastic changes to nearly every area of the Hawaiian Islands, including the habitats of the Maui cluster taxa (Wagner *et al.* 1990). In many cases, they are the primary causes of the historical declines of the Maui cluster taxa, and they continue to be primary threats to survival and recovery (USFWS 1986; USFWS 1991; USFWS 1992a; USFWS 1992b; USFWS 1994a; USFWS 1994b). Detailed descriptions of each of the alien animals and plants that threaten the Maui cluster taxa, and an analysis of the mechanism of their impacts, are given in Appendix H. Alien species of particular concern to individual Maui cluster taxa are also described in the Species Accounts section.

Table 1. Summary of threats to the Maui cluster taxa.

Taxon	Alien Animals	Alien Plants	Fire	Disease/ Pollinators	Human Impacts
Acaena exigua	p, s?, r?	X		X	X
Alectryon macrococcus	p, g, c, r, i	X	X	X	
Argyroxiphium sandwicense ssp.*macrocephalum*	g, i		X	X	
Bidens micrantha ssp. *kalealaha*	p, g,, c	X	X		
Clermontia oblongifolia ssp.*mauiensis*	p, s?, r?			X	
Cyanea lobata	p				X
Cyanea mceldowneyi	p, s?, r?	X			
Geranium arboreum	p, g, c, r	X	X		X
Geranium multiflorum	p, g	X			
Hedyotis coriacea		X	X		X
Huperzia mannii	p, g, c	X			
Lipochaeta kamolensis	g, c	X	X		
Lysimachia lydgatei	p, g	X	X	X	
Melicope adscendens	p, g, c, i	X	X		
Melicope balloui	p, i	X			
Melicope mucronulata	g, i	X		X	
Melicope ovalis	p, r, i	X			
Remya mauiensis	p, g	X	X		X
Scaevola coriacea	c	X		X	
Schiedea haleakalensis	s, i, g		X		
Tetramolopium capillare		X	X		
Total Number of Taxa Affected	19*	17	11	6	6

* Taxa affected by: Pigs - 14, Goats -12, Cattle - 7

Key: p - pigs
g - goats
c - cattle
r - rats
s - slugs
i - insects (notably, Argentine ant)

Fire and changes in microclimate are also partially responsible for the declines of the Maui cluster taxa, and continue to be immediate threats. In most terrestrial environments of the world, fire has been a pervasive disturbance strongly shaping the evolution of plants and animals. In contrast, fire does not appear to have played an important evolutionary role in native ecosystems of the Hawaiian Islands, and few endemic plants possess adaptations to fire. Lightning is relatively uncommon on oceanic islands because their small land mass is not conducive to convective buildup of thunderheads. Many native Hawaiian ecosystems may have lacked adequate fuel to carry fires ignited by lightning or vulcanism. Fires in modern Hawaii are mostly human-caused, are fueled primarily by alien grasses, and are highly destructive to most species of native plants. Opportunistic invasive plant species, on the other hand, especially *Melinis minutiflora* and *Pennisetum setaceum*, spread rapidly following fire or other disturbance. In natural areas of Hawaii, fire is therefore considered a negative influence that must be suppressed to the extent possible (Haleakala National Park 1990). Maui cluster taxa particularly vulnerable to fire include *Lipochaeta kamolensis* and *Remya mauiensis*.

There can be little doubt that the microclimate for native dryland forest regeneration on leeward East Maui has been drastically altered by loss of over 95% of the forest. Canopy opening has resulted in increased solar radiation reaching the ground, higher temperatures, and lower relative humidity—a desiccating environment that may preclude seedling establishment. The soil environment has also been substantially altered by cover of kikuyu grass and other alien grasses.

C. Overall Conservation Efforts

1. Federal Actions

The 21 taxa in this recovery plan were listed under the Endangered Species Act on May 16, 1986 (USFWS 1986), January 14, 1991 (USFWS 1991), May 15, 1992 (USFWS 1992a), May 13, 1992 (USFWS 1992b), September 30, 1994 (USFWS 1994a), and December 5, 1994 (USFWS 1994b), and therefore, are afforded the protection of this Act. Critical habitat was not deemed prudent 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.

The U.S. Army has set aside areas within the Pohakuloa Training Area for protection of rare plants, including the Maui cluster taxon *Hedyotis coriacea*. Management and fire suppression plans for these areas are being developed by the Army.

Many of the Maui cluster taxa occur in Haleakala National Park, administered by the National Park Service. The Park Service has conducted extensive management actions that benefit taxa of the Maui cluster, including fencing and removal of goats from the entire Park and continued pig control. In addition, the Park Service conducts propagation and research efforts for several of the taxa.

2. State Actions

The 21 taxa in this recovery plan are listed under State of Hawaii legislation (Hawaii Revised Statutes (HRS) Chapter 195D). 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 primary management of the Maui cluster taxa by the State of Hawaii includes the protection of some habitat areas from fire and feral ungulates. Some weeding of alien plant species occurs in Natural Area Reserves, and the State assists in the collection of seeds for the propagation of many of the Maui cluster taxa. In addition, the State has been involved in small-scale fencing projects for the protection of several of these taxa.

3. City and County and Nongovernmental Actions

Seeds and/or plants of many of the Maui cluster taxa have been collected by the National Tropical Botanical Garden (NTBG), and some have been successfully propagated in their facilities (propagation details are given in the following species accounts). Plans for these holdings include continued propagation research and study of the feasibility of long-term seed storage (Diane Ragone, NTBG, personal communication 1994). A summary of *ex situ* conservations actions is provided in Table 2.

D. Species Accounts

Figures depicting the current and historical ranges of each taxon may be found in Appendix C. Recovery priority numbers referred to in the species accounts are based on degree of threat, recovery potential, and taxonomic level, as described in Appendix I. Habitat types and species associated with the Maui cluster taxa are summarized in Appendix E, and land ownership and management are summarized in Appendix F.

Following each species account are suggested species-specific recovery actions. These do not reflect the order in which recovery actions should be accomplished or establish priority over other recovery tasks. Please refer to the Stepdown Narrative section of this plan for the overall recovery strategy.

1. *Acaena exigua* Gray

(Hawaiian name: liliwai) Recovery Priority # 5 (on USFWS scale of 1 to 18)

a. Description

Appendix D contains a line drawing of *Acaena exigua.*

Acaena exigua is a small perennial rosette herb in the rose family (Rosaceae) with narrow, fern-like, divided leaves and slender flowering stalks 5-15 centimeters (2-5.9 inches) long. It is easily hidden among the other low, tufted bog plants with which it grows. The narrow, oblong leaves are usually 10-25 millimeters (0.4-1.0 inch) long with 6-17 leaflets 1-4 millimeters (0.04-0.16 inches) long and 1-2 millimeters (0.04-0.08 inch) wide. The leaflet on the end is wider (to 3 millimeters [0.12 inches]). The upper surface of the leaves is glossy with conspicuous veins; the lower surface is whitish. The flowers lack petals and are arranged in short, dense spikes 5-10 millimeters (0.2-0.4 inch) long held on slender, sparsely leafy stalks 5-15 centimeters (2-6 inches) tall. The base of the flower is urn-shaped, sometimes with very short spines or bristles, and encloses a single cone-shaped dry fruit (achene) 1 millimeter (0.04 inches) long.

b. Taxonomy

Acaena exigua was described by Asa Gray in 1854 based on specimens collected in 1840 "on the table-land of the mountains of Kauai, in a marsh" (Gray 1854), likely the Alakai swamp, by plant collectors of the U.S. Exploring Expedition. Bitter (1910-1911), in a review of the genus *Acaena,* described three varieties of the Hawaiian species (var. *glabriuscula*, var. *subtusstrigulosa*, and var. *glaberrima*). The current taxonomic treatment (Wagner *et al.* 1990) treats *A. exigua* as a single, variable taxon and does not recognize varieties.

The genus *Acaena* comprises approximately 100 species, centered primarily in the Southern Hemisphere (Wagner *et al.* 1990). The sole Hawaiian species of the genus *Acaena* is distinguished from other Hawaiian members of the rose family in that it is a small, compact, high-elevation bog species with

flowers that lack petals. The specific epithet, *exigua*, means "small, short, poor, scanty," presumably due to the small size of the species.

c. Current and Historic Range and Population Status

No individuals of this species are currently known to exist. Historically, *Acaena exigua* was known from Puu-kukui on West Maui and from Mount Waialeale on Kauai. On Kauai, *Acaena exigua* was last collected by Wawra in 1869-1870; it has not been seen there in this century (Wagner *et al.* 1990). Rock (1913) states, (regarding West Maui): "*Acaena exigua*, which is very scarce on Waialeale, is here exceedingly common, together with *Viola mauiensis*." On West Maui, *Acaena exigua* has not been collected since 1957 (Wagner *et al.* 1990). Botanists have been searching for this species for years, but have not been successful, despite finding several other rare plant associates (R. W. Hobdy, Division of Forestry and Wildlife, Hawaii Department of Land and Natural Resources, personal communication 1990).

d. Life History

No details are known.

e. Habitat Description

Acaena exigua is known only from montane bogs at elevations of 1,600-1,800 meters (5,250-5,906 feet). This habitat is characterized by a thick peat substrate overlying an impervious clay substrate, with hummocks of sedges and grasses, stunted trees, and shrubs. Associated native species include the native sedges and grasses *Deschampsia nubigena, Dichanthelium cynodon, Dichanthelium hillebrandianum, Dichanthelium isachnoides*, and *Oreobolus furcatus*, and the native shrubs *Metrosideros polymorpha* and *Vaccinium* sp. Alien species include *Holcus lanatus, Juncus planifolius, Cyperus halpan*, and *Sacciolepis indica.*

f. Reasons for Decline and Current Threats

The reason for the disappearance of this species is not known. Though impact from herbivory and rooting by pigs is assumed and often cited, feral pigs have become established at Waialeale (Kauai) only

within the past two decades. The other known habitat, Puu-kukui (West Maui), is pig-free and apparently has always been so.

The main current threats to *Acaena exigua*, if it exists, are believed to include:

1) Small population size

Because *Acaena exigua,* if it still exists at all, presumably occurs at such low population levels and in such a restricted area a single severe environmental disturbance, such as a prolonged drought, could result in its extinction. In addition, the lack of genetic diversity could depress the reproductive vigor or adaptability of the species.

2) Human impacts (collecting and site degradation)

Trampling of associated native plant species and introduction (long-distance and regional) of invasive alien plant species in its montane bog habitat are threats to *Acaena exigua* caused by excessive human visitation.

3) Other factors

Though undocumented, consumption of vegetative or floral parts of this species by alien slugs and/or rats could have been a factor in the decline of the species and could continue to be a critical limiting factor. An alien pathogen such as a disease, fungus or nematode could also be a factor, as could loss of pollinators, or some as-yet-undetected micro-environmental change associated with the species' disappearance.

Potential future threats could include:

1) Feral pigs

In the montane bogs on Kauai, habitat degradation by feral pigs is currently a primary threat to the native bog plant communities, which comprise potential habitat for *Acaena exigua.* Puu-kukui on West Maui is currently pig-free. However, it is possible that feral pigs could reach the summit of Puu-kukui and cause serious degradation of the montane bog habitat if not adequately controlled.

2) Alien plant species

Accompanying feral pig activity on Waialeale is a substantial loss of native plant cover, dramatic increases in bare ground, and the progressive invasion of several invasive plant species, especially the rush *Juncus planifolius* (Juncaceae).

g. Conservation

None

h. Needed Recovery Actions

The reasons for decline of *Acaena*, apparently sometime between 1920 and the present, are unknown. Chronic impacts of feral pigs and increased cover of alien plant species in the montane bogs of Kauai have occurred only within the past two decades, long after the decline of this species. The West Maui bog complexes of Puu Kukui and Eke are virtually pristine, having never been damaged by feral pigs. Neither is there reason to believe that the bogs have been chemically altered, as evidenced by the continued presence of other bog-dependent plant associates (R. W. Hobdy, personal communication 1990). If *Acaena exigua* is relocated, determining the cause of its decline will be a high priority recovery action. If the species cannot be relocated after extensive searches, delisting due to extinction may be proposed.

1) Search for any individuals of this species in the former habitat.

Habitat is limited. Some searching has been done on an *ad hoc* basis, but a complete search of former habitats is needed. The plant is diminutive and easily overlooked. However, although the plant is small, the leaf and rosette morphology are so distinctive as to be unmistakable.

2) If plants are found, initiate research on limiting factors.

Research should investigate what more subtle threats, such as lack of pollinators, alien slugs, rodents or disease, are limiting factors to the survival of this species. These are likely to be the same unknown factors that caused the decline of the species in the first place.

3) If plants are found, protect and enhance existing population(s) and create new populations.

If plants are found, either on West Maui or on Kauai, steps should be taken to protect these plants from known and possible threats. Additionally, the species should be outplanted in available protected habitat within an existing reserve (West Maui NAR [Natural Areas Reserve], Puu Kukui Watershed owned by Maui Land and Pineapple, or Kapunakea Preserve managed by TNCH) on West Maui. The natural and re-established populations should be intensively monitored for vigor and reproductive viability, to ensure their continued existence and possibly to shed light on the original cause of decline.

2. *Alectryon macrococcus* Radlkofer

(Hawaiian names: mahoe, alaalahua) Recovery Priority # - 5

var. *macrococcus* Recovery Priority # - 3

var. *auwahiensis* Recovery Priority # - 6

In the original designation of endangered status for this taxon, the species as a whole was listed. However, for the purposes of recovery, the two subspecies are being considered as separate taxa, due to the great disparity in their status, distribution, and recovery needs.

a. Description

Appendix D contains a line drawing of *Alectryon macrococcus*.

Alectryon macrococcus is a tree in the soapberry family (Sapindaceae) consisting of two varieties, *macrococcus* and *auwahiensis*. Both reach heights of 3-11 meters (10-36 feet), with reddish-brown branches and net-veined paper- or leather-like leaves 20-55 centimeters (8-22 inches) long, with one to five pairs of sometimes asymmetrical egg-shaped leaflets 10-28 centimeters (4-11 inches) long by 4-12 centimeters (1.6-4.7 inches) wide. The upper surface of the leaf is glossy and smooth. The underside of the leaf has dense brown hairs, only when young in *Alectryon macrococcus* var. *macrococcus*, and whether young or mature (persistent) in *Alectryon macrococcus* var. *auwahiensis* (Linney 1987). Flower clusters up to 30 centimeters (12 inches) long consist of cup-shaped, small flowers 1.5-2.5 millimeters (0.06-0.1 inches) long with unequal lobes on short, individual stalks. The flowers have no petals and sometimes lack female parts. Fruits consist of one or two nearly spherical parts, the second of two often abortive; the inside of the seed coat is irregularly scarlet. The hard seeds are 5-10 millimeters (0.2-0.4 inches) long and glossy pale brown with irregular projections, and have a smooth, scarlet fleshy coating with an irregular sinus on one side.

The only member of its genus found in Hawaii, this species is distinguished from other Hawaiian members of its family by being a tree with a hard fruit 2.5 centimeters (0.9 inches) or more in diameter.

b. Taxonomy

The noted Hawaiian botanist W. Hillebrand was the first to collect this species but was unable to make a complete collection. Based on this incomplete material, Hillebrand (1888) described the material as "*Mahoe*, gen. nov.?", a questionably new, endemic genus. *Alectryon macrococcus* was described by

L. Radlkofer (1890) based on Hillebrand's specimens and the information in Hillebrand (1888). St. John and Frederick (1949) described *Alectryon mahoe* for Oahu specimens based on leaf shape, pubescence on lower leaflet surfaces, and details of flower structure. Linney (1987) included the Oahu population with *Alectryon macrococcus* var. *macrococcus* but recognized East Maui plants as a new variety, var. *auwahiensis*, based on the persistent pubescence on lower leaflet surfaces. This treatment of a single Hawaiian species with two varieties, var. *macrococcus* and var. *auwahiensis*, was adopted by Wagner *et al.* (1990). The specific epithet *macrococcum* has been used by some botanists (St. John and Frederick 1949; St. John 1973) in accordance with Gaertner's original neuter designation of the genus; however, Radlkofer's (1890) revision of the genus treated the genus as masculine and renamed all existing specific epithets to agree with the masculine gender at that time.

The genus *Alectryon* comprises 25 species from Malaysia, Australia, and New Zealand to Samoa and Hawaii (Wagner *et al.* 1990). The specific epithet *macrococcus* translates literally to "large (or long) berry," presumably referring to the distinctive large red seed and aril seed covering.

c. Current and Historic Range and Population Status

Alectryon macrococcus var. *macrococcus* occurs on Kauai, Oahu, Molokai and West Maui (Wagner *et al.* 1990). Six populations of *Alectryon macrococcus* var. *macrococcus*, totalling fewer than 100 plants, are known on Kauai, all on State-owned land in Waimea Canyon and in Na Pali Coast State Park. On Oahu, most known individuals occur at numerous sites in the Waianae Mountains (as far north as Kaluakauila Gulch to as far south as the ridge above Lualualei) and much less often in the Koolau Mountains. The total number of individuals on Oahu is estimated to be about 400. On Molokai, the five extant occurrences, totalling six plants, are located at Puu Kolekole jeep road, Kaunakakai Gulch, and Kamakou Preserve, on State and private land. On West Maui, the three existing occurrences, totalling just a few plants, are located along the Honokowai Ditch Trail and in Launiupoko Valley on privately owned land.

These 27 populations/occurrences are on city and county, State, Federal, and private land, most numbering only one or two individuals. Two populations each have between 50 and 200 individuals. The entire subspecies currently numbers about 500 individuals. Two populations of *Alectryon macrococcus* var. *macrococcus* on Oahu are on Federal property, one population on Schofield Barracks and the other on Lualualei Naval Reservation. Eight populations of *Alectryon macrococcus* var. *macrococcus* on Oahu are on State land, three in areas leased to the Federal government as part of Makua Military Reservation and five in a nearby State Conservation District.

On leeward East Maui, the var. *auwahiensis* occurs in the Auwahi and Kanaio districts. In 1910, J.F. Rock found about 40 trees in the rich forest of Auwahi on the south slopes of Haleakala. Currently, a single scattered population of about nine individuals of this taxon remains within a 29-hectare area on privately owned and State-owned (and privately leased) ranchland.

d. Life History

Alectryon macrococcus is a relatively slow-growing, long-lived tree that grows in xeric to mesic sites and is adapted to periodic drought. Little else is known about the life history of *Alectryon macrococcus*. Flowering cycles, pollination vectors, seed dispersal agents, and specific environmental requirements are unknown.

e. Habitat Description

The habitat of *Alectryon macrococcus* is dryland forest, once widespread on leeward exposures of all the Hawaiian Islands, but now almost completely eliminated. Both varieties of *Alectryon macrococcus* typically grow on dry slopes or in gulches, within dry to mesic lowland forests at elevations of 360-1,070 meters (1,180-3,510 feet). Mean annual rainfall is roughly 80-200 centimeters (2.6-6.6 feet) in this habitat. Most rainfall comes in the winter, whereas summers are hot and dry.

Associated native plants include *Metrosideros polymorpha, Aleurites moluccana, Diospyros sandwicensis, Nestegis sandwicensis, Psychotria, Pisonia, Xylosma, Streblus, Hibiscus, Antidesma, Pleomele, Acacia, Melicope knudseni, Hibiscus waimeae, Pteralyxia, Zanthoxylum, Doodia, Blechnum, Kokia kavaiensis, Bobea timonioides* (USFWS 1992a; Hawaii Plant Conservation Center (HPCC) 1994). Associated alien plants include *Lantana, Setaria, Triumfetta, Melia azedarach, Bocconia frutescens, Melinis minutiflora, Psidium cattleianum, Schinus terebinthifolius,* and *Pennisetum clandestinum* (HPCC 1994).

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this species include: impacts of feral cattle, goats and pigs; impacts of alien plant species; damage from the black twig borer; and seed predation by rodents.

Current threats to *Alectryon macrococcus* include:

1) Competition with alien plant species

The alien plants *Melinis minutiflora* (molasses grass), *Pennisetum clandestinum* (kikuyu grass), and *Schinus terebinthifolius* (Christmas berry) pose threats to *Alectryon macrococcus* reproduction because of competition with seedlings for light, space, and water. Christmas berry is now replacing the native vegetation of much of the southern Waianae Mountains and threatens to occupy the range of all Oahu populations of *Alectryon macrococcus* var. *macrococcus*. Most populations of *Alectryon macrococcus* var. *macrococcus* on Oahu and Molokai are immediately threatened by molasses grass. Kikuyu grass forms a thick mat that displaces reproduction of native plant taxa at Auwahi on East Maui. The West Maui individuals of *Alectryon macrococcus* var. *macrococcus* are immediately threatened by competition with strawberry guava (*Psidium cattleianum*).

2) Black twig borer (*Xylosandrus compactus*)

The black twig borer has been cited as an immediate threat to the extant populations of both recognized varieties of *Alectryon macrococcus* (J. Lau, TNCH, personal communication 1990). This pest burrows into the branches and introduces a pathogenic fungus, pruning the host severely, often killing branches or whole plants. The Waimea Canyon populations of *Alectryon macrococcus* var. *macrococcus*, most populations on Oahu, and the single population of *Alectryon macrococcus* var. *auwahiensis* suffers severe defoliation and reduced vigor due to infestations of this alien insect. Most populations of this species probably sustain some damage from the borer.

3) Seed predation by alien rodents

Predation on fruits and flowers by rodents, both black rats (*Rattus rattus*) and less often house mice (*Mus musculus*), threatens *Alectryon macrococcus*. Evidence of rat predation has been seen on both varieties of *Alectryon macrococcus*. Seed predation by black rats has inhibited reproduction of this species for many years. Virtually all *Alectryon* seeds lying beneath the canopies of trees in Auwahi and Kanaio districts on Maui are destroyed by black rats (Medeiros, Loope, and Holt 1986).

4) Alien ungulates

Herbivory, trampling, and soil erosion caused by goats are immediate threats to *Alectryon macrococcus* var. *macrococcus*. Currently, goats contribute to the substantial decline of all four populations of this taxon in Waimea Canyon on Kauai. Goats on State lands in this area are managed for recreational hunting. In the Waianae Mountains of Oahu, encroaching urbanization and hunting pressure tend to restrict goats to the drier upper slopes (Tomich 1986), where *Alectryon macrococcus* occurs. Over half of the Oahu populations of *Alectryon macrococcus* var. *macrococcus* are affected by increasing numbers of goats in scattered locations along the

Waianae Mountains, especially in Makua and Nakaleha. On Molokai, all five localities of *Alectryon macrococcus* var. *macrococcus* are restricted to a 7.5 square kilometer (4.7 square mile) area that is immediately threatened by goats (USFWS 1992a).

Both recognized varieties of *Alectryon macrococcus* are threatened by habitat degradation by feral pigs and have sustained loss of individual plants or habitat as the result of feral pig activity. Present throughout the Waianae Mountains of Oahu in low numbers, feral pigs pose a significant threat to the scattered populations of *Alectryon macrococcus* var. *macrococcus*.

Herbivory, trampling, and habitat degradation by cattle also threaten the species, particularly *Alectryon macrococcus* var. *auwahiensis*. The sole remaining habitat for this variety is on a cattle ranch consisting of private and State-leased lands. Although all individuals of *Alectryon macrococcus* var. *auwahiensis* are protected from ungulates with small woven-wire exclosures, these must be rigorously maintained. Cattle trample seedlings and damage mature plants by browsing (USFWS 1992a).

5) Wildland fire

Fire is a threat to some populations of *Alectryon macrococcus* var. *macrococcus*. Unintentionally ignited fires have resulted from ordnance training practices in Makua Military Reservation on Oahu. Although most fires have been contained within 0.01 hectares (0.02 acres), a single 120 hectare (300 acre) fire in July 1989 spread upslope and came to within 0.3 kilometers (0.2 miles) of a population of *Alectryon macrococcus* var. *macrococcus*, also threatening seven other populations in the area. Fires are also a potential threat to Waimea Canyon, Kauai, and less likely, but possibly, to west and east Maui populations (USFWS 1992a).

6) Small population size

Due to the very small remaining number of individuals of *Alectryon macrococcus* var. *auwahiensis* and their limited distribution, a single natural or human-caused environmental disturbance could easily be catastrophic. Given the limited size and scattered distribution of populations and individuals of both *Alectryon macrococcus* var. *macrococcus* and *A. macrococcus* var. *auwahiensis*, gene pool limitations may depress reproductive vigor and adaptability.

7) Other threats

Possible threats to both varieties include seed predation by insects (probably the endemic microlepidopteran *Prays* cf. *fulvocanella* Walsingham [Yponomeutidae]) and loss of pollinators.

g. Conservation

Makua Military Reservation and Schofield Barracks are controlled by the U.S. Army, and portions are used for ordnance training of their troops. The *Alectryon macrococcus* var. *macrococcus* plants on their land are not located inside impact or buffer zones and thus are not directly affected by military activities. The Army has constructed firebreaks around the plants on the Makua Military Reservation to minimize damage from unintentional fires that occasionally result from stray bullets.

To protect the population of *Alectryon macrococcus* var. *macrococcus* at Naval Magazine Lualualei, the U.S. Navy is working to control alien plants in areas where individuals of *Alectryon macrococcus* var. *macrococcus* are located. The Navy also allows recreational hunting on their lands to control the feral pig population (D.W. Wilborn, U.S. Navy, personal communication 1996).

At Auwahi, East Maui, small woven-wire enclosures have been constructed by a private conservation group, the Native Hawaiian Plant Society, with cooperation from Ulupalakua Ranch, to protect endangered and threatened plants from ungulates. One individual of *Alectryon macrococcus* var. *auwahiensis* is protected within one of these enclosures (R. Nakagawa, Native Hawaiian Plant Society, personal communication 1996).

Alectryon macrococcus var. *auwahiensis* has been propagated by Hawaii Division of Forestry and Wildlife (DOFAW) at its Maui baseyard near Kahului and at the Waimea Arboretum and Botanical Garden on Oahu. *Alectryon macrococcus* var. *macrococcus* has been propagated at the Honolulu Botanic Garden (Mehrhoff 1992) and at Lyon Arboretum on Oahu (G. Ray, Center for Plant Conservation, personal communication 1997). The National Tropical Botanical Garden (NTBG) has seed stored from a cultivated specimen of *Alectryon macrococcus* var. *macrococcus* and has successfully propagated both varieties (D. Ragone, personal communication 1994).

h. Needed Recovery Actions

Among the known populations of *Alectryon macrococcus*, there are a wide variety of situations in terms of microhabitat and degree and nature of threats. The situation is obviously most urgent for *Alectryon macrococcus* var. *auwahiensis*, of which only about nine individuals survive. As stated above, these two varieties are being considered as separate taxa for purposes of recovery.

1) *Alectryon macrococcus* var. *macrococcus*

a) Identify target populations for manipulative management.

To reach the downlisting objectives outlined in part II of this plan, five populations will need to be selected for protection, management and possible augmentation to reach the goal of 100 individuals each. Factors to consider in selection of target populations include land ownership, size of population, quality of surrounding habitat, severity of local threats, and geographic and morphological diversity. Management, depending on local site characteristics, should potentially include fencing, weed control, outplanting of local genetic material, and rodent control (perhaps only seasonally during fruiting season).

b) Survey known populations to determine effect of black twig borer and rodents.

Of existing populations, determine which sites are most vulnerable to the impacts of black twig borer and rodents. Determine if any sites are free from these factors. Sites free or relatively free from these influences are obviously prime candidates for protected "target" populations. Obviously if some sites, e.g., higher elevation, are free from black twig borers, extreme care should be taken not to introduce the insect with propagative material of *Alectryon*.

2) *Alectryon macrococcus* var. *auwahiensis*.

a) Initiate an emergency program.

This program needs to involve propagation, outplanting into managed (with weed control) exclosures on protected lands, establishment of "nurse forests" (see Appendix B) to nurture reestablishment of the taxon in the long run, and emergency assessment of and response to limiting factors, such as the black twig borer.

b) Establish outplanted populations in "safe" (through fencing where necessary) habitat and institute weed control as necessary at these sites.

At least four new populations of *Alectryon macrococcus* var. *auwahiensis* will have to be discovered or created through outplanting to reach the downlisting objectives. Potential sites include Kanaio State NAR, privately owned Ulupalakua Ranch, and the Kaupo Gap area of Haleakala National Park on East Maui.

3. *Argyroxiphium sandwicense* ssp. *macrocephalum* (Gray) Meyrat (Common name: Haleakala silversword. Hawaiian names: pohinahina, ahinahina) Recovery Priority # - 9

a. Description

Appendix D contains a line drawing of *Argyroxiphium sandwicense* ssp. *macrocephalum*.

Argyroxiphium sandwicense ssp. *macrocephalum* (Asteraceae: Madiinae) is a distinctive, globe-shaped rosette plant, with a dense covering of silver hairs. Usually single-stemmed, its swordlike, rigid, and succulent leaves are 15-40 centimeters (5.9-15.8 inches) long, 5-15 millimeters (0.2-0.6 inches) wide at the middle, usually three-angled in cross-section, and progressively erect to decumbent (flat-lying with upward-pointing ends). The inflorescence (flowering stalk) grows 0.5-3.0 meters (1.6-9.8 feet) tall and contains numerous flower heads (capitula). These are showy with 50-600 densely packed, pink to wine-red flowers. Each flower is 5-23 millimeters (0.2-0.9 inches) across. There are 11-42 petal-like ray florets and 50-600 minute disk florets per head. The fruits are dry and one-seeded (achenes), straight or curved like a bow, and 7-15 millimeters (0.3-0.6 inches) long. Each rosette dies after flowering once.

This subspecies is distinguished from *Argyroxiphium sandwicense* ssp. *sandwicense* by the shape and ratio of the dimensions of the inflorescence, the number of ray florets per head, and the combination of a) its longer, three-angled leaves; b) its silvery leaf hairs, which completely hide the leaf surface; and 3) its longer achenes.

b. Taxonomy

East Maui silverswords were described by Asa Gray in 1852 as *Argyroxiphium macrocephalum* from a specimen collected on Haleakala, Maui, in 1841 by naturalist Charles Pickering of the U.S. Exploring Expedition. Hillebrand (1888) reduced the taxon to varietal status as *Argyroxiphium sandwicense* var. *macrocephalum* (Gray) Hillebr. Keck (1936) did not recognize Hillebrand's var. *macrocephalum*, including it instead within a broad interpretation of *Argyroxiphium sandwicense*. Based on quantitative, geographic, and putative evolutionary differences, Meyrat *et al.* (1983) restored the Haleakala silversword to subspecies status, namely ssp. *macrocephalum* (A. Gray) Meyrat. This treatment of two subspecies in the alpine cinder deserts of the islands of Hawaii (ssp. *sandwicense*) and Maui (ssp. *macrocephalum*) was accepted in the most recent taxonomic treatments (Carr 1985, Carr in Wagner *et al.* 1990). The genus *Argyroxiphium* comprises five species endemic to Maui and the island of Hawaii, Hawaiian Islands. The subspecies epithet *macrocephalum* refers to the large flower heads of the Haleakala plants of this species.

c. Current and Historic Range and Population Status

Near extinction in the 1920s due to human vandalism and to browsing by goats and cattle, the Haleakala silversword has increased greatly under protection, and deserves attention as one of the most dramatic conservation success stories of the Hawaiian Islands.

Argyroxiphium sandwicense ssp. *macrocephalum* is a classic example of a taxon considered rare because of its highly restricted distribution (Rabinowitz *et al.* 1986). It is endemic to (only known from) a 1,000-hectare (2,500 acre) area at 2,100-3,000 meters (6,900-9,800 feet) elevation in the crater and outer slopes of Haleakala Volcano, within Haleakala National Park, Maui, Hawaii, apparently occupying most of its historic range (Loope and Crivellone 1986).

The first reliable information on Haleakala silversword numbers is from the summer of 1935. In that year, Ranger S.H. Lamb tallied 1,470 plants (88 of which were flowering) on a single cinder cone (Ka-moa-o-Pele) within Haleakala Crater (Lamb 1935). Since about 217 plants were flowering within the crater (Lamb 1935), a reasonable estimate of the total population at that time was about 4,000 individuals (Loope and Medeiros 1994b). Lamb's conclusion after consulting numerous individuals knowledgeable on the subject was that, in 1935, "the plants are probably as numerous now as they have ever been since 1906." Information gathered since illustrates the trend of the silversword population over about 60 years of protection. Since plants occur on otherwise barren cinder, fairly accurate counts are possible. Methods are described in original reports (Loope and Crivellone 1986; Kobayashi 1973, 1991, 1993).

Plants have been counted by successive investigators on the cinder cone, Ka Moa o Pele, where the largest number of plants survived in 1935. By 1979, the population on this volcanic cone had increased by a factor of about 4.4, from 1,470 to 6,528 individuals (Kobayashi 1991). Elsewhere in Haleakala Crater, the silversword has also increased in numbers and extent, with large local populations in areas where few plants survived in 1935. A census of the entire Haleakala silversword population has been attempted four times since 1971, with the following results: 1971 - 43,262 (Kobayashi 1973); 1979-80 - 35,000 (Kobayashi 1991); 1982 - 47,640 (Loope and Crivellone 1986); 1991 - 64,800 (Kobayashi 1993).

The current population of silversword is approximately 16 times larger than the estimated population in 1935. Annual trends in 11 fixed plots, 5 x 20 meters (16.4 x 65.6 feet), from 1982 through 1989, suggest occurrence of substantial annual fluctuations in the recruitment and survival of seedlings (Loope and Medeiros 1994c). The other subspecies of *Argyroxiphium sandwicense*, ssp. *sandwicense*,

endemic to Mauna Kea on the island of Hawaii, is federally listed as endangered, with only several hundred surviving individuals.

d. Life History

The monocarpic (flowers only once, at the end of its lifetime) Haleakala silversword matures from seed to its final stage in approximately 15-50 years (Loope and Medeiros 1994c). The plant remains a compact rosette until it sends up an erect, central flowering stalk, sets seed, and dies.

The silversword flowers from June to September, with annual numbers of flowering plants varying dramatically from year to year. Reliable counts of flowering plants were made in 1935 (217 flowered) and in 1941 (815 flowered) (Loope and Crivellone 1986). Numbers recorded in recent years have ranged from zero in 1970 to 6632 in 1991. The environmental stimulus for synchronous silversword flowering is as yet unknown. An apparent relationship of the 1991 mass flowering event to stratospheric alteration by the eruption of Pinatubo Volcano in the Philippines is intriguing. Investigations are underway by R. Pharis of the University of Calgary and L.L. Loope to explore a mechanism for enhanced silversword flowering related to increased UV-B radiation due to temporary reduction of stratospheric ozone.

Flying insects, especially native bees, moths, flies, bugs, and wasps, many of which are pollinators, are attracted in large numbers to the giant, aromatic inflorescences. It has been demonstrated that *Argyroxiphium sandwicense* ssp. *macrocephalum* is self-incompatible (Carr *et al.* 1986) and is reliant on insect pollinators for reproduction.

Rarely, hybrids between *Argyroxiphium sandwicense* ssp. *macrocephalum* and *Dubautia menziesii*, have been observed. Primarily found within Haleakala Crater, especially on Puu o Pele and Puu o Maui cinder cones, these hybrid individuals flower for several years before dying (Carr 1985).

e. Habitat Description

The habitat of *Argyroxiphium sandwicense* ssp. *macrocephalum* consists primarily of otherwise barren, unstable slopes of recent (less than several thousand years old) volcanic cinder cones. Mean annual precipitation is approximately 75-125 centimeters (30-50 inches). The substrate has almost no soil development and is subject to frequent formation of ice at night and extreme heating during cloudless days.

Associated native species include *Agrostis sandwicensis*, *Deschampsia nubigena*, *Dubautia menziesii*, *Silene struthioloides*, *Styphelia tameiameiae*, *Tetramolopium humile*, and *Trisetum*

glomeratum. Alien species occupy little area in Haleakala silversword habitat but include *Hypochoeris radicata, Heterotheca grandiflora,* and *Rumex acetosella.*

f. Reasons for Decline and Current Threats

The Haleakala silversword receives more attention from visitors to Haleakala National Park than any other plant species because of its striking appearance and its limited distribution. There is ample evidence that it attracted attention from indigenous Hawaiians. In pre-Park days, plants were often removed by visitors to Haleakala Volcano to prove that the party had reached the summit, a practice that eventually had a serious impact on the silversword population (Loope and Crivellone 1986; Loope and Medeiros 1994c). At one time the silverswords on Haleakala were uprooted and rolled down cinder cones for sport. Browsing by goats and cattle was also undoubtedly a factor in its decline, especially at the margins of its range. By the 1920s, silversword numbers were so depleted that the Maui Chamber of Commerce sent a petition to Washington, D.C., requesting that a serious effort be made to save the species (Loope and Crivellone 1986).

The main current threats to *Argyroxiphium sandwicense* ssp. *macrocephalum* include:

1) Loss of pollinators

The silversword has a somewhat vulnerable combination of traits. It is a slow-growing plant that flowers only once and dies, yet is self-incompatible. As a result, it is dependent upon the availability of pollinating insects, primarily localized endemic species, for seed set. The greatest threat to the pollinators of the silversword appears to be the Argentine ant (*Iridomyrmex humilis*). This introduced species occupies two disjunct areas between 2,070 and 2,850 meters (6,792 and 9,350 feet) elevation, totalling about 160 hectares (400 acres) in Haleakala National Park. Because queens are non-flighted, spread is relatively slow. This predaceous ant negatively affects the endemic arthropod fauna (Cole *et al.* 1992), including pollinators, which evolved in the absence of ant predation. A marked expansion in the ant's range was noted in 1993, especially at the higher elevation area (Medeiros *et al.* 1994).

Unless this ant species is controlled, it appears capable of spreading widely, with potentially catastrophic effects on endemic biota, including the silversword (Carr et al. 1986). Experimental control efforts are underway with a hydromethylnon/protein bait, using techniques developed for Argentine ant control in agricultural sites in California (Loope and Medeiros 1994a).

Alien yellowjackets (*Vespula pennsylvanica*) pose a lesser but significant threat toward elimination of silversword pollinators.

2) Native seed-eating and herbivorous insects

The silversword is dependent upon continuing seed production for its survival. The developing seeds are fed upon by the tephritid fly *Trupanea cratericola* (Swezey 1954). On average, 60% of the seeds produced by the silversword are destroyed by the small, white grub-like larvae of this fly (Kobayashi 1974). Developing seeds are also fed upon, sometimes extensively by the larvae of a native phycitid moth, *Rhynchephestia rhabdotis* (Swezey 1954, Zimmerman 1958). There is also an endemic cerambycid beetle, *Plagithmysus terryi*, which bores in roots and stems, and sometimes causes silversword plants to fall over (Betsy H. Gagné, DOFAW, personal communication 1987). The impacts of these insects have probably been overestimated historically. In earlier times, these insects were perceived as posing a serious threat to Haleakala silversword (e.g., Degener 1930), and perusal of Park files reveals that application of DDT to protect the plants was contemplated by Park managers as recently as the 1960s (Loope and Crivellone 1986). The locally endemic insects that evolved with the silversword are currently regarded by Park managers as an essential part of the silversword ecosystem.

3) Limited natural range

The limited natural range of this taxon makes it vulnerable to extinction due to a single catastrophic event such as a natural disaster or alien plant or animal introduction.

4) Other threats

Possible future threats include competition from alien plant species, namely mullein (*Verbascum thapsus*) and fountain grass (*Pennisetum setaceum*) (Loope, Nagata, and Medeiros 1992), and human impacts (collecting and site degradation). The human threats are currently controlled within the Park, but may become more serious as the number of visitors increases.

g. Conservation

As stated above, this taxon deserves attention as one of the most dramatic conservation success stories of the Hawaiian Islands. As a result of management within Haleakala National Park, human vandalism and feral ungulate browsing—formerly the most serious threats to the Haleakala silversword—have been virtually eliminated. Almost all sub-populations of *Argyroxiphium sandwicense* ssp. *macrocephalum* are within Haleakala National Park, which has successfully protected the taxon since the 1930s. Only a few individuals survive just outside the boundaries of the Park. This species has been successfully propagated at NTBG (D. Ragone, personal communication 1994; G. Ray, Center for Plant Conservation, personal communication 1997).

The Haleakala silversword is a highly charismatic, interesting species from the point of view of the casual Park visitor as well as that of the evolutionary biologist. Continued protection from feral ungulates and human vandalism is essential, and potential threats from the Argentine ant and alien plants must be addressed. Even given its limited range and precarious life cycle, the long-term prognosis for survival of this species now appears remarkably favorable. The Service will continue to evaluate the status of this plant to determine when a proposal to delist is appropriate, based on meeting its recovery criteria.

h. Needed Recovery Actions

1) Monitor and initiate control efforts against further spread of the Argentine ant in the crater and outer volcanic slopes of Haleakala Volcano.

Without intervention, it is likely that the Argentine ant will continue to slowly spread and eventually perhaps come to occupy much of the range of the silversword. Such an infestation is likely to deplete pollinator populations on which the silversword is highly dependent. The result of such a reduction of the native pollinators of the silversword is a reduced reproductive capacity and lessened chance for long-term survival. Chemical control using a bait-toxicant appears to be the best chance to restrict or eliminate high elevation populations of the Argentine ant on Haleakala, which are currently restricted in area. Such research is now ongoing in cooperation with scientists of the Clorox technical center.

Another important consideration in control of the Argentine ant is the prevention of further spread. Queens of the Argentine ant often forage with workers and are quick to establish small satellite nests. Such behavior facilitates potential transfer of queens with human activities such as transport of trash, roadfill, potted plants, firewood, etc. Management of high elevation areas on Haleakala can prevent such unintended impacts through using carefully considered protocols.

2) Establish outplanted populations in former habitat.

One of the chief impacts of the long term degradation of high-elevation habitat of silversword on Haleakala Volcano is the elimination of silversword populations in areas on the periphery of Haleakala Crater. As a result of fencing the boundary of Haleakala National Park in the mid-1980s, these areas are now protected from feral goats, which had extirpated the silversword from certain peripheral areas. Now that the habitat of these sites is protected, they are prime candidates for reintroduction. The best documented examples of appropriate sites are a) upper central Kaupo Gap, b) Kalapawili grasslands, and c) Puu Nianiau. Other areas such as the outer leeward slopes and southwest rift of Haleakala should be considered if protection from feral goats can be achieved there. Extreme caution should be taken not to introduce the Argentine ant with planted materials as

the species frequently nests in potted plants grown in the headquarters area of Haleakala National Park.

4. *Bidens micrantha* Gaud. ssp. *kalealaha* Nagata & Ganders
(Hawaiian names for native *Bidens*: kokolau, kokoolau, and koolau)
Recovery Priority # - 9

a. Description

Appendix D contains a line drawing of *Bidens micrantha* ssp. *kalealaha*.

Bidens micrantha ssp. *kalealaha* is an erect perennial herb in the aster family (Asteraceae). The base of the 50-150 centimeter (20-60 inches) plant is somewhat woody. Leaves are 6-19 centimeters (2.6-7.5 inches) long with 1-9 (usually 5-9) lance-shaped leaflets 3.5-13.5 centimeters (1.4-5.3 inches) long; some populations have ciliate (haired) leaf margins. Yellow flowers occur at the ends of branches in loose clusters of 15-75 heads; each flower is 15-45 millimeters (0.6-1.8 inches) in diameter on 1-40 millimeter (0.04-1.6 inches) stalks (peduncles). There are 5 sterile petal-like ray florets and 11-12 minute disk florets per head. The small seeds (5-14 x 0.7-2 millimeter [0.2-0.6 x 0.03-0.08 inch] achenes) are black, straight, and wingless.

Bidens micrantha ssp. *kalealaha* can be distinguished from other subspecies by the shape of the seeds, the density of the flower clusters, the numbers of ray and disk florets per head, differences in leaf surfaces, and other characteristics.

b. Taxonomy

Bidens micrantha was described by Charles Gaudichaud-Beaupré in 1829. *Bidens distans* was described by Earl Edward Sherff in 1930 as a Lanai Island endemic, based on three collections from that island collected between 1910 and 1918 (type=Forbes 148.L, BISH[1]). Sherff (1951a) described *Bidens micrantha* var. *rudimentifera* based on a specimen of *Bidens* collected on Haleakala, Maui, by William H. Hatheway and Amy B.H. Greenwell in 1950. The ssp. *kalealaha* was described by Kenneth Nagata

[1] Sytematists base scientific names of plants, where possible, on herbarium specimens designated as "types." Specimens are cited by giving the collector (Forbes), the collector's specimen number (148.L), and the specimen's location (BISH is the acronym for the Bishop Museum in Honolulu).

and Fred Ganders (Ganders and Nagata 1983) to combine the Maui and Lanai populations, hence *Bidens micrantha* ssp. *kalealaha* Nagata and Ganders.

The genus *Bidens* consists of approximately 230 species, mostly native to the Americas, Africa, and Polynesia, with fewer species in Europe and Asia (Wagner *et al.* 1990). The 19 Hawaiian species of the genus *Bidens* (Asteraceae) exhibit more morphological diversity than is found in the rest of the genus on five continents (Ganders and Nagata 1984). The subspecific epithet *kalealaha* is an anagram of the place name "Haleakala" (Nagata and Ganders 1983).

c. Current and Historic Range and Population Status

Historically, *Bidens micrantha* ssp. *kalealaha* was known from Lanai, the south slope of Haleakala on East Maui, and from one locality on West Maui (Ganders and Nagata in Wagner *et al.* 1990). On East Maui, Hillebrand and Lydgate collected this species at "Kula, Maui" (ca. 1869). Forbes (1920) collected it above Lualailua Hills and "east of Puu Keokea, south slope of Haleakala." Hatheway and Greenwell in 1950 collected *Bidens micrantha* and made this note: "5 ft. shrub, leaves shiny. Precipitous headwall of small canyon 200 yds. west of Kahua cabin, south slope of Haleakala. Elev. 7000 ft. Apparently these plants are palatable to feral goats, which have almost destroyed the climax subalpine woodland of this region. Persists in inaccessible places."

Ganders and Nagata (1983) state this taxon's distribution as: "Leeward slopes and inner crater walls of Haleakala, East Maui, from 750-2,300 meters elevation, and at least formerly on leeward Lanai." This taxon remains only on East Maui (Kahua, Manawainui to Wailaulau, and in Haleakala National Park) on State and Federal land. The four known populations, which extend over an area of about 15 x 3 kilometers (9.3 x 1.8 miles) on leeward East Maui, number no more than 2,000 individuals (A.C. Medeiros, personal observation 1990; USFWS 1992a).

The four known populations of *Bidens micrantha* ssp. *kalealaha* are distributed as follows: (1) on the southern slope of East Maui at 1,585-1,950 meters (5,200-6,400 feet) elevation, primarily on drainage headwalls between Manawainui and Wailaulau; (2) farther west, with *Dubautia platyphylla*, in several deep pit craters south of Kahua cabin at about 2,085 meters (6,840 feet); within Haleakala National Park it occurs: (3) sporadically along cliff walls in western Kaupo Gap at 1,830-1,950 meters (6,000-6,400 feet) and (4) on the inner walls of Haleakala Crater at about 2,195-2,317 meters (7,200-7,600 feet) (Medeiros, Loope, and Holt 1986).

Bidens micrantha ssp. *kalealaha* was probably once widespread on East Maui and Lanai, but has been drastically depleted by feral goats and has survived only on precipitous cliff faces inaccessible to goats. In October 1990, three years after feral goats were eliminated from Haleakala Crater, eight

juvenile plants (5-80 centimeters (1.5-24.4 inches) tall) of this taxon were noted at the base of the steep walls of western Kaupo Gap in Haleakala National Park on talus slopes and along stream courses at elevations of 1,800-1,900 meters (5,906-6,334 feet), below cliff faces inhabited by mature plants of the same species. The largest of the young plants was flowering. This is the first time this taxon was observed away from its typical near-vertical rock wall habitat. There appears to be ample habitat nearby for a much greater increase of this species, now that the effect of feral goat browsing has been eliminated (Loope and Medeiros 1994c).

d. Life History

Bidens micrantha is known to hybridize with other native *Bidens* such as *B. mauiensis* (Gray) Sherff and *B. menziesii* (Gray) Sherff, and possibly *B. conjuncta* Sherff (Wagner *et al.* 1990).

Little else is known about the life history of *Bidens micrantha* ssp. *kalealaha*. Flowering cycles, pollination vectors, seed dispersal agents, longevity, and specific environmental requirements are unknown.

e. Habitat Description

The original habitat of *Bidens micrantha* ssp. *kalealaha* is diverse, from open-canopy *Metrosideros/Acacia koa* forest to montane shrubland to cliff faces. Annual precipitation is in the range of 75-150 centimeters (30-59 inches). The substrate is comprised mostly of blocky lava flows with little or no soil development. Surviving *Bidens micrantha* ssp. *kalealaha* typically grow on sheer rock walls at elevations of 1,600-2,300 meters (5,250-7,550 feet). Associated native species include *Styphelia tameiameiae*, *Coprosma montana*, *Dodonaea viscosa*, *Lysimachia remyi*, *Viola chamissoniana*, *Dubautia menziesii*, and *Dubautia platyphylla*. Associated alien species include *Holcus lanatus*, *Hypochoeris radicata*, *Oenothera stricta*, and *Sporobolus africanus* (A.C. Medeiros, personal observation 1990)

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this subspecies were feral goats and cattle, and competition with alien plant species. Current threats include these:

1) Feral ungulates

Continuing habitat destruction by feral goats and pigs are major threats to the long-term survival of *Bidens micrantha* ssp. *kalealaha*. On leeward East Maui, within the habitat of this species outside Haleakala National Park, feral goats have destroyed much of the original native vegetation, except in those areas inaccessible to them such as sheer rock faces and steep watercourse sides. In these areas, ridge tops and flat areas are often eroded and pasture-like, with an abundance of alien plants. *Bidens micrantha* ssp. *kalealaha*, quite conspicuous when flowering, is restricted to largely inaccessible sites. Feral goats have been functionally eliminated within the habitat of this species in Haleakala National Park. While they are no longer an immediate threat to *Bidens micrantha* ssp. *kalealaha* within the Park, the potential still exists for the ingress and reestablishment of goats. Feral pigs are also present on the leeward slopes of East Maui within the habitat of this species but outside Haleakala National Park. They pose a moderate threat to this species, but modest in comparison to that of feral goats.

Cattle ranching occurs on the southern slope of Haleakala in the vicinity of *Bidens micrantha* ssp. *kalealaha* (R.W. Hobdy, personal communication 1990 in USFWS 1992a). Escaped domestic cattle pose a moderate threat to the long-term survival of this species.

2) Alien plants

Competition from a variety of invasive plant species threatens *Bidens micrantha* ssp. *kalealaha*, especially in conjunction with ecosystem damage caused by ungulates. Alien plant cover within Haleakala National Park slows the recovery of this taxon; establishment of new individuals is largely limited to stream beds, talus slopes, etc., where competition with alien grasses is not intense (L. Loope, Haleakala National Park, personal observation, October 22, 1990).

3) Fire

Fire is a major potential threat to the survival of *Bidens micrantha* ssp. *kalealaha*; a single fire could affect a significant portion of the population of *Bidens micrantha* ssp. *kalealaha* (A.C. Medeiros, personal communication 1990 in USFWS 1992a).

g. Conservation

Bidens micrantha ssp. *kalealaha* is not being propagated at any of the collections surveyed by Mehrhoff (1992)(G. Ray, Center for Plant Conservation, personal communication 1997). Propagating it by seed is, however, easy and it is being grown by several horticulturists of native species (D. Ragone, personal communication 1993).

Control of feral goats has been a priority within Haleakala National Park since the late 1970s. By the late 1980s, feral goats had been largely eliminated from Haleakala Crater and Kaupo Gap for the first time since their introduction in the 1800s. Within a few years, new plants of *Bidens micrantha* ssp. *kalealaha* were noted growing in the rocky scree slopes directly below the sheer cliffs where the species had escaped the feeding of feral goats; this is apparently the first significant recruitment of new plants of this species in decades. By the early 1990s, these new plants of *Bidens micrantha* ssp. *kalealaha* were flowering and producing seed.

h. Needed Recovery Actions

1) Construct exclosures on State lands between Kahua cabin and Pahihi.

Without protection, this subspecies will continue to decline due to degradation of habitat by feral animals, although individuals will survive on vertical and near-vertical rock faces. Exclosures for protection of this taxon could include other endangered species of the area, such as *Huperzia mannii, Cyanea comata, Ranunculus* spp., and *Clermontia lindseyana.*

2) Outplant into protected sites within former range in a manner that would preserve genetic distinctiveness of populations.

This genus in Hawaii—and this taxon specifically—are morphologically and genetically complex. Each population is likely to have its own unique characteristics. Maintenance of the individual characteristics of discrete populations is always an important factor to consider, but perhaps more so in this genus and species. Populations of this taxon should be kept discrete, and outplanting done in a manner that would preserve genetic distinctiveness of individual populations. It would be appropriate and beneficial to establish new populations within probable former range in Haleakala National Park and into the TNCH Kapunakea reserve on West Maui.

3) Monitor recovery of this taxon within upper elevation western Kaupo Gap in Haleakala National Park.

What happens at this site will indicate the potential of the taxon to recover elsewhere within its range.

5. *Clermontia oblongifolia* Gaud. ssp. *mauiensis* (Rock) Lammers
(Hawaiian names for genus: oha wai, oha, haha) Recovery Priority # - 6

a. Description

Appendix D contains a line drawing of *Clermontia oblongifolia.*

Clermontia oblongifolia ssp. *mauiensis* is a shrub or tree in the bellflower family (Campanulaceae) 2-7 meters (7-23 feet) tall with oblong to lance-shaped leaves (7-19 x 2-5 centimeters [2.8-7.5 x 0.8-2.0 inches]) on leaf stalks (petioles) about 2-11 centimeters (0.8-4.3 inches) long. The upper leaf surface is smooth and glossy dark green; the lower leaf surface is whitish green and may be smooth or downy. The edges of the leaves have small, thickened, rounded teeth. Inflorescences occur on stalks 5-45 millimeters (0.2-1.8 inches) long, bearing two or three flowers, each on an individual stalk 10-45 millimeters (0.4-1.8 inches) long. The curved, smooth, tubular flowers are greenish-white or purplish on the outside and white or cream within, approximately 6-8 centimeters (2.4-3.2 inches) long and 1-1.3 centimeters (0.4-0.5 inches) wide with a near-hemispherical base. The lobes, except the top one, are erect or slightly spreading, and as long as the tube. Its berries are orange and nearly spherical, 17-30 millimeters (0.7-1.2 inches) long.

Clermontia oblongifolia is distinguished from other members of the genus by its calyx and corolla, which are similar in color and are each fused into a curved tube that falls off as the flower ages. The species is also distinguished by the leaf shape, the male floral parts, the shape of the flower buds, and the lengths of the leaf and flower stalks, the flower, and the smooth green basal portion of the flower (the hypanthium) (Degener 1937, Lammers 1988, Lammers in Wagner *et al.* 1990, Rock 1913, USFWS 1992a). Subspecies *mauiensis* is the only subspecies of *Clermontia oblongifolia* ever found on Maui and Lanai.

b. Taxonomy

Clermontia oblongifolia was described by Charles Gaudichaud-Beaupré in 1829 based on specimens he collected in August 1816, probably from Oahu. On discovering a population of *Clermontia oblongifolia* on Maui in 1911, J.F. Rock described the variety *mauiensis* (Rock 1913). The type of the new variety (J.F. Rock 8804 BISH) was collected in rainforest in Honomanu Valley, northern Haleakala. In his comprehensive monograph of the Hawaiian lobelia, however, Rock (1919) did not recognize his own var. *mauiensis*, stating, "The specimens from Lanai and Maui differ somewhat from the Oahu specimens, but they must be referred to *Cl. oblongifolia.*"

Otto Degener (1937) reinstated the taxon but at the level of a form of *Clermontia oblongifolia*, namely forma *mauiensis* (Rock) Degener. Degener (1937) stated, "Though Rock finally equated his variety with the species . . . , it proves to be at least a distinct form." In a precursor to a modern review of the genus, Lammers (1988) raised the forma *mauiensis* to its current subspecific status, namely ssp. *mauiensis* (Rock) Lammers. A recent review of the genus (Lammers in Wagner *et al.* 1990) recognized three subspecies of *Clermontia oblongifolia*. Of the three, only the ssp. *oblongifolia*, which is restricted to Oahu, is relatively common (Lammers in Wagner *et al.* 1990). Degener (1937) stated that the ssp. *oblongifolia* is one of the most common *Clermontia* species in the Koolau Mountains of Oahu, especially above Honolulu. The ssp. *brevipes* (F. Wimmer) Lammers, which is restricted to Molokai, was last collected more than 30 years ago and only twice in the past 60 years. The ssp. *mauiensis* (Rock) Lammers historically occurred on Lanai and Maui but is now apparently extirpated from Lanai.

In May 1994, Richard Palmer of the University of Hawaii at Manoa collected material possibly referable to *Clermontia oblongifolia* ssp. *mauiensis* at 945 meters (3,100 feet) elevation on the lower flume road in Koolau Forest Reserve, northwest Haleakala. Two individuals were observed on jeep road cuts, with *Clermontia arborescens* and *Clermontia kakeana* growing nearby. DNA analysis of these specimens and material from the West Maui *Clermontia oblongifolia* ssp. *mauiensis* indicates that *Clermontia oblongifolia* and its subspecies may be hybrids of *Clermontia arborescens* and *Clermontia kakeana* (R. Palmer, personal communication 1997). To date, this information has not been confirmed via peer review and publication in botanical journals. The genus *Clermontia* comprises 22 species, all restricted to the Hawaiian Islands. The specific epithet *oblongifolia* refers to the oblong shape of the leaf blade. The subspecies epithet *mauiensis* refers to Maui Island, part of its range.

c. Current and Historic Range and Population Status

Historically, *Clermontia oblongifolia* ssp. *mauiensis* is known from Lanai and Maui (Lammers in Wagner *et al.* 1990). On Lanai, the subspecies *mauiensis* was first collected by Rock in Mahana Valley (Rock 8014-a) and Kaiholena Valley (Rock 8014-b) (Rock 1919). The taxon was last collected on that island in 1913 (Forbes 44.L; Munro 55 BISH) (Lammers in Wagner *et al.* 1990). For East Maui, Rock (1913) stated regarding the ssp. *mauiensis*, "A small tree 15 to 18 feet high, resembling very much the species on Oahu. This tree is not at all common, but can be found on the island of Maui on the windward slopes of Mt. Haleakala along the Kailua ditch trail in the valley of Honomanu at an elevation of 853-914 meters (2,800 to 3,000 feet) in the rainforest . . . The tree grows in company with *Clermontia macrocarpa* (= *Clermontia kakeana*), which is the most common species in that locality, and *Clermontia arborescens*." The last collection of this taxon on East Maui (Degener 7947 GH US) was made in 1927

(Lammers in Wagner *et al.* 1990). On West Maui, the ssp. *mauiensis* was collected for the first time (Lammers and Hobdy #5690 Ohio State Herbarium) in the 1980s. This single individual exists along the trail to Puu-kukui in the Honokowai section of the West Maui NAR on State land (Lammers in Wagner *et al.* 1990).

In summary, *Clermontia oblongifolia* ssp. *mauiensis* is currently known to exist only on West Maui. Good quality habitat still exists for this species in the windward rainforests of East Maui, and this taxon may still occur there. Because of the degradation of forest in its former habitat on Lanai, this taxon is likely extirpated on that island.

d. Life History

Clermontia oblongifolia ssp. *mauiensis* is known to flower from November to July (Rock 1919). Little is known regarding pollination vectors, seed dispersal, or other factors.

e. Habitat Description

Clermontia oblongifolia ssp. *mauiensis* typically grows on the sides of ridges in ohia-dominated montane wet forest at elevations between 850-900 meters (2,790-2,950 feet) (Hawaii Heritage Program [HHP] references; Rock 1913). Associated native species include *Coprosma*, *Clermontia*, *Hedyotis*, and *Melicope* (R.W. Hobdy, personal communication in USFWS 1992a).

f. Reasons for Decline and Current Threats

Possible causes for the historical decline of this species include feral pigs, rodent and slug predation, and loss of pollinators.

Current threats include:

1) Small population size

Because no more than a single individual of *Clermontia oblongifolia* ssp. *mauiensis* is known to exist, a single natural or human-caused environmental disturbance could easily be irreversibly catastrophic. In addition, the extremely limited gene pool may depress reproductive vigor.

2) Feral pigs

The single known individual of *Clermontia oblongifolia* ssp. *mauiensis* is not currently threatened by rooting of feral pigs (R. Hobdy, personal communication 1995). However, habitat

degradation by feral pigs would be a major threat to any other existing populations or individuals located in areas accessible to pigs.

g. Conservation

Over the past three years, Maui Land and Pine and TNCH have conducted management for the reduction of pigs in Kapunakea Preserve and the Honokowai section of the West Maui NAR where this subspecies still occurs. The combination of fencing, snaring and hunting under this program has reduced pigs to the point where they are no longer a direct threat to the single known individual of *Clermontia oblongifolia* ssp. *mauiensis*, so localized fencing for this individual is no longer necessary (R. Hobdy, personal communication 1995).

Germ plasm from *Clermontia oblongifolia* ssp. *mauiensis* is not held in any *ex situ* collections (G. Ray, Center for Plant Conservation, personal communication 1997). Fruits from the East Maui plants were collected and provided to the Lyon Arboretum (R. Palmer, personal communication 1997). Attempts by Lyon Arboretum to propagate *Clermontia oblongifolia* ssp. *mauiensis* were unsuccessful (G. Ray, Center for Plant Conservation, personal communication 1997).

h. Needed Recovery Actions

1) Complete taxonomic studies to determine subspecific status of the possible Koolau Forest Reserve *Clermontia oblongifolia* ssp. *mauiensis* population.

   Results of these studies should be used to determine appropriate management actions for these individuals.

2) Search for East Maui individuals of *Clermontia oblongifolia* ssp. *mauiensis*.

   Searches should be made on windward slopes (Huelo to eastern Kaupo) at 750-1,100 meters (2,500-3,500 feet) elevation. A definitive determination of Richard Palmer's recent specimen from Waikamoi should be made before more extensive exploration.

3) Propagate and outplant in protected areas.

   Establish in protected reserves on Maui in suitable habitat. Potential prime sites include TNCH's Kapunakea Preserve and West Maui State NAR for West Maui material and the Kipahulu section of Haleakala National Park for East Maui material.

6. *Cyanea lobata* Mann

(Hawaiian names for genus: haha) Recovery Priority # - 5

a. Description

Suitable drawings depicting *Cyanea lobata* are not available.

Cyanea lobata, a member of the bellflower family (Campanulaceae), is a sparingly branched shrub 1.3-2.3 meters (4.3-7.5 feet) tall with smooth to somewhat rough stems and oblong, irregularly lobed leaves 30-50 centimeters (12-20 inches) long, which may be broader at the end than at the base. The tops of the leaves are smooth; the lower surfaces may be rough and/or downy along the veins. The leaf stalks (petioles) are 7-22 centimeters (3-9 inches) long and are somewhat rough. Flower clusters (inflorescences) occur on stalks 30-75 millimeters (1.2-3.0 inches) long bearing 5-12 flowers, each on an individual stalk 18-35 millimeters (0.7-1.4 inches) long. The base of each flower is 8-12 millimeters (0.3-0.5 inches) long and 3-6 millimeters (0.1-0.2 inches) wide. The flowers are partially tubular, curved, greenish-white or purplish, 60-70 millimeters (2.4-2.8 inches) long and 5-11 millimeters (0.2-0.4 inches) wide, downy at least on the spreading lobes, which are approximately as long as the tube. The berries are yellow and spherical. Degener (1936) describes this species (as *C. baldwinii*) as a "branched straggling shrub with one of the branches taking root again in the ground."

This species is distinguished from other species of *Cyanea* by the size of the flower and the irregularly lobed leaves with petioles.

b. Taxonomy

Cyanea lobata was described by Horace Mann, Jr., in 1867 based on a specimen collected by Mann and William Tufts in Waihee Valley, West Maui, in 1864-1865 (Mann and Brigham 467). Rock (1919) described a new variety of this species, var. *hamakuae*, from specimens from Hamakua and Nahiku, windward East Maui. Lammers in Wagner *et al.* (1990) reassigned this variety to *Cyanea grimesiana* ssp. *grimesiana*.

Cyanea baldwinii was described by C.N. Forbes and G.C. Munro in 1920 based on Munro 674 (BISH, NY) collected in 1919. Lammers (in Wagner *et al.* 1990) treated *Cyanea baldwinii* as a synonym of *Cyanea lobata*. St. John and Takeuchi (1987) questioned the distinctions between the two closely related Hawaiian endemic genera *Cyanea* and *Delissea*. St. John (1987) merged the two genera under the older generic name *Delissea*, creating the new combinations, *Delissea baldwinii* (Forbes and

Munro) St. John and *Delissea lobata* (H. Mann) St.John. A recent treatment of the genus *Cyanea* (Lammers in Wagner *et al.* 1990) did not accept the generic changes proposed by St. John (1987).

As currently accepted, the genus *Cyanea* consists of 52 species, entirely restricted to the Hawaiian Islands (Lammers in Wagner *et al.* 1990). The specific epithet *lobata* refers to the characteristic irregular lobing of the leaf blades.

c. Current and Historic Range and Population Status

Historically, *Cyanea lobata* was known from Lanai and West Maui (Lammers in Wagner *et al.* 1990). On Lanai, *Cyanea lobata* (formerly *C. baldwinii*) was known from a single plant discovered in 1919. Though Munro collected a number of specimens of this species, all were from a single plant located at approximately 915 meters (3,000 feet) elevation at the extreme head of Hookio Gulch near the island's summit, Lanaihale, at 1,030 meters (3,380 feet) elevation. Despite intensive field work on that island in search of this species from 1919 to 1934, Munro found no other individuals of this taxon. Munro propagated material of the single known individual, outplanting individuals in the mountains of Lanai at Lanaihale and Waikeakua and in the garden at his residence on Tantalus, Oahu. Degener (1936) noted that by the 1940s, the original plant and all outplantings of *Cyanea baldwinii* on Lanai had perished. This species has not been collected since on that island.

On West Maui, based on his own collections made in the 1870s, Hillebrand (1888) stated regarding the distribution of *Cyanea lobata*, "gulches of Kaanapali, Honokahau, Wailuku, and elsewhere." No other collections were made on West Maui for more than a century. *Cyanea lobata* was rediscovered on West Maui in 1982 (R.W. Hobdy 1675 BISH) at 600 meters (2,000 feet) elevation in Waikapu Valley on privately owned land. The single known plant of this species was later destroyed by a landslide triggered by heavy rains (Hobdy *et al.* 1990, Lammers in Wagner *et al.* 1990). Based on its fairly extensive historical distribution and the lack of adequate surveys due to the inaccessibility of steep slopes in the West Maui mountains, there is a good chance that *Cyanea lobata* may still be extant.

d. Life History

Though a low, soft-wooded shrub, this species can be relatively long-lived. The sole individual of this species known from Lanai was discovered as an adult in 1919 and was still living in 1934, some 15 years later (Degener 1936).

Cyanea lobata is known to flower from August to February, even in individuals as small as 50 centimeters (19.7 inches) in height (Rock 1919, Degener 1936).

e. Habitat Description

Cyanea lobata has been seen and collected on steep stream banks at elevations of 550-915 meters (1,805-3,000 feet).

f. Reasons for Decline and Current Threats

The primary threats believed historically responsible for the endangerment of this species are the impacts of feral pigs, possible predation by rats and slugs, and possible loss of pollinators.

Current threats to *Cyanea lobata* include:

1) Feral pigs

Habitat degradation by feral pigs is a major threat to any *Cyanea lobata* populations or individuals located in areas accessible to pigs on West Maui.

2) Human impacts (collecting and site degradation)

Illegal collecting for scientific or horticultural purposes or excessive visits by individuals interested in seeing rare plants could result from increased publicity and would seriously threaten *Cyanea lobata*. Because of the few (if any) remaining individuals in existence, collection of whole plants or reproductive parts and/or site degradation caused by excessive foot traffic, would adversely impact the gene pool and threaten the survival of the taxon.

3) Small population size

The likely very small number of remaining individuals—if there are any— of *Cyanea lobata* and the limited and scattered distribution of the species are threats since a single natural or human-caused environmental disturbance could easily be catastrophic to all or part of the populations. In addition, the limited gene pool may depress reproductive vigor. Finally, cross-pollination would be a problem for single, isolated individuals.

g. Conservation

Cyanea lobata was propagated by Munro in the past but is not currently being propagated at any of the collections surveyed by Mehrhoff (1992) (G. Ray, Center for Plant Conservation, personal communication 1997).

h. Needed Recovery Actions

1) Search for any individuals of this species in former habitat.

The best chance for rediscovery of this species is in the mountains of West Maui. Habitat on Lanai is extremely limited (R.W. Hobdy, personal communication 1994). Searches should start in but not be limited to, Waikapu Valley where the species was last seen in 1982. Upper Kauaula Valley (western West Maui) is a good candidate. The vegetation of steep walls in deep valleys of windward West Maui is largely intact, with little alien plant invasion. There is a very good chance that this species occurs on steep walls of one or more valleys of West Maui, in sites inaccessible by normal means but accessible to climbers fully equipped with ropes, etc.

2) If plants are located, create new populations.

West Maui has a number of ungulate-free reserves, where pigs are removed, which would be good sites for new populations.

7. *Cyanea mceldowneyi* Rock

(Hawaiian names for genus: haha) Recovery Priority # - 2

a. Description

Suitable drawings depicting *Cyanea mceldowneyi* are not available.

Cyanea mceldowneyi, a plant of the bellflower family (Campanulaceae) is an unbranched shrub 2-3 meters (6.6-9.8 feet) tall with rough to prickly stems. Leaves of adult plants are oblong to inverted lance-shaped, 20-35 centimeters (7.9-13.8 inches) long, and 5-9 centimeters (2.0-3.5 inches) wide. The leaves have smooth to somewhat rough green upper surfaces and pale green, lightly downy undersides and are characterized by thickened, finely toothed edges and a pointed wedge-shaped base on smooth to rough leaf stalks (petioles) 3.5-6 centimeters (1.4-2.4 inches) long. Juveniles exhibit leaves that are oval to egg-shaped (large end at tip), 15-22 centimeters (5.9-8.7 inches) long and 5-9 centimeters (2.0-3.5 inches) wide with prickly green upper surfaces; pale-green, downy and prickly undersides; thickened, toothed edges; and a rounded base on prickly leaf stalks (petioles) 2.5-4.5 centimeters (1.0-1.8 inches) long. Flower clusters (inflorescences) occur on stalks (peduncles) 15-30 millimeters (0.6-1.2 inches) long bearing five to seven flowers, each flower on an individual stalk (pedicel) 10-14 millimeters (0.4-0.6 inches) long. The base of each flower is approximately 5 millimeters (0.2 inches) long and 4 millimeters (0.2 inches) wide. The flowers are partially tubular, curved, rough-surfaced and white with purple longitudinal stripes. Flowers are approximately 40 millimeters (1.6 inches) long and 8 millimeters (0.3

inches) wide, with the spreading lobes being about as long as the tube. The appearance and size of the berries are unknown.

This species is distinguished from other species of *Cyanea* by the combination of a densely armed trunk, long (40 millimeter [1.6 inches]) white-colored corollas, and leaf blade size and shape.

b. Taxonomy

Cyanea mceldowneyi was described by J.F. Rock (1957) based on the type specimen (Rock 25610 BISH) collected in rainforest west of Waikamoi Gulch, northwestern Haleakala, in 1954. Rock (1957) considered this taxon most closely related to *Cyanea rollandioides* Rock, now a synonym of *Cyanea platyphylla* (Gray) Hillebr., endemic to Hawaii Island. St. John and Takeuchi (1987) questioned the distinctions between the two closely related Hawaiian endemic genera, *Cyanea* and *Delissea*. St. John (1987) merged the two genera under the older generic name *Delissea*, creating the new combinations, *Delissea baldwinii* (Forbes and Munro) St. John and *Delissea lobata* (H. Mann) St. John. A recent treatment of the genus *Cyanea* (Lammers in Wagner *et al.* 1990) did not accept the generic changes proposed by St. John (1987).

As currently accepted, the genus *Cyanea* consists of 52 species, entirely restricted to the Hawaiian Islands (Lammers in Wagner *et al.* 1990). The specific epithet *mceldowneyi* honors Mr. George McEldowney, Kula (Maui) resident and friend of the species' author, Joseph F. Rock.

c. Current and Historic Range and Population Status

Historically, *Cyanea mceldowneyi* is known from rainforest from west of Waikamoi to Honomanu on northwestern Haleakala at 925-1,280 meters (3,030-4,200 feet) elevation (Rock 1919, Lammers in Wagner *et al.* 1990). Currently, this species is known from six populations, ranging from 899-1,280 meters (2,950-4,200 feet) in elevation, in the vicinity of Waikamoi Drainage on East Maui. All populations occur on private land owned by Alexander & Baldwin, none of which is part of the TNCH Waikamoi Preserve. All populations but one contain fewer than 10 individuals (R. Palmer, personal communication 1994). The "large" population of *Cyanea mceldowneyi*, which contains an estimated 100+ individuals, has been drastically reduced by feral pig impacts since the late 1970s (A.C. Medeiros and R.W. Hobdy, personal observations 1994). Feral pig activity is intense in the area, with much fresh disturbance (A.C. Medeiros, R.W. Hobdy, L. Loope, and P.A. Thomas, personal observations 1994). The status of the Honomanu population is not known.

d. Life History

No details are known.

e. Habitat Description

The habitat of *Cyanea mceldowneyi* is montane wet forest with mixed *Metrosideros* and *Acacia koa*. A detailed description of the habitat, species composition, etc., in the vicinity is given by Kitayama and Mueller-Dombois (1992). *Cyanea mceldowneyi* typically grows at elevations between 925 and 1,280 meters (3,034 and 4,200 feet).

Associated native plants include *Melicope clusiifolia, Hedyotis, Metrosideros polymorpha, Acacia koa, Clermontia arborescens, Diplazium sandwichianum, Broussaisia arguta, Cibotium, Cyrtandra, Dicranopteris linearis*, and *Cheirodendron trigynum* (USFWS 1992a; HPCC 1994). Associated alien plants include *Ageratina adenophora, Rubus argutus, Setaria palmifolia*, and *Tibouchina herbacea.*

f. Reasons for Decline and Current Threats

The primary threats thought to be historically responsible for the endangerment of this species include: destruction of habitat by cattle and feral pigs and impacts by alien slugs and black rats.

The main current threats to *Cyanea mceldowneyi* include:

1) Impacts of feral pigs

Habitat degradation and physical destruction by feral pigs is the major threat to *Cyanea mceldowneyi*. This species has undergone a substantial decline since the late 1970s in the vicinity of the Lower Waikamoi Flume, clearly attributable to direct impacts of feral pigs (A.C. Medeiros and R.W. Hobdy, personal communication 1994).

2) Alien plants

Habitat degradation by feral pigs works in concert with invasion of alien plant species. As of 1994, palmgrass (*Setaria palmifolia*) is rapidly spreading unchecked into the habitat of *Cyanea mceldowneyi*. Palmgrass invades the stream banks where *C. mceldowneyi* grows, forming dense stands and displacing native vegetation.

g. Conservation

Cyanea mceldowneyi has been successfully propagated by the Lyon Arboretum on Oahu (G. Ray, Center for Plant Conservation, personal communication 1997).

h. Needed Recovery Actions

1) Protect habitat of known populations of *Cyanea mceldowneyi*, especially the large population.
2) Construct a series of exclosures to protect extant populations in the lower Waikamoi area.
3) Establish new outplanted populations within protected (i.e., fenced) appropriate habitat in the Waikamoi area.

Some of the same areas could also be used for outplanting *Clermontia oblongifolia* ssp. *mauiensis*. Do weed control if it is needed and can be done without undue ground disturbance.

4) Determine status of Honomanu population and manage appropriately.

If this population is extant and pigs are present, consider low-impact construction of woven-wire exclosure to protect from feral pigs. Do weed control if needed and practical without undue ground disturbance.

8. *Geranium arboreum* Gray
(Hawaiian names: nohoanu, hinahina) Recovery Priority # - 2

a. Description

Appendix D contains a line drawing of *Geranium arboreum*.

Geranium arboreum, a member of the geranium family (Geraniaceae), is a large, branched, spreading shrub 2-4 meters (6.6-13.1 feet) tall. The green and somewhat hairy leaves, alternating closely after one another on the stem, are oval- or heart-shaped, usually 4-7 centimeters (1.6-2.8 inches) long and 2.5-4.5 centimeters (1.0-1.8 inches) wide with 5-8 noticeable veins and 8-14 small teeth on each edge. The leaf stalks (petioles) are 1-3 centimeters (0.4-1.2 inches) long and are encircled beneath (subtended) by tiny (12-14 millimeters [0.5-0.6 inch]), hairy, leaf-like appendages (stipules), which persist after the leaves have fallen. Magenta flowers 20-25 centimeters (7.9-9.8 inches) long occur in short-stalked groups of usually one to four, originating from the point of attachment of leaves to the stem. The upper three petals are erect, and the lower two petals are bent abruptly backward. Its flowers are the only ones

in the genus that are zygomorphic (not symmetrical like pie slices around a central point). A single dark-purple, net-surfaced 2.5 millimeter (0.1 inch) seed is produced in each of five cells of the elongated fruit.

b. Taxonomy

Geranium arboreum was described by Asa Gray (1854) from specimens collected by Charles Pickering and William Brackenridge of the U.S. Exploring Expedition on Haleakala, Maui, in 1841. In 1956, Degener and Greenwell changed the plant's name to *Neurophyllodes arboreum*; however, Gray's placement of the plant in *Geranium* is accepted by other botanists (Wagner *et al.* 1990).

The genus *Geranium* comprises 300 species worldwide, especially in temperate and warm temperate regions (Cronquist 1981). The specific epithet *arboreum* refers to the tree-like habit of this species.

c. Current and Historic Range and Population Status

The original range and abundance of *Geranium arboreum* are unknown; however, late 19th- and early 20th-century collections indicate that it once grew at elevations as low as 610 meters (2,000 feet) on the southern slopes of Haleakala Volcano, and that its distribution on the northern slopes extended beyond its presently known range. Today, isolated populations of *Geranium arboreum* grow primarily in steep, narrow gulches at 1,525-2,135 meters (5,000-7,000 feet) elevation on the northern and western slopes of Haleakala Volcano, East Maui (USFWS 1992b). At least 300 plants remain (Funk 1988) in 21 distinct sites (A. Medeiros, personal observations 1995). At least 250 plants occur in a single population in the Kula Forest Reserve. The remainder are mostly in two populations in the Hosmer Grove/Puu Nianiau area on the northwestern slope of Haleakala volcano on lands belonging to Haleakala Ranch, Haleakala National Park (fewer than six plants known), and Waikamoi Preserve. A few individuals occur in a fourth population on the privately owned Kaonoulu and Erehwon Ranch lands on western Haleakala (USFWS 1992b).

d. Life History

Geranium arboreum is the only species in its genus that appears to be bird-pollinated. Native honeycreepers appear to be a major pollination vector. *Geranium arboreum* from the southwest area of Haleakala in the Kula Forest Reserve produce seeds that are larger and fuller than seeds from the northwest extension of its distribution (A.C. Medeiros, personal observation 1994). Native honeycreepers are reasonably abundant at both sites. It is possible that the larger numbers and clumped

distribution of the southwest rift populations facilitate inter-plant visits by native birds and higher outcrossing frequency.

e. Habitat Description

Typical habitat of this rare shrub is in moist gulches near the upper limit of native forest growth. The remaining isolated populations of *Geranium arboreum* grow in steep, narrow canyons on the north and west outer slopes of Haleakala Volcano at 1,525-2,135 meters (5,000-7,000 feet) elevation in a narrow band (0.25 x 14 kilometers [0.16 x 8.7 miles]). The environment of these gulches is damp and shaded part of the day and often in clouds, as a result of the coincidence of this band with the layer just below the trade-wind inversion, an important meteorological phenomenon in the Hawaiian Islands. Fog drip is frequent. The climate zone just above is substantially drier and supports native shrubland, not forest. *Geranium arboreum* plants appear to obtain a significant portion of their water requirement by "combing" moisture out of the drifting fog (Funk 1982). Currently, vegetation in the ravines is often quite dense and consists mainly of mostly medium-sized woody shrubs, alien grasses and weeds, and mixed ferns (Funk 1982).

Associated native species include *Sophora chrysophylla*, *Vaccinium reticulatum*, *Dodonaea*, *Styphelia*, *Rubus hawaiiensis*, *Dryopteris wallichiana*, *Metrosideros*, *Myrsine lessertiana*, and *Coprosma* (HPCC 1994). Associated alien species include *Ageratina adenophora*, *Holcus lanatus*, redwood, and pines (HPCC 1994; A.C. Medeiros, personal observation 1994).

Geranium arboreum is a minor component of the vegetation occurring in small isolated populations in the gulches. The habitat of nearby and surrounding areas is subalpine or mesic shrubland; a few *Geranium arboreum* individuals grow near areas that have been converted to agricultural uses such as pasture land or experimental tree plots.

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this species include the impacts of alien cattle, goats, pigs and plants, and fire, which is known to have destroyed four individuals in the Kula Forest Reserve in 1984 (R.W. Hobdy, personal communication 1994).

The main current threats to *Geranium arboreum* include:

1) Alien plants

Displacement by alien plant species, primarily grasses and trees, poses the current primary threat to the long-term survival of *Geranium arboreum*. Mats of alien grasses cover ground that would

otherwise be available to *Geranium* seedlings. Alien tree species (e.g., *Acacia mearnsii* and *Myrica faya*) eventually form such dense stands that they virtually exclude native species, including *Geranium arboreum*. In the Polipoli Springs area at certain times of the year, pollen from alien pine trees completely covers the stigmas of *G. arboreum* and precludes any fertilization by its own species. *Geranium arboreum* does, however, have a longer flowering period than do the alien pines (Funk 1982, 1988; USFWS 1992b).

2) Impacts of feral pigs, cattle and goats

Feral animals continue to exert negative impacts on *Geranium arboreum*.

3) Fire

Fires in the habitat of *Geranium arboreum* continue to be of concern.

4) Small population size

The scattered distribution of the species has the positive effect of reducing the chance that a single natural or human-caused environmental disturbance could affect all populations. However, since the approximately 300 extant individuals occur in about 21 sites (grouped into four populations), each with only 1 to 25 plants, the limited local gene pools may depress reproductive vigor.

5) Human impacts (collecting and site degradation)

Illegal collecting for scientific or horticultural purposes or excessive visits by individuals interested in seeing rare plants could result from increased publicity, and could seriously impact *Geranium arboreum*. The species is attractive and could become the subject of increased collection in the future (USFWS 1992b).

6) Rabbits

Rabbits almost became established on East Maui within Haleakala National Park in 1990 as a result of release of pet rabbits by a careless pet owner. Rapid response by Park management to the problem is apparently all that prevented a catastrophe. The site where the incipient rabbit population existed was adjacent to habitat of *Geranium arboreum*. It is almost certain that similar incidents will occur in the future. If rabbits were to establish, they would pose a severe threat to the survival of this species.

g. Conservation

Geranium arboreum is not being propagated at any of the collections surveyed by Mehrhoff (1992) (G. Ray, Center for Plant Conservation, personal communication 1997). However, it is grown as an ornamental by a number of individuals. Varying degrees of success have been reported with efforts at

raising plants from wild-collected seed; inherent vigor, possibly genetic, of the seeds seems to have a direct correlation with the success of the seedlings. A cutting of *Geranium arboreum* has been successfully rooted on at least one occasion.

A very small proportion of the extant individuals of *Geranium arboreum* occurs within Haleakala National Park. Although the National Park Service does provide active management protection to sensitive resources, the small percentage of habitat of *Geranium arboreum* within the Park limits the potential benefits of Park management for this species (USFWS 1992b).

h. Needed Recovery Actions

1) Protect extant populations of this species by constructing a series of five to eight exclosures from leeward Haleakala to Puu Koolau, northwestern Haleakala.

Many sites on northwestern and southwestern Haleakala Volcano still have appreciable numbers of *Geranium arboreum* on which to center exclosure locations. On leeward Haleakala, this species is apparently extirpated and should be re-established from seed from the nearest extant populations, i.e., those of the southwest rift. Owners of sites appropriate for exclosures are the State of Hawaii (Kula Forest Reserve), Haleakala Ranch, Haleakala National Park, and TNCH (Waikamoi Preserve).

2) Conduct/encourage work on pollinators and reproductive biology.

Lack of adequate pollination may be a crucial limiting factor for this species. Emphasis of this work is to determine how important native honeycreeper birds are to quantity and quality of seed set of this species.

9. *Geranium multiflorum* Gray

(Hawaiian names: nohoanu, hinahina) Recovery Priority # - 8

a. Description

Appendix D contains a line drawing of *Geranium multiflorum*.

Geranium multiflorum, a member of the geranium family (Geraniaceae), is a compact, many-branched shrub 1-3 meters (3.3-9.8 feet) tall. Its stems are gray to reddish or dark-gray. The oval-shaped leaves, green and sometimes smooth on top and grayish and silky below, alternate on the stem of the plant and are prominently bunched only near the ends of the branches. The leaves are usually about 4.5-7 centimeters (1.8-2.8 inches) long and 1.5-3 centimeters (0.6-1.2 inches) long with 7-11 noticeable veins.

The edges of the leaves have tiny teeth to at least 1/3 the distance from the leaf apex to the base. The leaf stalks (petioles) are usually 1.5-2.5 centimeters (0.6-1.0 inches) long and are encircled beneath (subtended) by small awl-shaped leaf-like appendages (stipules) on the main plant stem that persist, covering the branches after the leaves have fallen. White flowers, normally with purple veins and purple at the center, have petals 10-15 millimeters (0.4-0.6 inches) long and usually occur in groups of 25-50, which extend beyond the leaves. A single dark reddish-brown shiny, lightly net-surfaced 2 millimeter (0.08 inch) seed is produced in each of five cells of the elongated fruit.

Geranium multiflorum is distinguished from others of the genus by its white, regularly symmetrical flowers and by the shape and pattern of teeth on its leaf margins. However, the species is morphologically and perhaps genetically variable. The variability, especially in terms of leaf size, shape, and leaf pubescence, exceeds that of all other species of Hawaiian *Geranium*.

b. Taxonomy

Geranium multiflorum was described by Asa Gray (1854) based on specimens collected by Charles Pickering, a member of the U.S. Exploring Expedition, on Maui in 1841. Other published names referring to the taxon as it is currently defined (Wagner *et al.* 1990) include *Geranium ovatifolium* (Gray 1854), *Geranium multiflorum* var. *canum* (Hillebrand 1888), *Geranium multiflorum* var. *ovatifolium* (Fosberg 1936), *Geranium multiflorum* ssp. *ovatifolium* (Carlquist and Bissing 1976), *Neurophyllodes ovatifolium* (Degener and Greenwell 1952), *Neurophyllodes multiflorum* (Degener and Greenwell 1952), *Neurophyllodes ovatifolium* var. *forbesii* (Degener and Degener 1967), and *Neurophyllodes ovatifolium* var. *superbum* (Degener and Degener 1967). St. John (1973) reinstated Degener's genus *Neurophyllodes* as *Geranium* in 1973, creating the new combinations *Geranium multiflorum* var. *forbesii* and *Geranium multiflorum* var. *superbum*. The current treatment (Wagner *et al.* 1990) does not recognize any infraspecific taxa of *Geranium multiflorum*.

The genus *Geranium* comprises 300 species worldwide, especially in temperate and warm temperate regions (Cronquist 1981). The specific epithet *multiflorum* refers to the many-flowered inflorescences.

c. Current and Historic Range and Population Status

Historically, *Geranium multiflorum* was known from Ukulele, Waieleele, and Waianapanapa on East Maui. This species is now known from Haleakala National Park, Hanawi Natural Area Reserve, Koolau Forest Reserve, and Waikamoi Preserve on Federal, State, and private (TNCH) land. The eleven known populations extend over a distance of about 10.5 x 5.5 kilometers (6.5 x 3.4 miles). Due to the

inaccessibility of the populations and the difficulty in determining the number of individuals (due to the plant's multi-branched form), the total number of individuals of this species is not known. However, it probably does not exceed 3,000 plants. In Koolau Gap, this species is sympatric with and may hybridize with *Geranium cuneatum* ssp. *tridens*.

d. Life History

No details are known.

e. Habitat Description

The habitat of *Geranium multiflorum* encompasses diverse vegetation types, with a range of mean annual precipitation from as low as 60 centimeters (23.6 inches) to over 500 centimeters (16.4 feet). Occurring primarily on the windward side of East Maui, this species is found mostly within wet forests. Substrates range from lava flows to rich soils. *Geranium multiflorum* grows at 1,580-2,260 meters (5,183-7,415 feet) in elevation—in montane grasslands, montane bog edges, fog-swept lava flows, gulch slopes of montane wet forests, and occasionally in subalpine shrublands.

The largest, loosely contiguous population of this species occurs in the tangled shrub ecotone between *Metrosideros* forest and *Deschampsia* grasslands on the northern outer slopes of Haleakala. Here, *Geranium multiflorum* is a distinctive and characteristic part of the area's vegetation. It also occurs in much drier habitats in Haleakala Crater and in Koolau Gap on sparsely vegetated lava. In these sites, the leaves of the species are much smaller and more down-covered (canescent) than in wetter locales.

Associated native species include *Vaccinium reticulatum, Vaccinium calycinum, Metrosideros polymorpha, Coprosma, Styphelia tameiameiae,* and *Sadleria cyatheoides*. Associated alien species include *Dactylis glomerata, Holcus lanatus, Hypochoeris radicata, Juncus planifolius*, and *Rubus argutus*.

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this species were the impacts of feral goats and pigs.

The main current threats to *Geranium multiflorum* include:

1) Feral ungulates

The browsing of feral goats and rooting of feral pigs continue to threaten this taxon.

2) Alien plants

In the moister parts of its range (ecotone of forest and Kalapawili grasslands, backwalls of Kipahulu Valley, and near Paliku), the long- term survival of *Geranium multiflorum* is threatened by prickly blackberry (*Rubus argutus*). This alien plant overtakes areas needed for reproduction, posing a serious threat to the habitat of *Geranium multiflorum* on Maui.

g. Conservation

Though *Geranium multiflorum* is not being propagated at any of the collections surveyed by Mehrhoff (1992) (G. Ray, Center for Plant Conservation, personal communication 1997), cultivated specimens are being raised near government housing in Haleakala National Park at 2,133 meter (7,000 foot) elevation. Management practices by the National Park Service in Haleakala National Park and by TNCH in Waikamoi Preserve have sharply reduced the numbers of goats and pigs, resulting in a much improved prognosis for long-term survival of *Geranium multiflorum*. Exclosures are not needed to assure the long-term survival of this species because most individuals occur in managed nature reserves.

h. Needed Recovery Measures

1) Maintain control of feral goats and pigs in Haleakala National Park, TNCH's Waikamoi Preserve and upper Hanawi NAR.
2) Control invasive alien plants, especially blackberry.

If these threats are kept under control and populations remain stable or increase over the next five years, this taxon may be considered for down-listing.

10. *Hedyotis coriacea* Sm.
(Hawaiian name: kioele) Recovery Priority # - 2

a. Description

Suitable drawings depicting *Hedyotis coriacea* are not available.

Hedyotis coriacea is a small, erect herb in the coffee (or madder) family (Rubiaceae) with leathery, more or less oval-shaped leaves. The leaves are 3-8 centimeters (1.2-3.2 inches) long and usually 1.5-3 centimeters (0.6-1.2 inches) wide, usually hairless on top, and net-veined and hairless or downy below.

Leaves are on 5-10 millimeter (0.2-0.4 inch) sheath-like leaf stalks (petioles) at the base of which are triangular leaf-like appendages (stipules) to 33 millimeters (1.3 inches) long. The stems are round or somewhat ribbed along their length. The flowers, about 5-11 millimeters (0.2-0.4 inches) long, occur in small clusters and are trumpet-shaped and fleshy. The fruits are cup- or top-shaped, 4-7 millimeters (0.2-0.3 inches) long, 3-4 millimeters (0.1-0.2 inches) in diameter, containing dark-brown, irregularly angled seeds.

Hedyotis coriacea is distinguished from other species of the genus by its small, triangular leaf-like appendages below the flower (calyx lobes), which do not enlarge in fruit, and the combination of fruits that are longer than wide and flower buds that are square in cross section.

b. Taxonomy

Hedyotis coriacea was described by Sir James Edward Smith in 1811 from a specimen collected by Archibald Menzies. This taxon has historically been known by several other names (not all validly published), including *Hedyotis conostyla* (Gaudichaud-Beaupré 1830), *Hedyotis coriacea* forma *conostyla* (Fosberg 1943), *Hedyotis menziesiana* (Steudel 1840), *Hedyotis smithii* (Walpers 1842-1847), *Kadua arnotii* (Don 1834), *Kadua conostyla* (Hooker and Arnott 1832), *Kadua menziesiana* (Chamisso and Schlechtendal 1829), *Kadua smithii* (Hooker and Arnott 1832), and *Oldenlandia conostyla* (A.P. de Candolle 1830). The most recent treatment (Wagner *et al.* 1990) recognizes only *Hedyotis coriacea.*

The genus *Hedyotis* comprises more than 250 species worldwide in tropical and subtropical areas, especially in the Old World (Wagner *et al.* 1990). The specific epithet *coriacea* refers to the coriaceous (leather-like) leaf texture.

c. Current and Historic Range and Population Status

Regarding *Hedyotis coriacea*, Hillebrand (1888) stated, "Hawaii in various regions (near the coast, U.S.E.E.). Nat. name: '*Kioele*' according to Gaudichaud." Fosberg (1943) stated, "A rare, perhaps now extinct, Hawaiian species evidently inhabiting dry to moist places, though little is known of its habitats. Collected by most of the early explorers, but not found since Forbes' collection in 1911."

Until recent rediscoveries, the latest collection of this species was made in 1949 (Degener *et al.* 20500 BISH) on the 1859 lava flow, Hawaii Island (Wagner *et al.* 1990). A single specimen of *Hedyotis coriacea* was rediscovered by Steve Perlman in the Lihau section of the West Maui NAR; the species conceivably could exist elsewhere on Maui as well. In September 1991, two individuals of the taxon

were rediscovered on Hawaii Island on the 1859 lava flow in the Pohakuloa Training Area (PTA), and several others were subsequently discovered. This is the only known natural occurrence of more than a single individual. Currently, fewer than 20 plants (about 17 on Hawaii Island and a single plant on West Maui) are the only known representatives of *Hedyotis coriacea* (Loyal Mehrhoff, USFWS, personal communication 1995).

d. Life History

Little is known about the life history of *Hedyotis coriacea*. Flowering cycles, pollination vectors, seed dispersal agents, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

The habitat of *Hedyotis coriacea* is largely undocumented. Gaudichaud (St. John and Titcomb 1983) included the following taxa in his "Third Region" in which *Hedyotis coriacea* is found: *Alyxia oliviformis*, *Athyrium microphyllum*, *Cibotium*, *Chamaesyce*, *Cheirodendron trigynum*, *Clermontia*, *Cyanea grimesiana*, *Exocarpus gaudichaudii*, *Freycinetia arborea*, *Metrosideros polymorpha*, *Osteomeles anthyllidifolia*, *Sadleria cyatheides*, *Scaevola chamissoniana*, and *Styphelia tameiameiae*.

On West Maui, apparent potential habitat of *Hedyotis coriacea* occurs on steep, rocky, slopes in dry *aalii* (*Dodonaea viscosa*)-dominated shrublands or forests at 470-7,00 meters (1,550-2,300 feet) elevation. Associated native species on West Maui include *Metrosideros polymorpha*, *Styphelia tameiameiae*, *Alyxia oliviformis*, *Bidens menziesii*, *Gouania hillebrandii*, *Sida fallax*, *Lipochaeta lavarum*, *Myoporum sandwicense*, and *Schiedea menziesii* (USFWS 1992a, HPCC 1994). Associated alien species on West Maui include *Leucaena leucocephala*, *Opuntia ficus-indica*, and *Chamaecrista nictitans* (HPCC 1994).

f. Reasons for Decline and Current Threats

On West Maui, *Hedyotis coriacea* has been almost extirpated by the combination of cattle, fires, and invasion of alien plant species. On Hawaii, the same factors and additionally, feral ungulates, have undoubtedly been responsible for the decline of this species.

The main current threats to *Hedyotis coriacea* include:

1) Small population size

The very small remaining number of individuals of *Hedyotis coriacea* and the limited and scattered distribution of the species are threats since a single natural or human-caused environmental disturbance could easily be catastrophic to the few surviving plants on each island. In addition, the limited gene pool may depress reproductive vigor.

2) Fire

The possibility of fire is a major threat to the existence of *Hedyotis coriacea*, particularly in view of the small remaining number of individuals of this species. Natural fires and fires accidentally set by hunters or military ordnance or personnel within PTA threaten native vegetation on the leeward side of Mauna Kea (USFWS 1991), including the habitat of the remnant individuals of *Hedyotis coriacea*. Habitat disturbance caused by military exercises at PTA may have threatened *Hedyotis coriacea* in the past. Planned military activities are now being reevaluated in light of the recent discovery of several endangered plants on PTA.

3) Weeds

Alien plants, particularly fountain grass on PTA, threaten *Hedyotis coriacea*.

4) Human impacts (military maneuvers, collecting, site degradation by hikers)

Illegal collecting for scientific or horticultural purposes or excessive visits by individuals interested in seeing rare plants could result from increased publicity, and would seriously threaten *Hedyotis coriacea*. Because of the few remaining individuals in existence, any collection of whole plants or reproductive parts would adversely impact the gene pool and threaten the survival of the taxon. Hikers may inadvertently cause disturbance to West Maui habitat (HPCC 1994).

g. Conservation

Hedyotis coriacea has been propagated at the National Tropical Botanical Garden (NTBG) (D. Ragone, personal communication 1994) and at the DOFAW nursery on Maui (R. Nakagawa, personal communication 1996). Planned military activities are presently being reevaluated in light of the recent discovery of several endangered plants on PTA.

h. Needed Recovery Actions

1) Establish and manage (e.g., weed control, fencing, etc.) additional populations of *Hedyotis coriacea* in Waikamoi Preserve and PTA.

If successful, this could provide the best protection against extinction of this species by stochastic events such as fire. New populations should be located in areas disjunct enough from existing populations so as not to be vulnerable to the same wildfire.

2) Protect the Pohakuloa Training Area population of *Hedyotis coriacea.*

Construction of an exclosure for, and monitoring of, the *Hedyotis coriacea* at PTA and control of surrounding alien plant species are needed.

3) Protect Lihau individual (West Maui) of *Hedyotis coriacea.*

Construction of an exclosure for, and monitoring of, *Hedyotis coriacea* and control of surrounding alien plant species are needed.

4) Conduct research on pollinators, reproductive biology, and other possible limiting factors.

This species often occurs in lower to middle elevation areas where alien ants are dominant and have caused the loss of most native Hawaiian insects. Emphasis of this work is to determine: a) whether species is self-incompatible, i.e., whether pollinators are a limiting factor in the reproductive biology of this species; and, b) whether native pollinators are present.

11. *Huperzia mannii* (Hillebr.) Holub

(Hawaiian name for genus: wawaeiole) Recovery Priority # - 2

a. Description

Suitable drawings depicting *Huperzia mannii* are not available.

Huperzia mannii, a member of the clubmoss family (Lycopodiaceae), is a pendent (hanging) epiphyte (growing on the outside of other plants instead of being rooted in the ground) with clustered, delicate red stems 4-10 centimeters (1.6-3.9 inches) long and less than 1 millimeter (0.04 inch) thick. Leaves, arranged in three rows on the stem, are pointed, flat, and lance-shaped, measuring 4-12 millimeters (0.2-0.5 inches) long and 1-2 millimeters (0.04-0.08 inches) wide. Fruiting spikes branch four to six times and are 12-20 centimeters (7-9 inches) long and 1-2 centimeters (0.4-0.8 inches) wide. Bracts on the fruiting spikes are arranged in two to four ranks, are 1 millimeter (0.04 inch) long, and conceal the spore capsules. This species can be distinguished from others of its genus in Hawaii by its epiphytic habit, its delicate red stems, and its forked fruiting spikes.

b. Taxonomy

Mann (1867-68) first collected *Huperzia mannii* on Maui before 1868, referring to it as "*Lycopodium phlegmaria*?" In 1888, Hillebrand (1888) named the taxon *Lycopodium phlegmaria* var. *mannii* in the original collector's honor. Hermann Nessel (1939) transferred the taxon to the genus

Urostachys. Carl Skottsberg (1942), believing the plant's characters to warrant specific status and retaining the genus *Lycopodium*, subsequently published the combination *Lycopodium mannii*. Some species of *Lycopodium* have recently been placed in the genus *Huperzia* (Ollgaard 1989).
The combination *Huperzia mannii* was published by Josef Holub (1991) after the proposed rule for its endangered status appeared in the Federal Register. This new combination has been accepted by most botanists specializing in this plant family and therefore has been incorporated into this recovery plan (USFWS 1992a). The specific epithet *mannii* honors Horace Mann, Jr., an important Hawaiian plant collector, who first collected this taxon.

c. Current and Historic Range and Population Status

Historically, *Huperzia mannii* was known from Kauai (Waiakoali), West Maui (Haelaau and Hanaula), and Hawaii Island (Captain Cook-Kona) (HHP 1994). Hillebrand (1888) stated regarding this species, "On the mountains above Maalaea bay, Maui. Only collected by Mann. One of the most slender forms of the species."

The majority of remaining *Huperzia mannii* is believed to occur on East Maui. It was first recorded there in 1976 (Higashino and Mizuno 1976) in the Healani region in the Kipahulu Forest Reserve at ca. 1,280 meters (4,200 feet) elevation. In 1982, Higashino (unpublished) noted that the Healani population consisted of two colonies, with an estimated total of 50 individuals.

Two populations of *Huperzia mannii* are known from the Kahikinui Forest Reserve on East Maui. In 1981, *Huperzia mannii* was discovered in Manawainui Gulch within the Reserve at 1,615 meters (5,300 feet) elevation. This population consists of six individuals growing on the trunks of two *Acacia koa* trees (Medeiros, Loope, and Holt 1986). In 1995, an additional population within the Reserve was discovered by Art Medeiros and Mahealani Kaiaokamalie. This second population within the Reserve is in an unnamed gulch west of Manawainui Gulch at 1,630 meters (4,880 feet) elevation. Seven individuals were observed at this site also growing on the trunks of *Acacia koa* trees (A.C. Medeiros and M. Kaiaokamalie, personal communication 1997).

A fourth East Maui population was discovered in 1992 on the southern rim of Kipahulu Valley, at a site referred to locally as "Cable Ridge," at 610-760 meters (2,000-2,500 feet) elevation, partially within Haleakala National Park, but also on adjacent State and private land. Cable Ridge has easily the largest known population of the species, numbering several hundred individuals, scattered over an area of about 260 hectares (650 acres) (A.C. Medeiros, personal communication 1994). At least a few individuals of *Huperzia mannii* occur in a fifth population on Lihau and Puu-kukui on West Maui. It is also sparingly present in a sixth population on Laupahoehoe NAR on the island of Hawaii, on State and

private land (HHP and HPCC references). The total number of extant individuals is thought to be fewer than 300 (L. Mehrhoff, personal communication 1995).

d. Life History

No details are known.

e. Habitat Description

Huperzia mannii typically grows on the native tree species *Metrosideros polymorpha* (ohia), *Acacia koa* (koa), and *Dodonaea viscosa* (aalii) in mesic to wet montane *ohia-koa* forests on Maui and the island of Hawaii at 600-1,600 meters (1,969-5,250 feet) elevation (USFWS 1992a; A.C. Medeiros, personal observation 1994). Associated native species are extremely numerous and include *Astelia menziesii*, *Coprosma* spp., *Cheirodendron trigynum*, *Ilex anomala*, *Metrosideros polymorpha*, and *Myrsine*. On Hawaii Island, *Sophora chyrsophylla* is present. (Cuddihy *et al.* 1982, HHP references, USFWS 1992a).

f. Reasons for Decline and Current Threats

The primary historical reasons for the endangerment of this species include habitat alteration by feral goats, cattle and pigs, and the impacts of alien plant species.

The main remaining threats to *Huperzia mannii* include:

1) Feral ungulates

Habitat degradation by feral pigs and goats and feral and stray domestic cattle is the major threat to *Huperzia mannii*. This epiphytic species depends on survival of its host trees. Although there is currently no direct evidence of predation on *Huperzia mannii*, it is not known to be unpalatable to goats or cattle (USFWS 1992a).

2) Alien plants

On Hawaii Island, blackberry (*Rubus argutus*) competes with and poses a threat to the habitat of *Huperzia mannii* (HHP 1994; Linda Cuddihy, Biological Resources Division, personal communication 1990). *Cyathea cooperi* and *Psidium cattleianum* are major threats at the Kipahulu, East Maui, site (A.C. Medeiros and L. Loope, personal communication 1994).

3) Small population size

The very small remaining number of individuals of *Huperzia mannii* and the limited and scattered distribution of the species are threats since a single natural or human-caused environmental

disturbance could easily be catastrophic to the few surviving plants on each island. In addition, the limited gene pool may depress reproductive vigor and adaptability.

g. Conservation

Huperzia mannii is not being propagated at any of the collections surveyed by Mehrhoff (1992). An exclosure was constructed in 1990, using barbed-wire and woven-wire, to protect the Kahikinui Forest Reserve Manawainui Gulch population of *Huperzia mannii* and associated species. This fence construction was a cooperative effort between the Native Hawaiian Plant Society and Maui DOFAW. Living Indigenous Forest Ecosystems (L.I.F.E.) plans to fence the second Kahikinui population of *Huperzia mannii* with funds provided by the Service.

h. Needed Recovery Actions

1) Protect Kipahulu (cable ridge) population, eastern Manawainui, bordering Haleakala National Park.

The "cable ridge" population of *Huperzia mannii* is easily the largest, far exceeding the combined number of individuals of all other known populations (A.C. Medeiros, personal communication 1994). Because of the size of this population of *Huperzia mannii* and the quality of surrounding habitat, protection of this population is the most important step for the long-term conservation of the species.

Protection involves construction of a woven-wire exclosure and elimination of feral pigs that are now common and destructive in the area. Control of invasive alien species may be necessary in some parts of the "cable ridge" population. For example, *Cyathea cooperi*, an alien tree fern is common and invasive in lower elevation areas of "cable ridge."

2) Protect State-owned Healani population, East Maui.

Currently, the two colonies are unprotected from feral goats and pigs. Continued degradation of this site will cause the loss of native tree species and conversion to alien grasslands. Without protection, the continued loss of *Acacia koa* and *Dodonaea viscosa* trees, which host *Huperzia mannii* at this site, will cause decline and eventual extirpation of these populations. Protection by woven-wire fence exclosures in this area has demonstrated potential for increasing cover and density of native tree species (Scowcroft and Hobdy 1986; R.W. Hobdy and A.C. Medeiros, personal observation 1994).

3) Support efforts at the Kahikinui Forest Reserve to protect the two known populations.

The exclosure constructed in 1990 in Kahikinui Forest Reserve (Manawainui drainage), as a cooperative effort between the Native Hawaiian Plant Society and Maui DOFAW, needs to be monitored for breaks in the fence and maintained. Once constructed, the proposed fence to protect the population discovered in 1995 will also require maintenance.

4) Survey the largely unexplored habitat between two largest known populations.

Surveys should be conducted at 900-1,525 meters (3,000-5,000 feet) elevation in the Manawainui area, between Kaupo Gap and Kipahulu Valley of Haleakala National Park. Much of this area is part of Kipahulu Forest Reserve.

12. *Lipochaeta kamolensis* Degener & Sherff in Sherff

(Hawaiian name for genus: nehe) Recovery Priority # - 2

a. Description

Suitable drawings depicting *Lipochaeta kamolensis* are not available.

Lipochaeta kamolensis is a low perennial herb in the aster family (Asteraceae). The occasionally somewhat woody stems are low-lying or free-climbing, 30 centimeters to 3 meters (1-9.8 feet) long, rooting along their lower surfaces. Leaves are long and narrow or triangular, about 3-6 centimeters (1.2-2.4 inches) long and 1-4 centimeters (0.4-1.6 inches) wide, both surfaces hairy, especially along the veins. The leaves are lobed, sometimes deeply, along the middle vein in a feather-like arrangement (pinnately lobed), and are on leaf stalks (petioles) about 1 to nearly 2 centimeters (0.8 inches) long. Flower heads occur singly or in pairs, each with 6 approximately 4-9 millimeter (0.2-0.4 inch) petal-like ray florets surrounding about 15 small (3 millimeter [0.1 inch]) disk florets. Each head is surrounded by lance-shaped leaf-like parts (bracts); old bracts are tan in color. The fruits are small (approximately 1.5-2 x 2 millimeters [0.06-0.08 x 0.08 inches]) and dry (achenes).

Lipochaeta kamolensis is distinguished from other species of the genus by its simple leaves, which are pinnately lobed or cut and by the size of the flower heads (Sherff 1951b; Wagner *et al.* 1990; USFWS 1992a).

b. Taxonomy

Lipochaeta kamolensis was described by Degener and Sherff (Sherff 1951b) from material collected in Kamole Gulch in 1948 by Otto Degener, Horace F. Clay, and R. Bertram. The validity of the species

has been accepted in comprehensive reviews of the genus by Gardner (1979) and Wagner *et al.* (1990). Gardner (1979) stated that *L. kamolensis* is most closely related to *L. subcordata* (endemic to Kauai, Lanai, and Hawaii Island), and to a lesser degree to *Lipochaeta venosa* (endemic to Hawaii Island) and *L. bryanii* (endemic to Kahoolawe).

The genus *Lipochaeta* comprises 20 species, restricted to the Hawaiian Islands. It is closely related to the widespread genera *Wedelia* and *Wollastonia* (Wagner *et al.* 1990). The specific epithet *kamolensis* refers to Kamole Gulch (Lualailua Hills quad), within its sole known habitat.

c. Current and Historic Range and Population Status

Until 1994, *Lipochaeta kamolensis* had only been found at its original discovery site on the southern slopes of Haleakala Volcano. The site is approximately 19 kilometers (11.8 miles) southeast of Ulupalakua Ranch office, a location given on some herbarium specimens (Gardner 1979; Sherff 1951b; Wagner *et al.* 1990). This population is near and just west of Kamole Gulch, in the vicinity of Kepuni Gulch, leeward Haleakala, at 230-290 meters (755-951 feet) elevation, both above and below Highway 31, mostly on Hawaiian Home Lands, but with some individuals on land belonging to Ulupalakua Ranch. This population, which extends over an area of about 40 hectares, contains an estimated several hundred individuals (R.W. Hobdy, personal communication 1990; USFWS 1992a). An incomplete assessment in April 1994 recorded 107 individuals (A.C. Medeiros and Paul Kruschelnycky, Biological Resources Division, personal observation 1994).

In 1994, a second population of *Lipochaeta kamolensis* was discovered, about 4 kilometers (2.5 miles) west of the Kamole/Kepuni Gulch population, on Hawaiian Home Lands in Alena, just east of the Lualailua Hills at about 600 meters (2,000 feet) elevation. This population needs careful analysis before definitive statements can be made, but it appears to consist of a "hybrid swarm" of individuals of pure *Lipochaeta kamolensis* and hybrids of *L. kamolensis, and L. rockii.* These hybrids cover an area of about 2 hectares (5 acres).

d. Life History

Gardner (1979) noted flowering in December-February. Flowering was observed in April 1994 (A.C. Medeiros, L. Loope, and P.A. Thomas, personal observation 1994). Vegetative growth normally occurs only during the November-April/May wet season. During the dry season, the plants are desiccated and appear to be metabolically inactive.

Though native bees (*Nesoprosopis* sp.) were observed nearby on flowers of other native species (e.g., *Argemone glauca*), only alien honeybees (*Apis melifera*) were observed visiting the flowers of *Lipochaeta kamolensis*.

e. Habitat Description

Degener's type collection made in 1948 notes: "Very rare, among lantana and grass" (Medeiros *et al.* 1986). Medeiros *et al.* (1986) reported that the habitat "is highly impacted by cattle" and that "very little native vegetation remains"; at that time *Lipochaeta kamolensis* was found to persist "in small depressions and along cattle trails." Mean annual rainfall for the area is in the neighborhood of 600-750 millimeters (24-30 inches). Rainfall is variable from year to year and highly seasonal, with most rain coming in November-April (Giambelluca *et al.* 1986).

Associated native plants include *Argemone glauca, Canthium odoratum, Dodonaea eriocarpa, Doryopteris decipiens, Eragrostis atropioides, Erythrina sandwicensis, Heteropogon contortus, Ipomoea indica, Mariscus hillebrandii, Nototrichium sandwicense, Osteomeles anthyllidifolia, Peperomia leptostachya, Plumbago zeylanica, Scaevola gaudichaudii, Tephrosia purpurea Waltheria indica*, and *Wikstroemia monticola.* Associated alien plants include *Abutilon grandiflorum, Aleurites molucana, Conyza bonariensis, Glycine wightii, Lantana camara, Leucaena leucocephala, Melinis minutiflora, Nicotiana glauca, Panicum maximum, Passiflora subpeltata, Rhychelytrum repens, Salvia coccinea, Stachytarpheta, Tridax procumbens*, and *Zinnia peruviana.*

f. Reasons for Decline and Current Threats

The primary threats historically and currently responsible for the endangerment of this species include ungulate trampling, grazing, and browsing; fire; and competition with alien plant species.

1) Ungulate trampling, grazing, and browsing

Habitat destruction and predation by feral goats and domestic cattle threaten *Lipochaeta kamolensis* (Medeiros *et al.* 1986; R.W. Hobdy, personal communication 1994). Ironically, however, heavy grazing of habitat surrounding *L. kamolensis* serves a partially positive role in removing much of the biomass of alien vegetation, which would potentially fuel wildland fires.

2) Alien plant species

The remaining habitat of *Lipochaeta kamolensis* has been much altered by alien plant species. Three species have spread widely within the last decade on leeward East Maui, and though present in the habitat of *Lipochaeta kamolensis* in limited cover, have the potential to dominate the site.

These species include a leguminous vine, *Glycine wightii*, and two invasive grasses, *Melinis minutiflora* (molasses grass), and *Panicum maximum* (Guinea grass).

3) Wildland fire

Fire is a major threat to the persistence of *Lipochaeta kamolensis*; a single fire could extirpate either of the only known populations (R.W. Hobdy, personal communication 1994). The fire threat would become much more severe with reduction of grazing/browsing and/or invasion of *Pennisetum setaceum* (fountain grass).

g. Conservation

In August of 1995, the Hawaiian conservation group L.I.F.E (Living Indigenous Forest Ecosystems) constructed an exclosure fence to protect the Alena *Lipochaeta* population from feral animals. Cattle and goats were removed from the 2.25-acre enclosed area, and hand weeding was conducted. The population of *Lipochaeta kamolensis* is responding well to these efforts with individuals of this species now covering some of the cleared areas within the fence (Mahealani Kaiaokamalie, personal communication 1997).

h. Needed Recovery Actions

1) Develop landowner commitment to protect the two known populations of *Lipochaeta kamolensis*.

Both known populations of *Lipochaeta kamolensis* are primarily on Hawaiian Home Lands, in the recent past leased for cattle grazing. Some individuals are on private land. Landowner commitment to conservation is essential for long-term stewardship of the population.

2) Construct experimental exclosures within known populations to protect some but not all *Lipochaeta kamolensis* individuals.

For the original population, some sites do not need to be fully encircled by woven-wire exclosures; only short sections of fencing will need to be used to tie in with natural barriers. Near the highway, only domestic cattle need to be excluded. Approximately 200-300 meters (660-990 feet) from the main road surface, feral goats are present and sometimes may be abundant. Protection of *Lipochaeta kamolensis* at the periphery of its known range may involve full fencing for the more difficult task of excluding feral goats as well as domestic cattle. Portions of the populations should be left unfenced until the effects of protection from grazing and browsing (increase in competing alien vegetation) are fully known.

3) Monitor selected invasive weeds within and outside exclosures to determine long-term effects and manage weeds as needed.

The most important weeds to monitor in the presence and absence of browsing that are currently present at the site include molasses grass (*Melinis minutiflora*), Guinea grass (*Panicum maximum*), and *Glycine wightii*.

4) Develop a fire management action plan with Maui DOFAW for protection of *Lipochaeta kamolensis*.

Establish likely scenarios, lines of defense, etc. Fire poses a serious threat to long-term survival of this species no matter how much protection it is given or how many additional populations are found or established.

5) Using seeds from known populations, establish outplantings of *Lipochaeta kamolensis* into protected sites.

Plant in low elevation 150-450 meter (500-1,500 foot) East Maui lava fields, as close as feasible to original sites. Avoid sites with other native *Lipochaeta* (e.g., *L. rockii* and *L. lavarum*) nearby, since the three species are known to hybridize. Outplanted populations should be protected from domestic and feral ungulates. One potential site for outplanting this species is on the rough aa lava of Ahihi-Kinau NAR. Though generally occupying lower elevation than the natural range of the species, this NAR comprises protected State-owned lands on rough lava at a seasonal dry leeward site. Other *Lipochaeta* of the leeward slopes of Haleakala (*L. lavarum* and *L. rockii*) that occur at the same elevation as *L. kamolensis*, also occur at lower elevation to near sea level.

13. *Lysimachia lydgatei* Hillebrand

(Hawaiian names for genus: kolokolo-kuahiwi) Recovery Priority # - 2

a. Description

Suitable drawings depicting *Lysimachia lydgatei* are not available.

Lysimachia lydgatei is a sprawling shrub in the primrose family (Primulaceae). The stems are 1-1.3 meters (3.3-4.3 feet) long and branched, woolly when young, but losing this coating with age. The leathery and roughly oval-shaped (49-70 x 14-22 millimeter [1.9-2.8 x 0.6-0.9 inch]) leaves are alternately positioned on the stems on 10-16 millimeter (0.4-0.6 inch) leaf stalks (petioles), the leaf edges smooth and the leaftips pointed. Both surfaces of the leaf blades are covered with minute rusty-colored hairs, which give the foliage a conspicuous golden-brown pubescent appearance characteristic of the species. Flowers are borne singly at the point of attachment of leaves to the stem on stalks (peduncles)

approximately 1-3 centimeters (0.4-1.2 inches) long when in fruit; flower parts are in sixes or sevens. Lance-shaped floral parts below the petals (sepals) are 7-8 millimeters (0.27-0.31 inches) long; the exact nature of other flower parts (petals, etc.) is unknown. The fruits are capsules, probably somewhat flattened spheres; seed characteristics are unknown.

Lysimachia lydgatei is distinguished from other species in its genus by the dense hairs on both the upper and lower surfaces of mature leaves (Hillebrand 1888, Wagner *et al.* 1990), giving the center of the plant a distinctive brown-woolly appearance.

b. Taxonomy

Lysimachia lydgatei was described by Wilhelm Hillebrand (1888) from an 1871 collection. Later in that century, Amos Arthur Heller (1897) created the new genus *Lysimachiopsis* into which he placed all endemic Hawaiian species of *Lysimachia*. The current treatment (Wagner *et al.* 1990) recognizes *Lysimachiopsis* only as a section of *Lysimachia* in which *Lysimachia lydgatei* is now placed (USFWS 1992a). This species is apparently closely related to and allosympatric with *Lysimachia remyi* (Kenneth Marr, University of British Columbia, personal communication 1992), a much more common, wider-ranging species native to Molokai and Maui (Wagner *et al.* 1990).

The genus *Lysimachia* contains approximately 150 species worldwide with diversity centered in the Himalayas (Wagner *et al.* 1990). The specific epithet *lydgatei* honors John Mortimer Lydgate, important Hawaiian plant collector.

c. Current and Historic Range and Population Status

Lysimachia lydgatei is currently known from at least three mountain summits of leeward West Maui on State NAR lands. About 50-100 individuals are thought to exist on Lihau, about 50 individuals on Halepohaku, and 50-100 individuals on Helu (S. Perlman and K. Wood, personal communication 1995). This species may also be present on Hanaula in the same area. Historically, this species is poorly known from only a single, fragmentary collection (Hillebrand s.n. BISH) made before 1871; the next collection was made in 1979 (Hobdy 519 BISH per Wagner *et al.* 1990).

d. Life History

Little is known about the life history of *Lysimachia lydgatei*. Flowering cycles, pollination vectors, seed dispersal agents, longevity, specific environmental requirements, and limiting factors are unknown.

e. Habitat Description

The habitat of *Lysimachia lydgatei* is stunted native vegetation on the sides of steep ridges and slopes in mesic shrubland at ca. 825-975 meters (2,700-3,200 feet) elevation.

Associated native species include *Dodonaea viscosa, Vaccinium, Styphelia tameiameiae, Dicranopteris linearis, Dubautia linearis, Myrsine sandwicensis, Sadleria, Carex, Scaevola chamissoniana, Eragrostis variabilis, Broussaisia arguta, Lobelia grayana, Coprosma, Dubautia scabra, Machaerina,* and *Bidens mauiensis* (HHP reference; R.W. Hobdy, personal communication 1990; USFWS 1992a; HPCC 1994).

f. Reasons for Decline and Current Threats

Based on available information, the lower-elevation portion of the habitat of this species has likely become reduced as a result of cattle ranching, wildfire, and invasion of alien plant species. Within the remaining habitat, however, the species appears to be maintaining stable populations.

The main potential threats to *Lysimachia lydgatei* include:

1) Wildland fire

Fire is a major potential threat to the survival of *Lysimachia lydgatei*; a single fire could extirpate the species (R.W. Hobdy, personal communication in USFWS 1992a).

2) Alien plants

The alien blackberry (*Rubus argutus*) poses a serious threat to the habitat of *Lysimachia lydgatei* (HHP and DOFAW 1989; USFWS 1992a).

3) Human impacts

Direct human impacts include trampling of *L. lydgatei* and surrounding native vegetation. This increased disturbance makes invasion by alien plant species more likely.

g. Conservation

Lysimachia lydgatei has been propagated at NTBG on Kauai (Mehrhoff 1992)(G. Ray, Center for Plant Conservation, personal communication 1997), which had one representative of this taxon as of February 1993 (D. Ragone, personal communication 1993).

This species does not appear to have declined as catastrophically as have many other endangered taxa in Hawaii over the past century. It is likely that habitat has been reduced, but surviving populations appear relatively stable. The lack of significant ungulate populations at higher elevations of the leeward

West Maui Mountains has resulted in maintenance of fairly intact native habitat. Compared to most other endangered Hawaiian species, *Lysimachia lydgatei* is probably comparatively "safe" for the present.

h. Needed Recovery Actions

1) Monitor changes in ungulates.

If feral ungulates become established, the area must be fenced and animals excluded.

2) Search for additional populations.

To meet recovery goals, a minimum of five additional populations must be found or established, and protected.

14. *Melicope adscendens* (St. John & E. Hume) T. Hartley & B. Stone
(Hawaiian name for genus: alani, alani kuahiwi) Recovery Priority # - 5

a. Description

Suitable drawings depicting *Melicope adscendens* are not available.

Melicope adscendens is a vine-like shrub in the rue family (Rutaceae). New growth on the long, slender branches is densely to sparsely covered with yellowish to golden-brown hairs, the hairs becoming grayish and more sparse with age. The papery or leathery leaves, widely spaced, occur in pairs opposite each other on 6-16 millimeter (0.2-0.6 inch) leaf stalks (petioles) and are generally oval-shaped (1.5-6.5 x 1-4 centimeters [0.6-2.6 x 0.4-1.6 inches]). The leaves have about 14 pairs of veins branching from the main vein and are generally smooth, with sparse hairs on the underside when young. Flowers occur on 13-17 millimeter (0.5-0.7 inch) stalks (peduncles) from the point of leaf attachment in groups of one to three flowers, each on an individual shorter stalk (pedicel). Male flowers are small (petals about 5 millimeters (0.2 inches) long) with tiny hairs; characteristics of female flowers are unknown. The fruit is apocarpous (breaking easily into four distinct sections), smooth on the outside, 14-15 millimeters (0.54-0.59 inches) wide, and subtended by persistent petals and other floral parts (sepals).

Melicope adscendens is distinguished from other *Melicope* species in its sprawling vine-like habit, long, thin peduncles, and apocarpous fruits.

b. Taxonomy

Melicope adscendens was described as *Pelea adscendens* by Harold St. John and his former student Edward P. Hume in 1944 based on a 1920 collection (C.N. Forbes 2100-M) from dryland forest at Auwahi (misspelled as "Auwalu"), leeward Haleakala. In 1989, Thomas C. Hartley and Benjamin C. Stone (1989) synonymized the genus *Pelea* under *Melicope*.

The genus *Melicope* contains approximately 200 species distributed from Madagascar through Southeast Asia, Australia, New Zealand and the Pacific as far east as the Hawaiian Islands and French Polynesia. The specific epithet *adscendens* is Latin for "ascending," perhaps referring to the ascendent branch tips of this trailing species.

c. Current and Historic Range and Population Status

Within historic times this species has apparently always been extremely rare. Before the 1980s this species was known only from two collections (Forbes 2100-M, Forbes 2088-M BISH) made on the same day, March 24, 1920, by Bishop Museum botanist Charles N. Forbes. Based on field note descriptions, the collections appear to be made at the 915-1,000 meter (3,000-4,000 foot) elevation level of middle or western Auwahi Districs (Medeiros *et al.* 1986). No collections or other records of its occurrence were made for the next six decades.

In 1982, *Melicope adscendens* was rediscovered in extreme western Auwahi District (A.C. Medeiros 230); a single individual was found below Puu Ouli at 1,220 meters (4,000 feet) elevation (Medeiros *et al.* 1986). In 1993, three additional individuals of this species were located at an elevation of 1,100 meters (3,600 feet) in Auwahi (A.C. Medeiros, personal observation 1993). Between 1995 and 1996, the Service funded the Biological Resources Division to conduct additional field surveys in this same area. Based on these surveys, 16 individuals of *Melicope adscendens* are known, all growing in close proximity, at 1,100-1,220 meters (3,600-4,000 feet) in extreme western Auwahi, leeward East Maui, on privately owned land.

d. Life History

Despite its vine habit, the species appears to be relatively long-lived; the first individual of this species rediscovered in 1982 is still extant 12 years later without signs of appreciable growth or decline. In limited diurnal observations, no flower visitors were observed. Fruiting collections have been made in March and July.

e. Habitat Description

The known individuals of *Melicope adscendens* occur at 1,000-1,220 meters (3,280-4,000 feet) elevation in the extreme western Auwahi district in dryland forest described in some detail by Rock (1913) and Medeiros, Loope, and Holt (1986). In his unpublished field notes (filed in the Bishop Museum library), botanist Charles N. Forbes mentions, of the species' habitat: "Open forest type with *Osmanthus* (= *Nestegis*) dominant, *Dracaena* (= *Pleomele*) second at least in the lower part." The four known plants grow tangled and interlocked amidst branches of the native shrubs *Dodonaea viscosa* and *Osteomeles anthyllidifolia*. Other associated native species include *Alectryon macrococcus, Alphitonia ponderosa, Chamaesyce celastroides* var. *lorifolia, Nestegis sandwicensis, Osteomeles anthyllidifolia, Pouteria sandwicensis, Santalum ellipticum, Xylosma hawaiiense*, and *Zanthoxylum hawaiiense*. Associated alien species include *Asclepias physocarpa, Melinis minutiflora, and Pennisetum clandestinum*.

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this species likely include: predation and habitat damage by ungulates; competition with alien plant species; possible predation of seeds by rodents, birds, or insects; loss of essential pollinators; insects or pathogens attacking young or mature individuals; loss of genetic variability; and fragmentation of the population, which makes cross-pollination difficult.

The main known threats to current survival of *Melicope adscendens* include:

1) Impacts of feral ungulates

   Rock (1913) noted the serious degradation of the botanically rich site of Auwahi as a result of browsing of goats and cattle. Pigs are now present in the area as well.

2) Alien plants, particularly, *Pennisetum clandestinum* (kikuyu grass) and *Melinis minutiflora* (molasses grass), threaten *Melicope adscendens*.

3) Seed predation by insects

   The endemic microlepidopteran *Prays* cf. *fulvocanella* Walsingham (Yponomeutidae) is known to feed on the buds, flowers and seeds of *Melicope* and *Platydesma*.

4) Fire is a continuing threat to this dry forest habitat.

g. Conservation

Melicope adscendens is not being propagated at any of the collections surveyed by Mehrhoff (1992) (G. Ray, Center for Plant Conservation, personal communication 1997). Where livestock are fenced out,

kikuyu grass proliferates, covering the *aa* lava substrate to depths of several feet. Small-scale efforts by the Hawaiian Native Plant Society to fence groups of trees and kill kikuyu grass with the herbicide glyphosate (Roundup) have had mixed results. Seedlings of native plants appear where seed banks exist. However, in most instances few of these seedlings survive. Meanwhile, the number of individuals of most of the native species of Auwahi are dwindling. About a dozen species have fewer than 20 individuals left; some, apparently including *Melicope adscendens*, are down to fewer than five individuals (although there is a good chance that more could be found with careful, systematic searching, in the opinion of A.C. Medeiros).

An innovative strategy, probably involving establishment of a nurse forest (see Appendix B), is needed to avoid complete loss of the Auwahi forest over the next three decades. Obviously, with only a few living individuals as of 1993, the status of *Melicope adscendens* is very precarious. The Maui office of the USGS Biological Resources Division and collaborators, with funding from the Service, have initiated an experimental "nurse forest" project at Auwahi, working in cooperation with Ulupalakua Ranch, the Native Hawaiian Plant Society, and Maui DOFAW.

h. Needed Recovery Actions

1) Initiate an emergency program to save *Melicope adscendens* from extinction.

This program needs to involve propagation, outplanting into managed (with weed control) exclosures on protected lands, establishment of "nurse forests" (see Appendix B) to nurture reestablishment of the taxon in the long run, and emergency assessment of and response to limiting factors. Potential sites include Kanaio State NAR, Ulupalakua Ranch (cooperative conservation agreement/easement necessary), and the Kaupo Gap area of Haleakala National Park on East Maui. All of these locations are within the likely historic range of the species.

2) Search for new populations (individuals).

The best chance for locating new individuals is between the two known populations, where similar habitat exists.

15. *Melicope balloui* (Rock) T. Hartley & B. Stone

(Hawaiian name for genus: alani, alani kuahiwi) Recovery Priority # - 5

a. Description

Suitable drawings depicting *Melicope balloui* are not available.

Melicope balloui is a small tree or shrub in the rue family (Rutaceae). New growth is covered with yellowish-brown hairs and waxy scales, the hairs becoming grayish and they, along with the scales, more sparse with age. The generally oval-shaped leathery leaves (5-10 x 3-7 centimeters [2-3.9 x 1.2-2.8 inches]) occur in pairs on 10-26 millimeter (0.4-1.0 inch) leaf stalks (petioles) opposite each other on the stems. The leaves have about 9-14 pairs of veins branching from the main vein connected by another vein near the periphery of the leaf. The leaves are slightly hairy, the underside becoming less hairy except around the main vein. Female flowers are yellowish green, tiny (petals approximately 4 millimeters (0.2 inches) long) and are densely covered with small hairs. They grow in flat clusters of five to nine, each on individual 5 millimeter (0.2 inch) stalks (pedicels), on 3-16 millimeter (0.1-0.6 inch) stalks (peduncles) from the point of leaf attachment. Details of male flowers are unknown. Petals and some other floral parts (sepals) usually persist as the fruit matures; the fruits are about 26 millimeters (1.02 inches) wide, each 12-13 millimeter (0.47-0.51 inch) part containing one or two 7 millimeter (0.3 inch) seeds.

Melicope balloui is opposite-leaved, distinguishing it from species in Section *Pelea*, locally *Melicope clusiifolia* and *Melicope haleakalae*. When sterile, *Melicope balloui* is not easy to distinguish from other opposite-leaved members of the genus. Juvenile plants of this species often have very large leaves (with blades exceeding 25 centimeters [9.9 inches]). Individuals of *Melicope balloui* bearing fruit can be distinguished from the more common and widespread *M. volcanica* and *M. molokiensis* by the distinctive silky-haired fruiting exocarp (capsule exterior) and sparsely haired endocarp (capsule interior).

b. Taxonomy

Melicope balloui is an East Maui endemic (found nowhere else), described as *Pelea balloui* by Joseph Rock in 1913; the type material (J.F. Rock and L. von Tempsky 8609) was collected in 1910 at 1,525 meters (5,000 feet) elevation on northwest Haleakala, "in dense rainforest . . . on the trail leading from Ukulele to Waikamoi Gulch" (Rock 1913). St. John (1944) described *Pelea ukuleleensis* based on a 1919 collection (Forbes 749.M BISH) made along the "lower trail-Ukulele" (C.N. Forbes field notes). In his comprehensive review of the genus, Stone (1969) reduced *Pelea ukuleleensis* to a synonym of *Pelea balloui*. A recent review (Hartley and Stone 1989) synonymized the near exclusively Hawaiian genus *Pelea* with *Melicope*, resulting in *Melicope balloui* (Rock) Hartley and Stone. Wagner *et al.* (1990) state that the correct name of this species may actually be *Melicope mannii*, pending a determination when a type specimen is designated for that taxon. Part of the description of *Pelea mannii* is based on *Mann & Brigham 376* ("AC, BISH" per Wagner *et al.* 1990), which is actually *Melicope balloui*.

The genus *Melicope* comprises approximately 200 species distributed from Madagascar through Southeast Asia, Australia, New Zealand and the Pacific as far west as the Hawaiian Islands and French Polynesia. The specific epithet *balloui* honors Professor Howard M. Ballou, colleague of the species' author, Joseph F. Rock.

c. Current and Historic Range and Population Status

Melicope balloui is a small tree of wet forest historically found between 1,280 and 1,525 meters (4,200-5,000 feet) elevation on northwest Haleakala. The species is rare and was known from only nine collections, the last occurring in 1927 (Degener 8563, BISH) (Wagner *et al.* 1990). A new disjunct distribution of *Melicope balloui* was discovered (Higashino *et al.* 1988) in Kipahulu Valley, part of Haleakala National Park, based on a specimen collected at about 760 meters (2,500 feet) elevation (L. Cuddihy 2053). *Melicope balloui* is now known to be rare at 760-1,010 meter (2,200-3,300 foot) elevation in mixed *Acacia koa* and *Metrosideros polymorpha* forests in Kipahulu Valley (Medeiros and Loope, in prep.). Based on available information, there appear to be fewer than 300 extant individuals.

d. Life History

No details are known.

e. Habitat Description

This species is "known only from wet forest, about 1,280-1,520 meters (4,200-4,990 feet), slopes of Haleakala, Maui, between Olinda and Ukelele (Wagner *et al.* 1990)" and from similar wet forest in Kipahulu Valley. Associated native species include *Acacia koa*, *Cibotium chamissoi*, *Cibotium glaucum*, *Diplazium sandwichianum*, *Melicope clusiifolia*, *Metrosideros polymorpha*, and *Sadleria pallida*. Associated alien species include *Cyathea cooperi*, *Paspalum conjugatum*, *Psidium cattleianum*, and *Rubus rosifolius*.

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this species likely include impacts by feral pigs and cattle and competition with alien plants.

The main current threats to *Melicope balloui* include:

1) Impacts by feral pigs

Feral pigs are currently being controlled in Haleakala National Park. Constant vigilance is required to keep fences repaired and to remove pigs that get in through breaks in the fence.

2) Displacement by alien plants

If uncontrolled, *Paspalum conjugatum* (Hilo grass), *Clidemia hirta* (Kosters' curse), *Psidium cattleianum* (strawberry guava), *Hedychium gardnerianum* (kahili ginger), and *Cyathea cooperi* (Australian tree fern) all potentially represent serious threats to the long-term survival of *Melicope balloui*.

3) Insect predation

The endemic microlepidopteran *Prays* cf. *fulvocanella* Walsingham (Yponomeutidae) is known to feed on the buds, flowers and seeds of *Melicope* and *Platydesma*.

g. Conservation

Melicope balloui has been successfully propagated at the Lyon Arboretum on Oahu (G. Ray, Center for Plant Conservation, personal communication 1997). Protection of the Kipahulu Valley ecosystem by Haleakala National Park through construction of barrier fences, pig removal, and alien plant management provided a major action toward recovery of this species before its listing.

h. Needed Recovery Actions

1) Maintain relatively pig-free condition of Kipahulu Valley of Haleakala National Park.

2) Continue alien plant control in Kipahulu Valley of Haleakala National Park, with emphasis on *Clidemia hirta*, *Cyathea cooperi*, *Hedychium gardnerianum*, and *Psidium cattleianum*.

3) Produce an accurate assessment of population numbers and distribution; establish simple baseline monitoring of known individuals.

Thus far, there has been little accurate information regarding population size and distribution of this species. Field work by trained resource management and research workers in Kipahulu over several years would allow this type of assessment. More accurate assessment of populations of this species will allow meaningful assessment of conservation potential and management needs.

4) Search for *Melicope balloui* on northwest Haleakala.

There is a very good chance that this species still exists in the habitat where it was first discovered, i.e., middle elevation forests of northwest Haleakala. Two reasons for the lack of

modern collections of this species from that region may be: 1) the lack of sufficient modern biological exploration of the area due to the generally closed access maintained by Haleakala Ranch, East Maui Irrigation, and DOFAW, and; 2) the cryptic nature of the species. With casual observation, *Melicope balloui* is easily confused with the more common and widespread *Melicope volcanica* and *Melicope molokaiensis,* both of which can be sympatric. Fruit characters, often unavailable, are the primary determinant used to separate *Melicope balloui* from these other two species.

5) Conduct/encourage research on limiting factors.

The degree of damage from insect predation needs to be investigated and remedied, if needed. Rodents do not seem to be an important limiting factor for *M. balloui* as they are for *M. ovalis*, which grows adjacent to *M. balloui.* Still, undetermined factors may be causing the rarity of *M. balloui.*

16. *Melicope mucronulata* (St. John) T. Hartley & B. Stone
(Hawaiian name for genus: alani, alani kuahiwi) Recovery Priority # - 5

a. Description

Suitable drawings depicting *Melicope mucronulata* are not available.

Melicope mucronulata is a small tree in the rue family (Rutaceae) growing to 4 meters (13 feet) tall. New growth is densely hairy. The generally oval-shaped, thin, leathery leaves (8-16 x 3.5-6.5 centimeters [3.2-6.3 x 1.4-2.5 inches]) occur in pairs on 20-35 millimeter (0.8-1.4 inch) leaf stalks (petioles) opposite each other on the stems. The leaves usually have six to eight pairs of veins branching from the main vein, connected by an arched vein from 3-10 millimeters (0.1-0.4 inches) from the periphery of the leaf. The top surface of the leaves is hairless; the underside is densely hairy when young, but less so with age. Flowers occur on 6-15 millimeter (0.2-0.6 inch) stalks (peduncles) from the point of leaf attachment to the stem in groups of three to nine flowers, each on an individual shorter stalk (pedicel), the entire array being somewhat hairy. The fruits are 24-28 millimeters (0.9-1.1 inches) wide with distinct smooth compartments 12-14 millimeters (0.47-0.55 inches) long, each compartment containing one or two 6 millimeter (0.2 inch) seeds. Floral details are unknown for this species.

This species is distinguished from others in the genus by the growth habit, the number of flowers in each flower cluster, the size and shape of the fruit, and the degree of hairiness of the leaves and fruit walls (Stone *et al.* in Wagner *et al.* 1990; USFWS 1992a).

b. Taxonomy

St. John (1944) described *Pelea mucronulata* based on a specimen collected in 1920 by C.N. Forbes. A recent review has synonymized the near exclusively Hawaiian genus *Pelea* under *Melicope*, resulting in the current name *Melicope mucronulata* (Hartley and Stone 1989). "*Pelea mucronulata* is a sparsely pubescent apocarpous species. More collections are needed to understand its relationship in the section, especially to *P. adscendens*" (Wagner *et al.* 1990).

The genus *Melicope* comprises approximately 200 species distributed from Madagascar through Southeast Asia, Australia, New Zealand, and the Pacific as far west as the Hawaiian Islands and French Polynesia. The specific epithet *mucronulata* refers to the small sharp point at the end of the fruit.

c. Current and Historic Range and Population Status

First discovered in 1920 in Kanaio, East Maui, *Melicope mucronulata* may be extinct there. This species was found in 1985 in Kupia on TNCH's Kamakou Preserve on East Molokai; three individuals were found there (HHP references, HPCC reference, Stone *et al.* in Wagner *et al.* 1990). "Known only from 3 collections made in 1920 in forest at Pakiloi [not found on modern maps] on the south slope of Haleakala, Maui, and a single collection made in 1985 from 870 meters (2,850 feet), Kupia Gulch, Molokai" (Wagner *et al.* 1990).

d. Life History

No details are known.

e. Habitat Description

The habitat of *Melicope mucronulata* is dryland forest on leeward East Maui and Molokai at about 670-870 meters (2,200-2,850 feet) elevation. Associated native species include *Dodonaea viscosa*, *Metrosideros polymorpha*, *Styphelia tameiameiae*, *Dubautia linearis*, *Chamaesyce celastroides* var. *amplectens*, *Pleomele*, *Myrsine*, *Exocarpus*, and *Wikstroemia* (HPCC 1994; USFWS 1992a).

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this species include habitat degradation by goats, cattle and pigs, and competition with alien plants.

The main current threats to *Melicope mucronulata* include:

1) Feral ungulates

The three remaining individuals of *Melicope mucronulata* on Molokai have been browsed by goats (HHP 1994). Although the plants appeared vigorous when last seen (HHP 1994), continued predation would severely threaten the population (USFWS 1992a).

2) Alien plants

The sole population of *Melicope mucronulata* on Molokai is immediately threatened by molasses grass (HHP reference; Joel Lau, TNCH, personal communication 1990; USFWS 1992a).

3) Seed predation by native insects

The endemic microlepidopteran *Prays* cf. *fulvocanella* Walsingham (Yponomeutidae) is known to feed on the buds, flowers and seeds of *Melicope* and *Platydesma*.

4) Small population size

The very small remaining number of individuals of *Melicope mucronulata* and the limited distribution of the species are major threats to the continued existence of this species; a single natural or human-caused environmental disturbance could easily cause the species' extinction. In addition, the limited gene pool may depress reproductive vigor (USFWS 1992a).

g. Conservation

Melicope mucronulata has been propagated at NTBG on Kauai (Mehrhoff 1992). Propagation has also been attempted at the Lyon Arboretum on Oahu (G. Ray, Center for Plant Conservation, personal communication 1997).

h. Needed Recovery Actions

1) Protect known individuals.

Feral goats and alien plant invasion presently threatening the only known three remaining individuals need to be controlled immediately, via fencing and weed and ungulate removal.

2) Determine numbers of populations and individuals of *Melicope mucronulata* extant.

It is important to determine whether the three known individuals on Molokai are all there is to work with. On East Maui, there may be taxonomic confusion with "lower elevation, less pubescent forms of *M. multiflora* (= *M. knudsenii*)" (which is also extremely depleted). There is a need for well-focused fieldwork and conclusive identification within this difficult genus.

3) Initiate an emergency program based on Maui and/or Molokai in conjunction with other dryland forest taxa (e.g., *Alectryon macrococcus* var. *auwahiensis*, *Melicope adscendens*, *Santalum frecinetianum* var. *lanaiense*) to save *Melicope mucronulata* from extinction.

This program should involve propagation, outplanting into managed (with weed control) exclosures on protected lands, establishment of "nurse forests" (see Appendix B) to nurture reestablishment of the taxon in the long run, and emergency assessment of and response to limiting factors. It may be necessary to obtain material from Molokai for reintroduction of this taxon to Maui, but introduction of Molokai material to Maui should be a last resort. Potential sites include Kanaio State NAR, Ulupalakua Ranch, and the Kaupo Gap area of Haleakala National Park on East Maui.

Establishment of quicker growing native species (*Dodonaea*, *Osteomeles*, etc.) may mimic the conditions of original pristine dryland forest understory. The increased humidity, soil moisture, and shade and decreased wind exposure may increase survival of outplanted germinants of this species. This emergency experimental effort could be conducted either on Molokai or on East Maui in conjunction with other highly depleted dryland forest species.

17. *Melicope ovalis* (St. John) T. Hartley & B. Stone
(Hawaiian name for genus: alani, alani kuahiwi) Recovery Priority # - 5

a. Description

Suitable drawings depicting *Melicope ovalis* are not available.

Melicope ovalis is a tree in the rue family (Rutaceae) that attains a height of 5 meters (16 feet). New growth is somewhat hairy, the brownish pubescence becoming more sparse with age. The hairless, oval-elliptic leaves (8-16 x 4-10 centimeters [3.2-6.3 x 1.6-3.9 inches]) occur in pairs on stout 30-40 millimeter (1.2-1.6 inch) leaf stalks (petioles) opposite each other on the stems; the leaves become brittle when dry. The leaves have about 10-12 pairs of primary veins branching from the main vein, connected by an arched vein 7-12 millimeters (0.3-0.5 inches) from the periphery of the leaf. Flowers occur on 3-12 millimeter (0.1-0.5 inch) stalks (peduncles) from the point of leaf attachment to the stem in groups of

three to seven flowers, each on an individual 10-13 millimeter (0.4-0.5 inch) stalk (pedicel). Floral details are unknown. Fruits are roughly cube-shaped and about 10 millimeters (0.4 inches) long; each section of the fruit contains one or two 5 millimeter (0.2 inch) seeds.

Melicope ovalis is opposite-leaved, distinguishing it from species in Section *Pelea*, locally *Melicope clusiifolia* and *Melicope haleakalae*. When sterile, *Melicope ovalis* is not easy to distinguish from other opposite-leaved members of the genus. However, the foliage and fruits of *Melicope ovalis*, especially young, nearly fully expanded leaves, have a strong, sweet, aromatic odor, similar to the fruits of mokihana (*Melicope anisata* Mann) of Kauai. Individuals of *Melicope ovalis* bearing fruit can be distinguished by the characteristic rounded-cuboid capsules, often borne abundantly.

Melicope ovalis also differs from other *Melicope* species in the shape of certain flower parts (carpels), type of flower clusters, the nearly hairless surface of the ovaries and fruit, the type and quantity of hairs on the leaves and new growth, and the lengths of the flower stems and flower cluster stems (Wagner *et al.* 1990).

b. Taxonomy

Melicope ovalis was described as *Pelea ovalis* by Harold St. John (1944) from the type specimen (Forbes 2670.M BISH), collected by B.P. Bishop Museum botanist Charles N. Forbes in 1920 from "Mountains above Hana," Maui. C.N. Forbes, in his unpublished field notes (filed in the Bishop Museum library), notes of the type collection: "Tree 15 feet high. Leaves brittle with a slight soapy taste, bright green. Capsules globose (not truly square), fragrant and with a fine taste like licorice." According to these notes, Forbes collected the species in dense *Metrosideros* forest near Paki cinder cone (976 meters or 3,200 feet elevation), northeastern Haleakala. A recent review has synonymized the nearly exclusively Hawaiian genus *Pelea* under *Melicope*, resulting in the current name *Melicope ovalis* (Hartley and Stone 1989).

The genus *Melicope* contains approximately 200 species distributed from Madagascar through Southeast Asia, Australia, New Zealand and the Pacific as far west as the Hawaiian Islands and French Polynesia. The specific epithet *ovalis* presumably refers to the oval-elliptic leaf blade shape.

c. Current and Historic Range and Population Status

Recent reviews of this species have considered it of uncertain status and perhaps extinct. Wagner *et al.* (1990) state that *Melicope ovalis* is known only from the type specimen (Forbes 2670.M BISH) collected by Charles N. Forbes in 1920 from the "mountains above Hana, Maui." The first recent

indication that the species may still be extant was a collection from Kipahulu Valley of Haleakala National Park in the late 1980s (L.W. Cuddihy & G.L. Santos 2239 BISH). A more recent, limited reconnaissance by A.C. Medeiros suggests that, though uncommon, the taxon occurs over an area of at least several hundred hectares in Kipahulu Valley, at 855-1,430 meters (2,800-4,700 feet) elevation. A minimum of several hundred individuals exist. This species is believed to be substantially more common than *Melicope balloui*.

d. Life History

No details are known.

e. Habitat Description

Melicope ovalis is found in ohia and koa forest, especially on stable (non-eroding) banks of watercourses at 854-1,433 meters (2,800-4,700 feet) in Kipahulu Valley within Haleakala National Park. Associated native species include *Acacia koa*, *Cibotium chamissoi*, *Cibotium glaucum*, *Diplazium sandwichianum*, *Melicope clusiifolia*, *Metrosideros polymorpha*, and *Sadleria pallida*. Associated alien species include *Paspalum conjugatum*, *Paspalum urvillei*, *Psidium cattleianum*, *Psidium guajava*, *Rhychospora caduca*, and *Youngia japonica*.

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this species include impacts by feral pigs and cattle, seed predation by alien rodents (especially black rats), and impacts of non-native plant species.

The main current threats to *Melicope ovalis* include:

1) Seed predation and bark-stripping by alien rodents, especially black rats

In comparison with other *Melicope* species in Hawaii, *M. ovalis* appears to be particularly vulnerable to attack of seeds by alien black rats. This vulnerability may be because the relatively large size of the capsules and prolific fruiting of the species makes it more attractive to rodents than other *Melicope* species.

2) Displacement by alien plants

If uncontrolled, *Paspalum conjugatum* (Hilo grass), *Clidemia hirta* (Kosters' curse), *Psidium cattleianum* (strawberry guava), *Hedychium gardnerianum* (kahili ginger), and *Cyathea cooperi*

(Australian tree fern) all potentially represent serious threats to the long-term survival of *Melicope ovalis*.

3) Seed predation by native insects

In comparison with other *Melicope* species in Hawaii, *M. ovalis* appears to be particularly vulnerable to attack of seeds by native insects. The endemic microlepidopteran *Prays* cf. *fulvocanella* Walsingham (Yponomeutidae) is known to feed on the buds, flowers and seeds of *Melicope* and *Platydesma*.

g. Conservation

Melicope ovalis has so far not been propagated (G. Ray, Center for Plant Conservation, personal communication 1997). However, seeds of the species have recently been made available to NTBG. Protection of the Kipahulu Valley ecosystem by Haleakala National Park through construction of barrier fences, pig removal, and alien plant management provided a major action toward recovery of this species before its listing.

h. Needed Recovery Actions

1) Continue alien plant and pig control in Kipahulu Valley of Haleakala National Park, with emphasis on *Clidemia hirta*, *Cyathea cooperi*, *Hedychium gardnerianum*, and *Psidium cattleianum*.

2) Conduct/encourage research on impacts of rodent predation, and remedy any problems noted.

If rodents, such as black rats (*Rattus rattus*), are found to be an important limiting factor in the long-term survival of *Melicope ovalis*, some form of seed protection (e.g., gathering and subsequent planting of seeds or trapping and/or poisoning of rats) may be required

3) Produce an accurate assessment of population numbers and distribution; establish simple baseline monitoring of known individuals.

Thus far, there has been little accurate information regarding population size and distribution of this species. Field work by trained resource management and research workers in Kipahulu over a few years would allow this type of assessment. More accurate assessment of population levels of this species will allow meaningful assessment of conservation potential and management needs.

4) Search for *Melicope ovalis* elsewhere on windward Haleakala, especially in the area where it was first found.

18. *Remya mauiensis* Hillebrand

(no common name) Recovery Priority # - 5

a. Description

Appendix D contains a line drawing of *Remya mauiensis*.

Remya mauiensis is a sprawling, many-branched shrub in the aster family (Asteraceae), which grows to 1-2 meters (3-6 feet) tall, forming loosely tangled clumps that sprawl on or among the branches of other vegetation. Branches are ascending and densely leafy along the new growth, the young parts with dense whitish hair. The leaves are papery and narrow oval-shaped (9-18 x 0.8-2.6 centimeters [3.5-7 x 0.3-1 inches])with forward-pointing teeth on the margins; leaf stalks (petioles) are 0-1 centimeters (0.4 inches) long. The upper leaf surfaces have long, tangled hairs when young, becoming less dense when older; the lower surfaces have grayish-white tangled hairs. Flower heads occur in dense, woolly clusters on short stalks; the tiny, cream-colored flower heads (dimensions no greater than 5 millimeters [0.2 inches]) are comprised of both ray (resembling "petals") and minute disk florets. The fruits are small (about 1.5 millimeters [0.06 inch]) and dry (achenes).

Remya mauiensis can be distinguished from *Remya kauaiensis* on the basis of leaf characteristics: the leaves of *Remya mauiensis* are much longer relative to their width than those of *Remya kauaiensis*.

b. Taxonomy

Remya mauiensis was described by Wilhelm Hillebrand (1888) from his own collections of the species in 1851 and 1871. The genus *Remya* is endemic to the islands of Kauai and Maui and comprises three species (Wagner *et al.* 1990). The specific epithet *mauiensis* refers to Maui, the island to which it is restricted.

c. Current and Historic Range and Population Status

Apparently, *Remya mauiensis* has never been common during historical times. Hillebrand collected *Remya mauiensis* twice in the 1800s (Hillebrand 1888), and Forbes collected it once in 1920; all of these collections were from West Maui (Herbst 1988). The species was thought to be extinct until its rediscovery on the slopes of Manawainui Gulch, West Maui, in 1971 by L.E. Bishop, W. Gagné, and S. Montgomery. It has since also been found in an adjacent gulch. While all potential habitat has not been searched for *Remya mauiensis*, the results of botanical exploration of the region to date demonstrate that

this species is extremely rare (Herbst 1988). Because of the often dense growth of surrounding vegetation, it is difficult to determine the exact number of individuals of *Remya mauiensis* in a population. This species is known from two small populations occupying less than 1 hectare (2.4 acres) on adjacent ridges on West Maui; there appear to be seven plants in one population and two in the other (R.W. Hobdy, personal communication 1990). Both populations occur on State-owned land (Herbst 1988).

d. Life History

No details are known.

e. Habitat Description

Remya mauiensis grows chiefly on steep, north or northeast-facing slopes at 850-1,250 meters (2,790-4,100 feet) elevation and is found primarily in mixed mesophytic forests, or the remnants of such forests (Herbst 1988). Associated native species include *Diospyros sandwicensis, Metrosideros polymorpha, Xylosma hawaiiense, Nestigis sandwicensis, Mysine, Wikstroemia, Dodonaea viscosa, Diplazium sandwichianum, Lysimachia remyi, Melicope* spp., *Alyxia oliviformis, Pleomele auwahiensis*, and *Styphelia tameiameiae* (HPCC 1994).

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this species likely include the impacts of feral ungulates, fire, and competition with alien plant species.

The main current threats to *Remya mauiensis* include:

1) Degradation and loss of habitat due to alien ungulates

It is clear that habitat well-suited for *Remya mauiensis* and likely within its former range has been destroyed or degraded by cattle, goats, and pigs, and that the remaining extant individuals are found growing only in areas relatively inaccessible to these animals. Browsing and grazing by feral and domesticated livestock have impacted *Remya mauiensis* and its habitat through outright destruction of the plants and secondarily through erosion that results from the loss of vegetation, trampling and rooting by these animals (Herbst 1988).

2) Displacement by alien plant species

Browsing and associated habitat disturbance caused by feral ungulates have favored the invasion and spread of numerous aggressive, alien plant species that may compete for space, light, water, or nutrients. Such alien species have replaced *Remya mauiensis* throughout its presumed former habitat (Herbst 1988). Competition from alien plants may also be the reason for the low number of *Remya mauiensis* in areas such as Manawainui Plant Sanctuary, where populations have been protected from ungulates (R. Hobdy, personal communication 1995).

3) Wildland fire

Remya mauiensis occurs in a fire-prone area (dry much of the year), and is jeopardized with extinction by brush fires set accidentally or intentionally (Herbst 1988).

4) Small population size

The very small remaining number of individuals of *Remya mauiensis* and their limited and scattered distribution are threats since a single natural or human-caused environmental disturbance could easily be catastrophic to the species. In addition, the limited gene pool may depress reproductive vigor.

5) Human impacts (collecting and site degradation)

As these plants grow mostly on steep slopes, visits to the area by individuals wishing to see or photograph a rare plant could result in increased erosion. Illegal collecting for scientific or horticultural purposes or excessive visits by individuals interested in seeing rare plants could result from increased publicity, and could affect the species (Herbst 1988).

g. Conservation

All known individuals of *Remya mauiensis* grow on State-owned land within a woven wire exclosure, the 22.4 hectare (56 acre) Manawainui Plant Sanctuary, built and maintained by Maui DOFAW. Current State regulations prohibit the removal, destruction, or damage of plants (Herbst 1988).

Remya mauiensis has been successfully propagated at NTBG on Kauai (Mehrhoff 1992; G. Ray, Center for Plant Conservation, personal communication 1997). NTBG had 3250 seeds in short-term storage as of February 1993 (D. Ragone, personal communication 1993).

h. Needed Recovery Actions

1) Evaluate the status of *Remya mauiensis* in the Manawainui Plant Sanctuary exclosure; if warranted, initiate alien plant control.

The very small number of *Remya mauiensis* in this large, ungulate-free area requires further attention. Monitoring of *R. mauiensis* and of alien plant species in the exclosure should be implemented to determine whether removal of browsing pressure has allowed aggressive alien species, such as molasses grass, to dominate the area. If so, localized control of molasses grass and other alien species may be necessary to allow continued survival of extant individuals and to promote success in establishing new populations within the exclosure.

2) Using seeds from existing populations, establish and maintain outplanted populations within the Manawainui Plant Sanctuary exclosure.

19. *Scaevola coriacea* Nutt.

(Common names: dwarf naupaka, false jadetree, Hawaiian name for genus: naupaka)

Recovery Priority # - 2

a. Description

Appendix D contains a line drawing of *Scaevola coriacea.*

Scaevola coriacea is a low, flat-lying perennial herb in the goodenia family (Goodeniaceae). Its older stems are somewhat woody, and the leaves are relatively far apart, giving the plant a sparse appearance. The succulent leaves of this plant are oval- to spoon-shaped, 2-5 centimeters (0.8-2 inches) long, 1-2 centimeters (0.4-0.8 inches) wide and are smooth or somewhat scaly with rounded tips, with 0.7-1.5 centimeter (0.3-0.6 inch) leaf stalks (petioles). Flowers occur in branched clusters 1-2 centimeters (0.4-0.8 inches) long from the point of leaf attachment in groups of one to three "half-flower"-looking lobed flowers, each 2 centimeters (0.8 inches) long, with petals that are yellowish green on the outside and cream-colored within. The dark purplish-black two-seeded fruit is egg-shaped and sparsely hairy, 5-10 millimeters (0.2-0.4 inches) long and about 5 millimeters (0.2 inches) wide.

Scaevola coriacea is easily distinguished from other *Scaevola* by its prostrate habit and thick, succulent leaves (Carr 1981). The species produces long, running sprouts; single plants may cover up to 10 square meters (30 square feet) of surface area (Wagner *et al.* 1990).

b. Taxonomy

Scaevola coriacea was described by Thomas Nuttall in 1843 based on a specimen he collected "on the island of Atooi (Kauai), near the sea" in 1835. The genus *Scaevola* consists of over 100 species,

most native to Australia (Wagner *et al.* 1990). The specific epithet *coriacea* presumably refers to the distinctive coriaceous (leather-like) leaf texture.

c. Current and Historic Range and Population Status

Scaevola coriacea has been recorded on Niihau (extirpated), Kauai (extirpated), Oahu (extirpated), Lanai (extirpated), Maui (extant), Hawaii Island (extirpated), and two offshore islets off West Maui and Molokai (extant). It has never been collected on the Northwest Hawaiian Islands or on Molokai. On Kauai, *Scaevola coriacea* was collected by Thomas Nuttall "near the sea" in 1835, the last record of this species made on that island. On Niihau, Remy collected the species sometime between 1851 and 1855. By 1913, J.F.G. Stokes was unable to find the species on that island (Forbes 1913). On Oahu, Hillebrand (1888) collected *Scaevola coriacea* at "cape Kaena, on lava near seashore," but it apparently was absent from that area by 1922 (Degener and Greenwell 1950). J.F. Rock made the last known collection of this species on Oahu at Barbers Point in 1919 (Degener and Greenwell 1950). On Lanai, Munro collected this species twice, first in 1922 at Keonohau, northern Lanai (Munro 692 BISH), and then probably in the 1930s (Munro 931) at Kahue, Paomai district, Lanai (Carr 1981). The last collection of *Scaevola coriacea* on Lanai was made in 1938 (St.John & Hosaka 18834 BISH) on the coast at Lae Wahie, Mahana, northern Lanai Island (Degener and Greenwell 1950). Historically on Maui, *Scaevola coriacea* was first collected by Mann and Brigham on the "Isthmus of Maui" in 1864-1865. Hillebrand (1888) reported it from Kalepolepo, on the coast just south of modern Kihei, on southwestern Haleakala Volcano. In 1948-1949, Otto Degener reported *Scaevola coriacea* "scattered here and there on the sun-scorched consolidated sand dunes extending from Wailuku to Waihee Point" (Degener and Greenwell 1950). On Hawaii Island, it was first collected in 1779 by David Nelson (St. John 1979) and also reportedly by the U.S. Exploring Expedition in 1840-1841 (Degener and Greenwell 1950). This record is the last of the species made on that island.

In the early 1800s, an extensive sand dune system covered much of the central isthmus from between present-day Kahului and Wailuku extending out onto the north coast of West Maui. This ecosystem, including much of the former habitat of *Scaevola coriacea*, has been progressively displaced by development. In 1981, the total number of plants known was approximately 350, 300 of which were found at Waiehu Point (Carr 1981). The Waiehu Point population occurred, before 1986, on four consolidated sand dunes on Waiehu Golf Course, owned by the State and by a privately owned company, Bonded Realty Inc. In 1986, the realty company developed its land into residential lots. This action caused the loss of approximately two-thirds of the species' remaining habitat. The landowners arranged for living specimens to be taken from the area for replanting before the population's destruction.

Plantings from cuttings of the original population were made at the entrance to the subdivision. These plantings failed. By 1994, all but two of the planted *Scaevola coriacea* were dead (R. Hobdy, personal communication 1995). The primary reason for failure of these plantings was that the planting site comprised inappropriate habitat; the sandy substrate at the site was not consolidated as is the natural habitat of the species. Invasion and overtopping by alien herbs and shrubs, especially *Pluchea symphytifolia*, also contributed to the failure. The Waiehu population is now much smaller as a result of recent urban development in that area. A detailed field survey will be necessary to fully assess the situation.

Currently this species survives only on Maui and two offshore islets. The four surviving populations of this species, with dates of first record and ownership, are: 1) Waiehu Pt., about 36 hectares (90 acres), <<300 plants, 1948, State & Bonded Realty Inc.; 2) Kaupo, about 0.4 hectare (1 acre), 20 plants, 1978, Kaupo Ranch; 3) Mokeehia Islet, about 40 square meters (130 square feet), 15 plants, 1981, State; and 4) Mokuhooniki Islet, about 12 square meters (40 square feet), 4-5 plants, 1981, State. The islets are part of the Hawaiian State Seabird Sanctuary and are under the jurisdiction of the State Department of Land and Natural Resources. The Waiehu Point population is split between land in State and private ownership. The State-owned land is under the jurisdiction of the County of Maui. The Kaupo population is entirely on private land.

d. Life History

This species is salt-tolerant, relatively long-lived, and flowers year round.

e. Habitat Description

Scaevola coriacea usually occurs in relatively hot, dry coastal sites on low, consolidated sand dunes near sea level. The sites receive high insolation, and most of the vegetation is at or near ground level. Associated native species include *Bidens mauiensis*, *Boerhavia* spp., *Fimbristylis cymosa*, *Gnaphalium sandwicensium Heliotropium curassavicum*, *Jacquemontia ovalifolia*, *Lipochaeta integrifolia*, *Nama sandwicensis*, *Osteomeles anthyllidifolia*, *Scaevola sericea*, *Sida fallax*, and *Waltheria indica* (HPCC 1994; Herbst 1972; A.C. Medeiros, personal observation 1994). Associated alien species include *Casuarina equisetifolia*, *Cynodon dactylon*, *Ficus microcarpa*, *Heterotheca californica*, *Leucaena leucocephala*, *Macroptilium lathyroides*, *Sonchus oleracea*, *Stachytarpheta*, *Verbensina encelioides*, *Wedelia trilobata* (HPCC 1994; Herbst 1972; A.C. Medeiros, personal observation 1994).

f. Reasons for Decline and Current Threats

The primary threats historically responsible for the endangerment of this species include the impacts of domestic cattle and loss of habitat due to building and road construction and associated human impact.

The main current threats to *Scaevola coriacea* include:

1) Development/subdivision encroachment

Scenic coastal areas near human population centers are prime sites for housing and other developments. On the central isthmus of Maui and northeast West Maui coasts, consolidated sand dunes have been almost completely replaced by development.

2) Human impacts (site degradation)

The Waiehu Point population occurs on sand dunes, within State land in Waiehu Golf Course and private house sites. Because the plants occur on such small tracts of lands between the golf course and residential areas, habitat degradation by human traffic is a serious threat to the few surviving individuals of this species at this site. Habitat degradation of the remaining fraction of public land by the activity of golfers off the fairway is also a potential, but probably minimal, threat to the plant (USFWS 1986).

3) Small population size

Further reductions of the breeding population may have adverse effects on the reproductive capacity and survival ability of this species (Carr 1981; USFWS 1986).

4) Alien plants

Trampling, accelerated erosion, and other physical characteristics associated with site degradation lead to increased invasion by alien plant species, such as *Leucaena leucocephala* and *Ficus microcarpa*. Landscaping plants, such as *Wedelia trilobata*, have escaped from residential lots and are usurping *Scaevola coriacea* habitat on road cuts in Waiehu, Maui.

5) Domestic cattle

The Kaupo population is marginally threatened by the feeding and trampling of domestic cattle. Though unfenced, the populations are protected from more substantive damage by the steep slope on which the species grows at this site. The steep slope appears to be the factor that has resulted in the long-term survival of the species at the Kaupo site.

g. Conservation

Scaevola coriacea has been propagated at the Honolulu Botanic Garden, NTBG, the Waimea Arboretum and Botanical Garden (Mehrhoff 1992) and at Lyon Arboretum on Oahu (G. Ray, Center for

Plant Conservation, personal communication 1997). NTBG had over 20 plants and/or seeds of this taxon as of February 1993 (D. Ragone, personal communication 1993). *Scaevola coriacea* was once cultivated at the Maui Botanical Gardens but individuals no longer exist there (R. Nakagawa, personal communication 1996). *Scaevola coriacea* is presently cultivated at numerous other sites in Hawaii, including Wailea Point (Maui), Lahaina Harbor (Maui), the Maui DOFAW nursery, Kanaha Pond Wildlife Sanctuary (Maui), and the courtyard of the Plant Science Building at the University of Hawaii (Oahu) (USFWS 1986; A.C. Medeiros, personal communication 1994; R. Nakagawa, personal communication 1996). Mokeehia and Mokuhooniki Islets are State bird sanctuaries; thus, the populations on those islets are protected. A special permit from the State is required to visit the islet (USFWS 1986).

h. Needed Recovery Actions

There are no known species-specific recovery actions for this species at this time. Please refer to the Stepdown Narrative section of this plan for the overall recovery strategy.

20. *Schiedea haleakalensis* Degener & Sherff Recovery Priority # - 2

a. Description

Appendix D contains a line drawing of *Schiedea haleakalensis*.

Schiedea haleakalensis is a small shrub in the pink family (Caryophyllaceae), growing 30-60 centimeters (12-24 inches) tall. It has thick, woody rootstocks, climbing herbaceous branches and thin needle-like leaves. The slightly fleshy, one-nerved, narrow leaves (40-80 x 1-3 millimeters [15.8-31.5 x 0.04-0.1 inches]) occur in pairs, the distance between pairs on the stem being about 2 centimeters (0.8 inches). The small (under 5 millimeters [0.2 inch]) flowers occur at the ends of stems in branched clusters. The capsules are approximately 4 millimeters (0.2 inches) long with sculptured, gray to red-brown, roughly ovoid seeds 0.6 to 1.0 millimeters (0.02-0.04 inches) long. This species can be distinguished from the similar *Schiedea menziesii* by smooth (vs. hairy) flower clusters (inflorescences) and generally narrower leaves.

Schiedea haleakalensis can be distinguished from the other species of the genus on East Maui by its shrubby, dwarfed appearance, its arid high-elevation habitat, and its crowded, smooth inflorescence

composed of bisexual flowers (Degener and Degener 1956, Degener and Greenwell 1956, Sherff 1942, Wagner *et al.* 1990; USFWS 1992a).

b. Taxonomy

Schiedea haleakalensis was described by Degener and Sherff (Sherff 1942) after its discovery by Otto Degener, Emilio Ordonez, and Felix C. Salucop in 1939 (USFWS 1992a). It was retained as a good species by a recent review of the Hawaiian flora (Weller in Wagner *et al.* 1990). The genus *Schiedea* contains 22 species restricted to the Hawaiian Islands (Wagner *et al.* 1990). The specific epithet *haleakalensis* refers to Haleakala Peak, 2,500 meters (8,200 feet) elevation, southeastern Haleakala Crater, at the base of which the first collections of this species were made.

c. Current and Historic Range and Population Status

Due to the lack of early collections, the historical range of *Schiedea haleakalensis* is unknown. This species is currently known from three populations in Haleakala National Park on East Maui: Holua (2,195-2,440 meters [7,200-8,000 feet] elevation), on north-facing cliffs of Haleakala Peak (2,285-2,345 meters [7,500-7,700 feet] elevation), and in upper western Kaupo Gap (1,800-1,860 meters [5,900-6,100 feet] elevation) (Wagner *et al.* 1990; A.C. Medeiros and L. Loope, personal communication 1990). The three populations are estimated to contain a total of 100 to 200 individuals, which together extend over a total area of about 11 hectares (A.C. Medeiros and L. Loope, personal communication 1990). However, due to the inaccessibility of the habitat, a complete survey is lacking.

Schiedea haleakalensis has survived only on precipitous cliff faces inaccessible to goats. In spite of the removal of goats in the late 1980s from habitat of this taxon in Haleakala National Park, no establishment by seedlings has ever been observed. Slugs may be completely devouring the seedlings (A.C. Medeiros, personal communication 1997).

d. Life History

Little is known about the life history of *Schiedea haleakalensis*. This species is known to be gynodioecious (bearing female and both-sexed flowers on separate plants) (Stephen Weller, University of California at Irvine and A.C. Medeiros, personal communication 1994) and, hence, probably requires cross-pollination by small insects for seed set. Small flies and moths have been noted visiting the flowers at both known populations (Loope and Medeiros 1994c). These insects are generally relatively short-

flighted. Fruits and seeds have been observed in August/ September. There are no obvious dispersal devices for seeds other than gravity and water-borne movement.

e. Habitat Description

The current habitat of *Schiedea haleakalensis* is in rock cracks on sheer cliffs at 1,800 and 2,440 meters (5,910 and 8,010 feet) elevation adjacent to barren lava and predominantly native subalpine shrublands and grasslands. The substrate is cinder, weathered volcanic ash, or bare lava with little or no soil development. Periodic freezing temperatures occur in this habitat. Associated native species include *Artemisia mauiensis*, *Bidens micrantha*, *Dubautia mensiezii*, *Styphelia tameiameiae*, *Vaccinium reticulatum*, and *Viola chamissoniana* (Medeiros, Loope, and Holt 1986).

f. Reasons for Decline and Current Threats

The primary threat historically responsible for the endangerment of this species is habitat degradation and herbivory by feral goats.

The main current threats to *Schiedea haleakalensis* include:

1) Small population size

The very small remaining number of individuals of *Schiedea haleakalensis* and the limited and scattered distribution of the species are threats since a single natural or human-caused environmental disturbance could be catastrophic to all or a significant part of the populations. In addition, the limited gene pool may depress reproductive vigor. Just as importantly, a very small, scattered population may not receive adequate cross-pollination.

2) Feeding by slugs (*Milax gagates*)

Based on recent unpublished evidence, recruitment of *Schiedea* germinants [seedlings] can be catastrophically suppressed by herbivory of alien slugs in the Waianae Mountains of Oahu (Steve Weller and Ann Sakai, University of California at Irvine, personal communication 1994). Nocturnal herbivory by the invasive garden slug *Milax gagates* has been observed to partially defoliate larger, established plants of *Schiedea haleakalensis* in the western Kaupo population (A.C. Medeiros, personal observation 1994). This slug is now widespread on upper Haleakala Volcano in a variety of high-elevation sites, arid to wet, and has been observed feeding on such rare native plants as the greensword (Gagné 1983).

3) Invasion of habitat and elimination of pollinators by the Argentine ant (*Iridomyrmex humilis*)

This ant species is capable of reducing or eliminating native pollinators wherever it invades on Haleakala Volcano (Cole *et al.* 1992). As of 1994, the invasion had descended from Kalahaku on the rim of Haleakala Crater to the crater floor very near the Holua population of *Schiedea haleakalensis.*

4) Feral ungulates

Although feral goats have been removed from Haleakala National Park by a program of active management and are no longer an immediate threat to native plant species within the park, the potential for the ingress and reestablishment of goats exists. Maintenance of a goat-free situation requires continuation of an active management program, which requires substantial sustained commitment by Haleakala National Park and funding for fence maintenance and goat removal.

5) Fire

The possibility of fire is a threat to the existence of *Schiedea haleakalensis*; a single fire could affect a significant portion of the population of *Schiedea haleakalensis* (A.C. Medeiros, personal communication 1990).

g. Conservation

Exclusion of feral goats from Haleakala National Park required a major effort by the National Park Service. Without that important step, no serious possibility would exist for the recovery of *Schiedea haleakalensis*. *Schiedea haleakalensis* is not being propagated at any of the collections surveyed by Mehrhoff (1992). However, Dr. Stephen Weller, who is cultivating taxa of the genus *Schiedea* in a greenhouse at Irvine, California, for studies of breeding systems, was able to obtain three seeds of *Schiedea haleakalensis* during a trip into Haleakala Crater in July 1991. By January 1992, three individuals of this taxon were growing in his greenhouse. Progeny were also obtained later from seeds from these three individuals. Weller finds that the species is very easy to grow (S. Weller, personal communication 1993).

h. Needed Recovery Actions

1) Maintain goat-free status of Haleakala National Park.

One of the benefits of goat control in the Park is that the increase of biomass (which will continue over many decades following removal of feral goats) may increase the availability of moister, semi-shaded microsites for germination and increase the numbers of generalist native insects, such as flies, moths and bees, which can act as pollinators for this pollinator-dependent species.

2) Monitor status and threats to the three known populations of *Schiedea haleakalensis*.

This work presents practical difficulties because of the location of extant populations on sheer or even underhung rock faces with few relief features. Access to *Schiedea haleakalensis* populations using technical rock-climbing equipment appears feasible but has not yet been attempted. When using ropes in monitoring, care must be taken not to damage cliff vegetation.

3) Prevent the Argentine ant from reaching populations of *Schiedea haleakalensis*.

21. *Tetramolopium capillare* (Gaud.) St. John
(Hawaiian name: pamakani) Recovery Priority # - 2

a. Description

Appendix D contains a line drawing of *Tetramolopium capillare*.

Tetramolopium capillare is a slender, low-growing or sprawling shrub in the aster family (Asteraceae). Stems are 50-80 centimeters (19.7-31.5 inches) long and densely glandular when young. The leaves are slender (10-25 x 0.3-0.4 millimeters [0.4-1 x 0.01-.02 inch]) with pointed tips. The leaves are involute—that is, the leaf edges strongly roll toward the top surface of the leaf. The leaves, attached directly to the main stem of the plant, are firm and resistant to signs of wilting. The leaves are hairless or with small hairs near the base. Glandular flower heads occur singly on stalks and measure 7-10 millimeters (0.3-0.4 inches) in diameter with 30-50 petal-like white, 3.5-4.3 millimeter (0.1-0.2 inch) ray florets and 15-25 red-tinged greenish-yellow 3.6 millimeter (0.1 inch) disk florets; the bases of the heads are covered with 45-50 small grasslike appendages (bracts). The dry fruits (achenes) are under 3 millimeters (0.1 inches) long and under 1 millimeter (0.04 inch) wide.

This taxon can be readily distinguished from the apparently related *Tetramolopium remyi* by its shorter flower stalk, smaller heads, and lax or sprawling habit (Wagner *et al.* 1990).

b. Taxonomy

Tetramolopium capillare was described by Charles Gaudichaud-Beaupré in 1830 as *Senecio capillare*. In an analysis of this species, St. John (1965) placed it in the genus *Tetramolopium*, hence *T. capillare* (Gaud.) St.John, its currently accepted name. However, St. John (1974) erected a new endemic genus *Luteidiscus*, consisting of three species, and including *Tetramolopium capillare* as *Luteidiscus capillare* (Gaud.) St. John. In a recent review of the Hawaiian representatives of the genus

Tetramolopium (Lowrey in Wagner *et al.* 1990), the genus *Luteidiscus* St. John was not accepted and was considered a synonym within a broader interpretation of the genus *Tetramolopium*.

The involute leaves, glandular pubescence, and intermediate branching pattern indicate a close relationship to *Tetramolopium remyi*. On Maui, the known historical ranges of *Tetramolopium capillare* and *T. remyi* overlap. Despite the close relationship with *Tetramolopium remyi*, *T. capillare* is readily distinguished by its shorter peduncle, smaller heads, and lax or sprawling habit (Wagner *et al.* 1990).

The genus *Tetramolopium* consists of about 36 species restricted to New Guinea, the Cook Islands (Mitiaro Island), and the Hawaiian Islands (Lowrey in Wagner *et al.* 1990). Of these, about 25 species are endemic to high mountains of New Guinea, 10 species are endemic to primarily coastal, leeward, and high-elevation sites of the Hawaiian Islands, and a single indigenous species occurs in coastal habitats of both the Cook and Hawaiian Islands (*T. sylvae* Lowrey). According to Lowrey in Wagner *et al.* (1990), *T. capillare* is a member of the section *Tetramolopium*, which consists of six Hawaiian endemic species, primarily of coastal and xeric leeward ecosystems. The specific epithet *capillare* means "of hair" in Latin.

c. Current and Historic Range and Population Status

Regarding *Tetramolopium capillare*, Lowrey in Wagner *et al.* (1990) states, "known only from dry forest and shrubland among rocks in the foothills, West Maui from Lahainaluna to Wailuku. The species was last collected in 1955 (St. John 25604 BISH) from the Lahainaluna area of West Maui." Lowrey in Wagner *et al.* (1990) considered *Tetramolopium capillare* probably extinct.

A single individual was subsequently found by A.C. Medeiros at Halepohaku, West Maui. Steve Perlman and Ken Wood of NTBG revisted this area in 1991 and found eight individuals growing on Ulaula and one individual on Koai. In 1993, Perlman, Wood, and Robert Hobdy of Maui DOFAW located *Tetramolopium capillare* on two cliffs in Kauaula Valley, West Maui. There were approximately 25 plants on one cliff and 75-100 plants on the other. These two cliffs are separated by about one-third mile (S. Perlman and R. Hobdy, personal communications 1997). Thus, *Tetramolopium capillare* is currently known only from Halepohaku and Kauaula Valley, West Maui, with fewer than 200 individuals divided among 2-4 populations.

d. Life History

No details are known.

e. Habitat Description

Virtually no field notes were made regarding the ecology of this species by early collectors. Presumably, the species grew in dryland forest and shrubland of lowland, leeward West Maui. Associated species within the presumed potential habitat of this species include *Metrosideros polymorpha, Styphelia tameiameiae, Dodonaea viscosa, Machaerina angustifolia, Gahnia gahniiformis, Dubautia scabra, Lysimachia remyi, Deschampsia nubigena, Bidens menziesii, Lipochaeta lavarum, Heteropogon contortus, Dubautia linearis, Myoporum sandwicensis, Achyranthes splendens, Argemone glauca,* and *Waltheria indica* (HPCC 1994). Associated alien species include *Leucaena leucocephala, Conyza, Buddleia asiatica, Prosopis pallida,* and *Rhynchetrum repens* (HPCC 1994).

f. Reasons for Decline and Current Threats

Degraded by grazing, wildland fires, and alien plant invasions, the original vegetation of dryland forest and shrubland of lowland, leeward West Maui was lost nearly without documentation by the early 1900s.

Currently, the main threats to *Tetramolopium capillare* include:

1) Alien plants

Non-native plants threatening this species include *Leucaena leucocephala, Conyza, Buddleia asiatica, Prosopis pallida,* and *Rhynchetrum repens* (HPCC 1994).

2) Fire

Fire is a continuing threat to this species and its habitat.

3) Small population size in a single location

Because this species occurs at such low population levels and in such a restricted area, a single severe environmental disturbance could result in its extinction.

g. Conservation

In 1992, Steve Perlman and Ken Wood collected seeds from the Koai individual. The seeds were planted and germinated but later died (S. Perlman, personal communication 1997).

h. Needed Recovery Action

Use seed from existing (and any additionally discovered) populations to outplant into protected areas on West Maui, such as at Lihau or Manawainui Plant Sanctuary, providing necessary management to maximize chances of successful establishment and long-term survival.

E. Recovery Strategy

Recovery of these plants, as detailed in the following step-down narrative, begins with protecting and managing their current habitats. Current threats to the plants are addressed through fencing and/or hunting to control ungulates; control of alien plants; protection from fire; control of rodents, insects and disease; protection from human disturbance; collection, storage and maintenance of genetic material; and a comprehensive monitoring program, including searching for new populations, as appropriate. A research program is recommended to study each taxon's growth and reproductive viability, reproductive strategy and pollinators, possible pests and diseases, and determine the parameters of viable populations. The research results will be used to improve management practices.

A program is needed to augment very small populations and re-establish new populations within the historical ranges of the species. This program would include 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.

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

RECOVERY

A. Objectives

Objectives for stabilizing, downlisting, and delisting are provided for the Maui plant cluster taxa. The order of tasks listed in the step-down outline and narrative does not necessarily designate the order in which these 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 neighboring populations that the two 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.

The long-lived perennials in this plan are: *Alectryon macrococcus, Geranium arboreum, Geranium multiflorum, Melicope adscendens, Melicope balloui, Melicope mucronulata,* and *Melicope ovalis.*

The short-lived perennials in this plan are: *Acaena exigua, Bidens micrantha* ssp. *kalealaha, Clermontia oblongifolia, Cyanea lobata, Cyanea mceldowneyi, Hedyotis coriacea, Huperzia mannii, Lipochaeta kamolensis, Lysimachia lydgatei, Remya mauiensis, Scaevola coriacea, Schiedea haleakalensis* and *Tetramolopium capillare. Argyroxiphium sandwicense* ssp. *macrocephalum* does not fit into either of these categories due to its unique life history.

Because we have only limited knowledge of the life history of each of these taxa (except *Argyroxiphium sandwicense* ssp. *macrocephalum*) with respect to specific requirements for their short-term and long-term survival, only tentative criteria for stabilizing, downlisting, and delisting are established here. 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 the 20 endangered Maui cluster taxa so that more meaningful recovery objectives can be quantified.

Interim Objectives and Criteria for the 20 Endangered Taxa

The interim objective is to stabilize all existing populations of the Maui taxa. 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 Maui and, if possible, at least one other island 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 and a minimum of 50 mature individuals per population for short-lived perennials.

Downlisting Objective and Criteria for the 20 Endangered Taxa

For downlisting, a total of five to seven populations of each taxon should be documented on Maui and at least one other island 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, and a minimum of 300 mature individuals per population for short-lived perennials. Each population should persist at this level for a minimum of five consecutive years before downlisting is considered.

Delisting Objective for the 20 Endangered Taxa

For delisting, a total of 8 to 10 populations of each taxon should be documented on Maui and at least one other island where they now occur or occurred historically. As with downlisting, there may be 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 likely to

become an endangered species within the foreseeable future throughout all or a significant portion 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 and a minimum of 300 mature individuals per population for short-lived perennials. Each population should persist at this level for a minimum of five consecutive years.

Delisting Objective for *Argyroxiphium sandwicense* ssp. *macrocephalum*

Recommended guidelines for delisting of this taxon differ from the general guidelines given above because this taxon has probably never had more than a single population. Delisting of this taxon would be appropriate if the threat to its pollinators from the alien Argentine ant is controlled through management action, no other threat of comparable magnitude arises during that time, and the single population continues to exceed 50,000 individuals.

These recovery objectives may be refined and this recovery plan revised as more is learned about the life history of the taxa and population modeling is conducted.

B. Stepdown Outline

1 Protect current populations, manage threats and monitor.

11. Provide long-term protection for existing populations.

111. Identify and map all extant populations.

1111. Map known locations.

1112. Search for additional populations and add new locations to species distribution maps.

112. Identify areas for preservation (i.e., management units).

113. Provide long-term protection for those areas not already afforded legal protection.

12. Manage threats to current populations.

121. Develop threat management plans.

122. Implement threat management plans.

1221. Control feral ungulates.

12211. Determine fencing strategy.

12212. Construct and maintain fencing.

12213. Remove ungulates within fenced areas.

12214. Monitor fenced areas for ungulate damage and effects on weeds.

1222. Conduct essential alien plant control.

12221. Determine effective control methods.

12222. Map alien vegetation.

12223. Implement weed control.

12224. Prevent introduction of new alien plant species to Hawaii

1223. Develop and implement fire protection plans.

1224. Control other introduced animals.

12241. Determine control methods for, and control rodents.

12242. Determine control methods for, and control slugs.

12243. Determine control methods for, and control black twig borer and other damage-causing insects.

1225. Control disease, if necessary.

1226. Ensure availability of pollination vectors, if necessary.

1227. Protect areas from direct threats from humans.

12271. Educate the public.

12272. Post signs, as appropriate.

12273. Control public access to sensitive areas.

1228 Maintain genetic stock *ex situ*.

1229. Control other threats, as necessary.

13. Monitor status of wild populations.

2. Conduct essential research.

21. Collect diagnostic data on crucial associated ecosystem components.

22. Study various aspects of growth.

23. Study reproductive viability.

24. Determine parameters of viable populations.

3. Expand existing wild populations.

31. Develop plans for expansion of populations when necessary.

311. Determine optimum propagation methods.

312. Determine appropriate augmentation methods.

32. Propagate *ex situ*.

33. Prepare sites.

34. Plant.

35. Monitor and maintain new individuals.

4. Reestablish wild populations within the historic range.

41. Develop specific plans for reestablishment.

411. Identify reestablishment sites on Maui.

412. Identify reestablishment sites on other islands.

42. Implement reestablishment plans.

421. Protect reestablishment sites.

422. Manage reestablishment sites.

423. Plant.

424. Monitor and maintain new populations.

5. Validate recovery objectives.

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

52. Refine/revise downlisting and delisting criteria.

C. Stepdown Narrative

1. Protect current populations, manage threats and monitor.

Given the degraded nature of the habitat of many species in the Maui plant cluster, their precariously low numbers, and the severity of the threats acting upon them, the highest priority actions to be carried out immediately for these taxa must be aimed at protecting those individuals and populations that currently exist and managing their habitat to control the threats affecting their survival. Protection and management are most urgent for those nine taxa nearest extinction: *Acaena exigua, Alectryon macrococcus* var. *auwahiensis, Clermontia oblongifolia* var. *mauiensis, Cyanea lobata, Melicope adscendens, Melicope mucronulata, Hedyotis coriacea, Remya mauiensis,* and *Tetramolopium capillare*. A monitoring program to track the status of the populations and to assess the effectiveness of threat management will also be essential.

11. Provide long-term protection for existing populations.

Habitat of the Maui cluster taxa that is not currently afforded long term protection from threats, such as development, agriculture, and maintenance of alien ungulates for hunting programs, should be identified and protected.

111. Identify and map all extant wild populations.

Protection of the extant populations will involve locating all extant individuals, mapping their precise locations, and providing this information to land managers.

1111. Map known locations.

This task has already been initiated. Maps exist for rare plants on TNCH preserves, Ulupalakua Ranch and some Haleakala National Park and DOFAW lands. Mapping should be completed for the remaining known but unmapped Maui cluster taxa locations. Protection status should be noted for each map location.

1112. Search for additional populations and add new locations to species distribution maps.

Surveys of all reported and possible occurrences of each taxon should be conducted. Occurrence data, including presence 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. Specific

search areas are detailed in the species accounts for *Acaena exigua, Cyanea lobata, Bidens micrantha* ssp. *kalealaha, Clermontia oblongifolia* ssp. *mauiensis, Cyanea mceldowneyi, Hedyotis coriacea, Huperzia mannii, Melicope adscendens, Melicope balloui, Melicope mucronulata* and *Melicope ovalis.*

112. Identify areas for preservation (i.e., management units).

Areas to be chosen for preservation should, ideally, contain multiple populations of multiple species that can be managed under a single, coordinated, management plan. These sites should include areas adequate for buffer zones and fire breaks and for expansion of existing populations and establishment of new populations when necessary. Similar areas should be designated to include new populations of any Maui cluster taxa found after the initial areas are chosen. The Hawaii and Pacific Plant Recovery Coordinating Committee is presently in the process of identifying essential habitat areas for the taxa contained in this plan, from which management units may later be delineated. Candidate species and species of concern, as well as listed plant taxa, should be included in these management units.

113. Provide long-term protection for those areas not already afforded legal protection.

Much of the habitat for the 21 taxa included in this plan receives some degree of protection. A large proportion is owned by the State of Hawaii. The State has shown its commitment to protecting rare plant taxa on Maui by constructing exclosures around many rare plant taxa, and establishing sanctuaries, such as Manawainui Plant Sanctuary. By "inreach" to other State agencies, DOFAW should ensure that all departments within the State that are responsible for activities on these lands, such as land zoning, development projects, forestry projects, recreational programs, etc., are made aware of the presence of these listed plant taxa. In addition, the State should take steps to establish procedures to ensure that all State activities contemplated in the area are reviewed with respect to their potential impact on the listed plant taxa, with appropriate measures taken to minimize or preclude all negative impacts.

Federal lands important to the endangered taxa of the Maui cluster are managed by the Department of Defense and Haleakala National Park. Park lands are already protected and managed to benefit endangered species, and the Park is committed to continuing protection and management programs. Much progress has already been made towards protecting threatened and endangered plants on Department of Defense lands, and this work should continue.

The remaining habitat is owned by TNCH, Maui Land & Pineapple, Ulupalakua Ranch, Haleakala Ranch, Kaupo Ranch, C. Brewer & Co., Amfac/JMB Hawaii, Kamehameha Schools/Bishop Estate, Campbell Estate, Alexander and Baldwin, Inc., the County of Maui, and various individuals. Many of these landowners have already taken significant steps toward

protection of endangered plants on their lands, and every effort should be made by DOFAW and/or the USFWS to assist the landowners, as necessary, to continue the development and implementation of long-term management plans for these lands.

Habitat of the Maui cluster taxa that is not currently afforded long term protection from threats such as development, agriculture, and maintenance of alien ungulates for hunting programs, should be identified and protected. To ensure maximum protection for the Maui cluster plants, it is essential to develop long-term management agreements that identify specific conservation efforts and promote cooperation among landowners. Long-term management agreements should be arranged for as much habitat as possible for each taxon.

12. Manage threats to current populations.

Management of protected areas to reduce and/or eliminate threats to the Maui cluster taxa is essential to the survival and recovery of these taxa.

121. Develop threat management plans.

Threat management plans should be developed for each protected area and carried out in a cooperative manner, with every attempt made to enter into partnerships with landowners on whose lands the plants may occur and whose lands lie adjacent to management units. Management plans should be as all-encompassing as possible, incorporating several protected areas into a single overall plan for restoration and management of the habitat on Maui of the 21 taxa identified in this recovery plan, along with other native components of the forest. Where these 21 taxa occur on other islands, their needs should be addressed in management plans written for those locally protected areas. Similarly, the needs of plant taxa addressed in other recovery plans that also occur on Maui should be incorporated into the management plans addressed here. A summary of associated listed species and the recovery plans in which they are addressed is presented in Appendix E.

These management plans should be tailored to fit the unique needs of the areas covered, and may include some or all of the tasks below as well as others that become necessary as more is learned about the areas and species. Among the actions that must be included in all, or the majority of, the threat management plans for these 21 taxa are protection from: grazing and trampling by feral ungulates; competition from alien plants; and fire. Other actions that may be specific to certain taxa and management units only are: protection from other introduced species, such as insects and rodents, and protection from disease.

122. Implement threat management plans.

Once threat management plans have been developed, implementation should proceed.

1221. Control feral ungulates.

The numbers of goats, pigs, and other feral ungulates in the forests of Hawaii are extensive. Controlling these ungulates to the point where they are no longer impacting native vegetation is absolutely imperative. Most of the taxa included in this plan cannot afford to wait many years for protection from ungulates.

Ideally, island-wide programs to eradicate feral ungulates should be instigated and supported on Maui and other islands where these taxa occur. Such removal of feral ungulates would also slow down the degradation of watershed lands. However, public support of hunting is fervent and the likelihood of acceptance of an ungulate eradication program seems remote. Pursuing the establishment of game preserves in Hawaii, where areas are set aside for hunting of game animals, should be a high priority within the State.

The most effective method currently known for providing immediate protection from feral ungulates in Hawaii is fencing of discrete management units. Although this approach is costly, maintenance-intensive, and not altogether foolproof, it does work, as demonstrated at Hawaii Volcanoes and Haleakala National Parks and elsewhere, and is a feasible solution for feral ungulate control in Hawaii. In order to provide stable natural communities in which the Maui cluster taxa can survive and reproduce without constant species-specific management, fencing must ultimately be done on a large scale, protecting whole drainages rather than creating "postage stamp" exclosures.

12211. Determine fencing strategy.

Areas to be fenced should be prioritized, based on the number of species to be protected, severity of threat (grazing pressure) and number of other protected populations. Fencing needs are particularly urgent for those nine taxa nearest extinction: *Acaena exigua, Alectryon macrococcus* var. *auwahiensis, Clermontia oblongifolia* var. *mauiensis, Cyanea lobata, Melicope adscendens, Melicope mucronulata, Hedyotis coriacea, Remya mauiensis*, and *Tetramolopium capillare*.

A combination of short-term, small-scale fencing to protect those populations under immediate threat and longer-term, large-scale fencing may be necessary. However, even "small" exclosures should be sufficiently large to

offset the negative impacts of the actual fencing and fence and site maintenance (e.g., scarification and soil compaction of fence line and adjacent area). As a general guideline, an absolute minimum-sized exclosure should have its perimeter at least 50 meters (160 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, hopefully similar habitat, for potential replanting efforts (and/or native buffer habitat that is resistant to invasion of alien species). To reduce construction and maintenance costs, fences should be constructed along ridge lines and tied into streamcourses at natural barriers (such as the tops of waterfalls) as much as possible.

Some specific areas for fencing are described in the species accounts for *Alectryon macrococcus, Bidens micrantha* ssp. *kalealaha, Cyanea mceldowneyi, Geranium arboreum, Huperzia mannii, Lipochaeta kamolensis, Melicope adscendens* and *Melicope mucronulata* and in Appendix B.

12212. Construct and maintain fencing.

Once the best method and configuration for fencing each site is determined, fencing and maintenance should begin as soon as possible. Fences should be impervious to all ungulates found in the area(s). Ongoing inspection and maintenance of fences are as important as initial fencing in ensuring the continued exclusion of ungulates from the fenced areas.

12213. Remove ungulates within fenced areas.

Once the fences have been completed, it will be necessary to remove ungulates from within the fenced areas. In all cases it is critically important to realize and act on the fact that habitat disturbance by hunting or snaring activities can be highly detrimental to the fragile ecosystems of Hawaii. Direct damage to the environment as well as the possibilities of introduction of seeds of invasive alien plants and the creation of inroads for remaining ungulates and subsequent pathways for invasion of alien plants are of major consequence in such areas. Eradication options would include baited hunting, snaring, and poisoning. Also, hunting from helicopters is a highly effective method for ungulate eradication, particularly in extremely rugged terrain. Hunters and others who will be working in the habitat of the Maui cluster taxa should be apprised of the existence and whereabouts of the plants so that they do not inadvertently damage them.

12214. Monitor fenced areas for ungulate damage and effects on weeds.

Ongoing monitoring for ungulates within the large fenced areas is necessary to ensure their continued absence. Monitoring should also record the possible increased vigor of alien plants, which may be released from grazing pressure, and the effects of this on the Maui cluster taxa.

1222. Conduct essential alien plant control.

One of the most important aspects of habitat management for the Maui cluster taxa is the control of alien weeds. Weed control may become even more important if the removal of ungulates relieves grazing and browsing pressure on some alien plant species. In all cases it is critically important to realize that habitat disturbance by weed removal activities can be highly detrimental to native ecosystems. Steps should always be taken to minimize the effects of: (1) direct damage to the environment; (2) introduction of seeds of invasive alien plants; and (3) the creation of inroads for remaining ungulates and subsequent pathways for invasion of alien plants.

12221. Determine effective control methods.

For each negative effect known or discovered for any introduced species, effective control methods should be ascertained. Before implementation, any control method must be known to have minimal adverse effects on the rare plant taxa whose protection is targeted.

12222. Map alien vegetation.

Periodic mapping of alien vegetation is recommended using various techniques, including direct ground observations and aerial color and/or infrared photographs, to compare with previous maps and photos in order to determine overall changes in alien vegetation patterns where the Maui cluster plants occur. Advantages of aerial techniques include (1) the fact that such techniques are not directly invasive into the sensitive habitat of the endangered plants and that (2) large areas that may otherwise be inaccessible for observation may be monitored. Such mapping would allow changes in distributions and abundance of alien plants to be followed so that appropriate management actions may be taken.

12223. Implement weed control.

Weed control should be aggressively implemented in the vicinity of the Maui cluster taxa, particularly within fenced areas. Control methods may include hand-pulling and possibly local herbicide application in some cases. Weed control should begin immediately for each population, beginning with the immediate vicinity of the existing plants and continuing until control is achieved in the full management site. Follow-up visits to each site are necessary to ensure that weeds are permanently controlled. Weed control must be ongoing and sites should be monitored periodically to determine when additional intervention is necessary.

Control efforts should be supervised by a botanist experienced in safe control methods to ensure that crews do not compact soil, damage root systems or improperly apply herbicides. Also, care should be taken to protect associated native species, as well as the threatened and endangered species, during weed removal.

12224. Prevent introduction of new alien plant species to Hawaii.

Introduction of alien plants and other species to the State of Hawaii and between islands needs to be halted to prevent further threats to the Maui cluster taxa and their habitats. 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.

1223. Develop and implement fire protection plans.

Protection from fire is critical to the survival of the Maui cluster plants, particularly for those in mesic or dry habitats, including *Alectryon macrococcus*, *Bidens micrantha* ssp. *kalealaha*, *Hedyotis coriacea*, *Lipochaeta kamolensis*, *Melicope adscendens*, *Melicope mucronulata* and *Tetramolopium capillare*. Protection must be both local and on a larger scale to prevent fires from spreading to where the plants grow.

Plans to protect each site from fire should be developed and implemented. Public education regarding the prevention and consequences of fires should be undertaken.

"Fire-free" zones should be established, with hunters and other land users informed of the dangers of smoking and open flames in sensitive areas (i.e., any dry areas). Firebreaks with a minimum width of 6 meters (20 feet) should be constructed around fire-prone management areas wherever feasible. This minimum width may not be sufficient to protect populations from fire in especially dry conditions.

1224. Control other introduced animals.

The effects of introduced organisms, including rodents, slugs, harmful insects and disease on the Maui cluster taxa need to be determined in order to better manage the endangered plants and their habitats. Determining and controlling the effects of introduced organisms is likely to be particularly important for *Alectryon macrococcus*, *Melicope ovalis*, *Clermontia oblongifolia* var. *mauiensis*, *Cyanea lobata*, *Cyanea mceldowneyi* and *Schiedea haleakalensis*.

12241. Determine control methods for, and control rodents.

Currently, seed predation by rodents is known to be a threat to *Alectryon macrococcus*, and *Melicope ovalis* and is a probable threat to *Clermontia oblongifolia* var. *mauiensis*, *Cyanea lobata, and Cyanea mceldowneyi*. No currently approved predator control methods can adequately regulate populations of rats in Hawaii (U.S. Forest Service 1992). Research into effective methods of rodent control for all taxa needs to be undertaken, ensuring that control measures do not adversely affect components of the native ecosystem.

12242. Determine control methods for, and control slugs.

For all taxa threatened by slugs, research into effective methods of slug control needs to be undertaken. Currently, slugs are known predators on *Schiedea haleakalensis*. Control slugs as needed to allow survival and reproduction of endangered plant taxa, ensuring that control measures do not adversely affect components of the native ecosystem.

12243. Develop control methods for, and control the black twig borer and other damage-causing insects.

The black twig borer is a definite threat to *Alectryon macrococcus* and a potential threat to all four *Melicope* species covered in this plan. The Argentine ant is a particularly serious threat to *Argyroxiphium sandwicense*

ssp. *macrocephalum* and *Schiedea haleakalensis*. Other insect pests (e.g., the two-spotted leafhopper) may be found that attack these and/or other species. Control methods, which may include pesticide use and/or biocontrol, should be developed and implemented for each of these insects if they are needed.

1225. Control disease, if necessary.

Presently, no Maui cluster taxa are known to be threatened by disease. However, any species- or group-specific disease introduced to these taxa could rapidly result in extinction, given the small, remnant number of individuals and populations of these taxa. Any sign of disease that may be noted in the future during regular monitoring (e.g., wilting, fungal infestations, etc.) should be immediately investigated and controlled, as necessary.

1226. Ensure availability of pollination vectors, if necessary.

Based on the results of research tasks 21 and 23, measures should be established to ensure that pollination vectors remain available to the Maui cluster taxa. If it is discovered that pollination vectors for certain taxa are in fact missing or depleted, necessary measures should be taken to compensate for or improve the situation.

1227. Protect areas from direct threats from humans.

Areas where the Maui cluster taxa grow should be protected as much as possible from hikers, vehicles, and other possibilities of direct human disturbance.

12271. Educate the public.

As a part of protection of areas from human use, public awareness and education regarding these endangered taxa should be fostered. Public education programs should be instigated, perhaps in conjunction with programs designed for other listed species. Other programs of public education regarding rare species and protection of native habitat should also be supported.

12272. Post signs, as appropriate.

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. Such regulations should be strictly enforced by appropriate Federal and State agencies. Based on the specific situation, such signs may not be necessary for some populations that are in remote areas and/or areas not frequently visited. Signs may attract undue attention to these populations thereby exposing them to vandalism. Again, the decision regarding sign placement depends on the circumstances surrounding each population.

12273. Control public access to sensitive areas.

Where possible, roads and/or trails that pass through habitat of the Maui cluster taxa should be rerouted or closed to prevent ready access to these areas. In cases where such action is not feasible, 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 excessive erosion or other damage to the Maui cluster plants or their habitat. If hiking is permitted, it is suggested that hikers must first obtain permission from the appropriate authority. This authority should inform hikers of the presence of sensitive environments and precautions that should be taken in these areas (e.g., cleaning of boots and clothing, the importance of staying on existing trails). The authority is also responsible for monitoring public use and maintenance activities in sensitive areas and for changing management if any adverse effects are noted.

1228. Maintain genetic stock *ex situ*.

Cultivated populations of most Maui cluster taxa should be maintained in order to establish pools of genetic resources to safeguard against loss of the material due to catastrophe in wild populations. Some of this material may also be used in expanding existing populations and establishing new ones (see Tasks 3 and 4). Additionally, the existence of cultivated plants may reduce any demand for field-collected specimens of these rare taxa by providing a propagated source taxa for which there might be a horticultural and/or research demand. It should be noted, however, that cultivation of these plants is not a substitute for their preservation in the wild.

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 from as many individuals as feasible should be collected. Collection methods and quantities of materials collected should be devised so as 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 storage facilities for long-term storage, using the best available techniques for preservation. Seeds in long-term storage should be periodically tested for viability and recollected as necessary.

1229. Control other threats, as necessary.

The need for control of other threats may become apparent as more is learned about the Maui cluster taxa. 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 Maui cluster taxa should be implemented.

13. Monitor status of wild populations.

Wild populations of the Maui cluster taxa should be monitored, at a minimum, annually, to ensure that current information is available regarding the status of each taxon and the effectiveness of management techniques. A detailed monitoring plan should be designed and implemented for each population site or management unit (Task 112). Permanent plots should be set up and noted on site maps (Task 1111) to establish baseline information on population size and local distribution, as well as the occurrence of other species in the vicinity. Individual plants may also be carefully tagged as appropriate for monitoring purposes. Data collection should include number, size class, condition and general location of all Federally listed (and, ideally, other rare) individuals, and any other relevant observations (such as habitat changes, indications of predation or disease, flowering, seed set, etc.). If possible, monitoring should be timed to coincide with a biologically relevant life history event (e.g., seed set or germination). Plots should be set up to allow point- and/or line-intercept monitoring methods as appropriate for each situation.

2. Conduct essential research.

Research into various aspects of the life history, habitat, pollinators, reproductive biology, symbionts, etc. must be carried out to better understand the requirements for perpetuation of these plants. Research on associated ecosystems may reveal subtle interactions essential to the taxa and the ecosystems they occupy. The results of this research should be evaluated and incorporated into the management process and development of scientifically credible recovery targets.

21. Collect diagnostic data on crucial associated ecosystem components.

Within each management area, the composition of the flora and fauna (invertebrate, bird, and other) should be established in an attempt to gain an understanding of any relationships between these

organisms and the Maui cluster plants and to provide large areas of habitat in which these taxa may survive and reproduce without constant species-specific management. The information gained from this effort will also be of great value in selecting potential reintroduction sites.

22. Study various aspects of growth.

For taxa with apparent problems in growth or vigor, aspects of growth should 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.

23. Study reproductive viability.

Each taxon should be initially studied to determine seed set, seed germination and seedling survival. Studies can be discontinued on any taxon that is found to not have problems with these components. Any problems noted in these initial studies (e.g., low seed set) would require further investigation to determine the cause of the problem. Studies should be cross-referenced with others that may be ongoing (e.g., seed predation by rodents). Study of pollination vectors is particularly important for *Cyanea mceldowneyi, Geranium arboreum* and *Hedyotis coriacea.*

24. Determine parameters of viable populations.

Parameters of viable populations need to be established to develop population models to validate criteria for downlisting or delisting (Task 5). These parameters include: minimum numbers of individuals and populations needed for long-term survival; demographics; longevity; minimum range needed for long-term survival; genetic relationships and susceptibility to inbreeding depression; and dispersal potential.

3. Expand existing wild populations.

It is hoped that by eliminating current threats through management, populations of the Maui cluster taxa will expand naturally. However, in certain special instances, wild populations of the Maui cluster taxa may need to be augmented. Augmentation should be done conservatively and only after careful consideration of all factors involved, particularly the threat of introducing detrimental organisms into the wild populations. Augmentation efforts should always be well-documented as to lineage and methods.

31. Develop plans for expansion of populations when necessary.

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 artificially enhanced.

Populations of each taxon should be evaluated and determination made whether they are appropriate for addition of living material. As new occurrences of each taxon are discovered, each new site should be evaluated for potential augmentation, and the result of this analysis indicated in the site management plan. Because of their very low numbers, populations of *Acaena exigua, Alectryon macrococcus, Clermontia oblongifolia* ssp. *mauiensis, Cyanea lobata, Hedyotis coriacea, Lipochaeta kamolensis, Lysimachia lydgatei, Melicope adscendens, Melicope mucronulata, Remya mauiensis, Scaevola coriacea, Schiedea haleakalensis*, and *Tetramolopium capillare* will almost certainly need to be augmented.

Only progeny from plants of the same site/population should be used to augment a population so that the existing local gene pool is not contaminated with genetic material from other origins. The goal of such augmentation is to allow a better chance for populations to survive in areas where they are known to occur naturally. All phases of augmentation operations should be adequately documented.

311. Determine optimum propagation methods.

Several available methods may be used to propagate these taxa. The most effective methods and techniques of propagating each taxon need to be determined. In some cases, detailed studies of temperature and light regimes, soil and nutrient requirements and other factors may be necessary, to maintain the taxa ex situ.

312. Determine appropriate augmentation methods.

Appropriate methods for augmentation of populations will need to be determined, taking into consideration principles for selection of sites and plant materials, site preparation, planting, and monitoring. Such decisions should be conservative and carefully considered.

Direct seeding into the population to be augmented, if it is feasible, should be considered the method of choice. It is more cost-effective and much less labor-intensive to store seeds than to grow and maintain a large supply of individual plants for transplantation. In addition, the risk of introducing greenhouse pests into wild populations is greatly reduced. However, in cases where direct seeding proves unsuccessful, growing and transplanting individual plants may be necessary.

32. Propagate *ex situ*.

Ex situ propagation should be pursued for possible augmentation of current populations and reintroduction into appropriate sites, in the event that direct seeding (Task 312) does not prove

feasible. This task involves producing substantial numbers of individuals for outplanting. *Cultivation of these plants is not a substitute for their preservation in the wild.*

33. Prepare sites.

Each site selected for population expansion must be prepared and protected appropriately, including building exclosures and controlling exotic species therein, as outlined above.

34. Plant.

Before planting, a preliminary site survey to identify appropriate microhabitats should be conducted. The selected material should then be planted. If transplanting already-started plants, care should be taken regarding the matching of soils, 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 be overly dry and weaken or kill the newly transplanted specimen).

35. Monitor and maintain new individuals.

Augmented populations should be monitored carefully. Ongoing maintenance of each site should occur after initial preparation and planting. The same protections and procedures regarding exclosures, ungulate removal, etc., should apply to new sites as have been recommended for existing sites. Any transplants that do not survive should be replaced.

4. Reestablish wild populations within the historic range.

If necessary to meet recovery objectives, populations should be reestablished in areas where they are known to have occurred historically. Ideally, stock for reestablishment would consist of genetically uncontaminated, cultivated materials known to have originated from the historical site. Usually, however, stock that best approximates the original material will be used. The goal of reintroduction is to permanently reestablish viable populations of these taxa in stable and secure conditions for their perpetuation.

For each taxon, appropriateness of reintroduction into wild situations should be assessed. Such reintroductions should be recommended conservatively and only after careful consideration of potential consequences. Genetic purity of populations is a prime concern, as is the possibility of introducing pathogens or alien organisms into natural areas. Reintroduction efforts should always be well-documented as to lineage and methods, and reintroduction sites should be closely monitored.

41. Develop specific plans for reestablishment.

Specific plans should be created for the reestablishment of wild populations when naturally occurring populations are not sufficient to reach recovery objectives. Plans for each taxon should include documentation of all activities and the following general concepts.

The choice of sites should be based on the best information possible, including results of research tasks 21 and 23, to match the site conditions to the requirements of the taxon. Identification of reintroduction sites will require map inspection of potential sites to determine appropriate elevation and aspect, followed by visits to each site to determine availability of appropriate microhabitats, soil types, associated native species, absence (or controllability) of alien species, and other variables.

411. Identify reestablishment sites on Maui.

Unless new populations are discovered, populations must be established for all Maui cluster taxa except *Geranium multiflorum* and *Alectryon macrococcus* var. *macrococcus*, to reach downlisting objectives. Taxa in most immediate need of population establishment to prevent extinction include *Acaena exigua* (if found), *Alectryon macrococcus* var. *auwahiensis*, *Clermontia oblongifolia* ssp. *mauiensis*, *Cyanea lobata*, *Hedyotis coriacea*, *Melicope adscendens*, *Melicope mucronulata*, and *Remya mauiensis*.

412. Identify reestablishment sites on other islands.

Unless new populations are discovered, reestablishment sites on other islands within the species' historical range for *Acaena exigua*, *Alectryon macrococcus*, *Hedyotis coriacea*, *Huperzia mannii*, *Melicope mucronulata* and *Scaevola coriacea* may have to be identified to reach downlisting objectives.

42. Implement reestablishment plans.

Plans prepared for the reestablishment of populations should be implemented. As with expanded populations, material for population establishment should be carefully chosen to best approximate the original material that did or might have existed in the site previously. Extreme caution should be taken 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.

421. Protect reestablishment sites.

If the sites chosen in task 41 are outside the management units already established in task 112, they should be protected and managed as discussed in tasks 113 and 12 (above).

422. Manage reestablishment sites.

Each selected site must be prepared appropriately, including the building of exclosures and exotic species control therein, as necessary.

423. Plant.

The selected material should then be planted. 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 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).

424. Monitor and maintain new populations.

Newly established populations should be monitored and maintained regularly. The same protections and procedures regarding exclosures, feral animal removal, etc., as have been recommended for existing sites should also apply to new sites.

5. Validate recovery objectives.

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

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

For each of the Maui cluster taxa, a determination of the number of populations needed for long-term survival should be made. The number of individuals needed in each population to ensure the long-term maintenance of genetic diversity must also be determined for each taxon. These determinations would be accomplished based on monitoring of wild, expanded and newly established populations over a number of years. These data could then be used to construct a population model for each taxon. Parameters to be considered include demographics, longevity, susceptibility to inbreeding depression, and dispersal potential.

52. Refine/revise downlisting and delisting criteria.

Recovery criteria for each of the Maui cluster taxa should be periodically revised to reflect scientific information gathered during recovery efforts (e.g., data on viable population sizes, longevity, etc.). Until additional sound information is available, the criteria presented in this recovery plan should be used as the basis for downlisting and delisting.

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IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated cost for the Maui plant cluster 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, duration 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 species, 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

FWS-PIE-		U.S. Fish and Wildlife Service, Pacific Islands Ecoregion, Honolulu, Hawaii
DLNR	-	Hawaii Department of Land and Natural Resources
BRD	-	Biological Resources Division, U.S. Geological Survey
NPS	-	National Park Service
BOT	-	Various Botancial Gardens (e.g., National Tropical Botanical Garden [NTBG], Lyon Arboretum, Waimea Botanical Garden, etc.).
FWS-LE	-	U.S. Fish and Wildlife Service, Law Enforcement
TNCH	-	The Nature Conservancy of Hawaii
DOD	-	U.S. Department of Defense
MCFD	-	Maui County Fire Department
KCFD	-	Kauai County Fire Department
HCFD	-	Hawaii County Fire Department
HDOA	-	Hawaii Department of Agriculture
ADC	-	U.S. Department of Agriculture, Animal Damage Control
PL	-	Private Landowners
HPPRCC	-	Hawaii and Pacific Plant Recovery Coordinating Commitee

Key to Other Codes Used in the Implementation Schedule

C	-	Task will need to be performed continuously
O	-	Task is ongoing
TBD	-	To Be Determined

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE MAUI PLANT CLUSTER

Priority Number	Task Number	Task Description	Task Duration	Responsible Party	Total Cost FY 2017	Cost Estimates ($1,000's) FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
1	1111	Map known locations	5	*TNCH	15	3	3	3	3	3
				BRD	50	10	10	10	10	10
				DLNR	15	3	3	3	3	3
				FWS-PIE	15	3	3	3	3	3
1	1112	Search for additional populations	5	*DLNR	150	30	30	30	30	30
				FWS-PIE	35	7	7	7	7	7
				BRD	35	7	7	7	7	7
				NPS	35	7	7	7	7	7
				BOT	35	7	7	7	7	7
				PL	35	7	7	7	7	7
1	112	identify areas for preservatio	3	*FWS-PIE	3	1	1	1		
				DLNR	15	5	5	5		
				HPPRCC	3	1	1	1		
1	113	Provide long term security for areas not already afforded legal protection	5	*DLNR	25		5	5	5	5
				FWS-PIE	25		5	5	5	5
				DOD	10		2	2	2	2
				TNCH	10		2	2	2	2
				PL	2.5		0.5	0.5	0.5	0.5
1	12211	Determine fencing strategy	3	* DLNR	75		25	25	25	
				PIE	15		5	5	5	
				TNCH	3		1	1	1	
				NPS	6		2	2	2	
				BRD	6		2	2	2	
				DOD	3		1	1	1	
				PL	3		1	1	1	
1	12212	Construct and maintain fencing	C	* DLNR	1200			100	100	100
				PIE	1200			100	100	100
				NPS	310			25	25	25
				TNCH	140			10	10	10
				DOD	140			10	10	10
				PL	140			10	10	10
1	12213	Remove ungulates from fenced areas	10	* DLNR	600				60	60
				PIE	150				15	15
				NPS	100				10	10
				TNCH	20				2	2
				DOD	20				2	2
				PL	20				2	2
1	12214	Monitor for ungulates in fenced areas	C	* DLNR	180					10
				PIE	180					10
				NPS	90					5
				TNCH	9					0.5
				DOD	9					0.5
				PL	9					0.5
1	12221	Determine alien plant control methods	5	*HDOA	50		10	10	10	10
				DLNR	150		30	30	30	30
				BRD	150		30	30	30	30
				NPS	50		10	10	10	10

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE MAUI PLANT CLUSTER

Priority Number	Task Number	Task Description	Task Duration	Responsible Party	Total Cost FY 2017	Cost Estimates ($1,000's) FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
1	12223	Implement weed control	C	* DLNR	1200			100	100	100
				FWS-PIE	1200			100	100	100
				NPS	350			25	25	25
				TNCH	140			10	10	10
				DOD	140			10	10	10
				PL	70			5	5	5
1	1223	Develop and implement fire protection plans	5	* DLNR	225		25	50	50	50
				FWS-PIE	225		25	50	50	50
				KCFD	32.5		2.5	7.5	7.5	7.5
				MCFD	20.5		2.5	4.5	4.5	4.5
				HCFD	20.5		2.5	4.5	4.5	4.5
				TNCH	20.5		2.5	4.5	4.5	4.5
				NPS	45		5	10	10	10
				DOD	20.5		2.5	4.5	4.5	4.5
				PL	9		1	2	2	2
1	12241	Determine methods and control rodents	C	* DLNR	400		40	50	50	50
				ADC	210		10	10	10	10
				FWS-PIE	275		15	25	25	25
				BRD	280		40	40	40	40
				NPS	100			5	5	5
				TNCH	32			5	5	5
				DOD	32			5	5	5
				PL	32			5	5	5
1	12242	Determine methods and control slugs	C	*HDOA	150		10	15	15	15
				DLNR	150		10	15	15	15
				FWS-PIE	77		5	10	10	10
				BRD	82		10	10	10	10
				NPS	84			1	1	1
				TNCH	10			0.5	0.5	0.5
				PL	10			0.5	0.5	0.5
1	12243	Determine methods and control black twig borer and other insects	C	*HDOA	57		5	5	5	5
				DLNR	138		10	12	12	12
				FWS-PIE	51		7	7	7	7
				BRD	66		10	10	10	10
				NPS	100			5	5	5
				TNCH	10.5		0.5	0.5	0.5	0.5
				DOD	10.5		0.5	0.5	0.5	0.5
				PL	10.5		0.5	0.5	0.5	0.5
1	1225	Control disease, if necessary	TBD	*HDOA	0			TBD		
				DLNR	0			TBD		
				FWS-PIE	0			TBD		
				TNCH	0			TBD		
				NPS	0			TBD		
				DOD	0			TBD		
				PL	0			TBD		
1	1226	Ensure availability of pollinators if necessary	TBD	*DLNR				TBD		
				FWS-PIE				TBD		
				HDOA				TBD		
				TNCH				TBD		
				NPS				TBD		
				DOD				TBD		

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE MAUI PLANT CLUSTER

Priority Number	Task Number	Task Description	Task Duration	Responsible Party	Total Cost FY 2017	Cost Estimates ($1,000's) FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
2	12271	Educate the public	C	* DLNR	132		20	20	20	20
				FWS-PIE	132		20	20	20	20
				NPS	31.5		1.5	1.5	1.5	1.5
				TNCH	10.5		0.5	0.5	0.5	0.5
2	12272	Post signs, as appropriate	C	* DLNR	78		20	20	2	2
				NPS	29		5	5	1	1
				TNCH	19.5		5	5	0.5	0.5
				DOD	19.5		5	5	0.5	0.5
2	12273	Control public access	C	*DLNR	105		5	5	5	5
				NPS	63		3	3	3	3
				DOD	105		5	5	5	5
				FWS-LE	10.5		0.5	0.5	0.5	0.5
1	1228	Maintain genetic stock *ex situ*	O	DLNR	120	10	10	5	5	5
				FWS-PIE	120	10	10	5	5	5
				*BOT	300	50	50	10	10	10
1	1229	Control other threats as necessary	TBD	*DLNR	0	TBD				
				FWS-PIE	0	TBD				
				TNC	0	TBD				
				NPS	0	TBD				
				DOD	0	TBD				
				PL	0	TBD				
1	13	Monitor status of wild population	C	*DLNR	2200	100	100	100	100	100
				NPS	260	50	10	10	10	10
				FWS-PIE	340	90	50	10	10	10
				BRD	220	10	10	10	10	10
				TNCH	110	5	5	5	5	5
				PL	110	5	5	5	5	5
2	12224	Prevent introduction of alien plants to Hawaii	O	*HDOA	660	30	30	30	30	30
				DLNR	220	10	10	10	10	10
NEED 1 (Secure and manage current sites)					17023	461	845	1393	1446	1435.5

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE MAUI PLANT CLUSTER

Priority Number	Task Number	Task Description	Task Duration	Responsible Party	Total Cost FY 2017	Cost Estimates ($1,000's) FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
2	21	Study associated ecosystem components	10	* BRD	500		50	50	50	50
				DLNR	500		50	50	50	50
				FWS-PIE	500		50	50	50	50
2	22	Study growth	5	* BRD	250		50	50	50	50
				DLNR	250		50	50	50	50
				FWS-PIE	250		50	50	50	50
2	23	Study reproductive viability	5	* BRD	250		50	50	50	50
				DLNR	250		50	50	50	50
				FWS-PIE	250		50	50	50	50
2	24	Determine parameters of viable populations	5	* BRD	250		50	50	50	50
				DLNR	250		50	50	50	50
				FWS-PIE	250		50	50	50	50
NEED 2 (Conduct essestial research)					3750	0	600	600	600	600
2	311	Determine propagation methods	O	*BOT	1100	50	50	50	50	50
				DLNR	1100	50	50	50	50	50
				FWS-PIE	220	10	10	10	10	10
2	312	Determine augmentation methods	10	*BOT	375	50	50	50	50	50
				DLNR	700	100	100	100	100	100
				FWS-PIE	350	55	55	55	55	55
2	32	Propagate *ex situ*	O	*BOT	6600	300	300	300	300	300
				DLNR	6600	300	300	300	300	300
				FWS-PIE	1100	50	50	50	50	50
2	33	Prepare sites	5	* DLNR	0			TBD		
				FWS-PIE	0			TBD		
				TNCH	0			TBD		
				NPS	0			TBD		
				DOD	0			TBD		
				PL	0			TBD		
2	34	Plant	5	* DLNR	0				TBD	
				PIE	0				TBD	
				TNCH	0				TBD	
				NPS	0				TBD	
				DOD	0				TBD	
				PL	0				TBD	
2	35	Monitor and maintain new individuals	C	*DLNR	0					TBD
				FWS-PIE	0					TBD
				TNCH	0					TBD
				NPS	0					TBD
				DOD	0					TBD
				PL	0					TBD
NEED 3 (Expand current populations)					18145	965	965	965	965	965

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE MAUI PLANT CLUSTER

Priority Number	Task Number	Task Description	Task Duration	Responsible Party	Total Cost FY 2017	Cost Estimates ($1,000's) FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
2	411	Identify sites for reestablish-ment on Maui	5	* DLNR	125		25	25	25	25
				FWS-PIE	25		5	5	5	5
				BRD	125		25	25	25	25
				NPS	25		5	5	5	5
				HPPRCC	10		2	2	2	2
2	412	Identify sites for reestablish-ment on other islands	5	* DLNR	125		25	25	25	25
				FWS-PIE	25		5	5	5	5
				BRD	125		25	25	25	25
				HPPRCC	25		5	5	5	5
2	421	Protect reestablish-ment sites	2	DLNR	0		TBD			
				FWS-PIE	0		TBD			
2	422	Manage reestablish-ment sites	5	* DLNR	0			TBD		
				FWS-PIE	0			TBD		
				TNCH	0			TBD		
				NPS	0			TBD		
				DOD	0			TBD		
				PL	0			TBD		
2	423	Plant	5	* DLNR	0					TBD
				FWS-PIE	0					TBD
				TNCH	0					TBD
				NPS	0					TBD
				DOD	0					TBD
				PL	0					TBD
2	424	Monitor and maintain new populations	C	*DLNR	0					TBD
				FWS-PIE	0					TBD
				TNCH	0					TBD
				NPS	0					TBD
				DOD	0					TBD
				PL	0					TBD
NEED 4 (Reestablish in former range					610	0	122	122	122	122
3	51	Determine number of populations and individuals needed for lon term survival	3	* BRD	120					
				DLNR	120					
				FWS-PIE	120					
3	52	Refine/revise downlisting and delisting criteria	3	*FWS-PIE	60					TBD
				DLNR	60					TBD
				HPPRCC	1.5					TBD
					0					
NEED 5 (Validate recovery objectives)					481.5	0	0	0	0	0
TOTAL COST					80019	2852	5064	6160	6266	6245

APPENDIX A

INDIVIDUALS WHO PROVIDED INFORMATION DURING PLAN DEVELOPMENT

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APPENDIX B
DRAFT MANAGEMENT PROPOSAL

Sample draft proposal for an integrated cooperative project aimed at recovery of multiple endangered plant taxa and preventing associated taxa from declining to endangered status

Project Title: Conservation of five endangered and six rare dryland tree species of Auwahi district, leeward Haleakala, Hawaiian Islands.

Potential Project Coordinators: Arthur C. Medeiros and Lloyd L. Loope, Biological Resources Division, Maui; Robert Hobdy, DOFAW, Maui

Potential Collaborators: USFWS, Ulupalakua Ranch, Lyon Arboretum, Native Hawaiian Plant Society, Maui DOFAW, Mr. Rene Sylva, Botany Department of University of Hawaii, Haleakala National Park, TNCH, etc.

Project site: Auwahi district, leeward Haleakala, Maui, Hawaiian Islands.

Introduction:

The leeward forests on the southern slopes of Haleakala have long been recognized for their diversity of dryland tree species. Joseph Rock, in his classic 1913 book "Indigenous Trees of the Hawaiian Islands," identified the Auwahi region of Haleakala as one of the most important botanical sites in the islands. Today, despite retaining substantial species diversity, Auwahi is in a state of serious degradation. The most alarming ecological trends are the nearly complete lack of seedling production and the death and senescence of tree-sized individuals.

Potential reasons for the lack of forest regeneration are partially documented by Medeiros, Loope and Holt (1986). They include:

- displacement by alien plants, especially kikuyu grass (*Pennisetum clandestinum*)
- loss of original native understory with resultant changes of ground level climate, i.e. greater aridification and exposure

- seedling herbivory by ungulates
- seed predation by alien animals (rodents and insects)
- seedling herbivory by alien insects
- loss of co-evolved pollinators
- loss of co-evolved seed scarifiers and dispersers
- loss of genetic variability due to catastrophic reduction of numbers of individuals

If meaningful conservation of the remaining dryland forest is to be achieved at Auwahi, it must occur within the next decade, as remaining biological resources are progressively becoming diminished. About a dozen species have fewer than 20 individuals left; some are down to as few as 5 individuals.

Auwahi is one of the most important dryland forests remaining in the islands. It provides the habitat, in some cases, the sole habitat, for a number of proposed and listed endangered dryland trees. The landowner, Ulupalukua Ranch, has willingly cooperated with conservation organizations in protection of the biological diversity of the area, and conservation efforts have begun. The Native Hawaiian Plant Society (NHPS) has constructed nine fenced exclosures to protect small groups of trees. Within these areas, kikuyu grass has been eliminated with herbicide (glyphosate–Roundup®). Though seedlings of native species have appeared, seed banks of many areas are apparently depleted. Conservation efforts must continue intensively and immediately, to prevent the loss of any remaining native dryland forest.

Five target endangered dryland tree species:

1. *Alectryon macrococcus* Radlk. var. *auwahiensis* Linney (9 trees known)
2. *Melicope adscendens* (St. John & Hume) Hartley and Stone (4 trees known)
3. *Melicope knudsenii* (Hillber.) Hartley and Stone (12 trees known)
4. *Santalum freycinetianum* Gaud. var. *lanaiense* Rock (50 trees estimated)
5. *Zanthoxylum hawaiiense* Hillebr. (9 trees known)

A sixth species, *Melicope mucronulata*, could be added as a target species if material from leeward Haleakala were located or a decision were to be made to reintroduce the taxon from material from Molokai.

Six rare target dryland tree species:

1. *Alphitonia ponderosa* Hillebr. (100-200 trees estimated)
2. *Nothocestrum latifolium* Gray (1000-2000 trees estimated)
3. *Ochrosia haleakalae* St. John (100-200 trees estimated)
4. *Pleomele auwahiensis* St. John (~5000 trees estimated)
5. *Pouteria sandwicensis* (Gray) Baehni & Degener (~1000 trees estimated)
6. *Streblus pendulinus* (Endl.) F.V. Muell. (~2000 trees estimated)

Restoration/Research Plan:

I. Locate all individuals of the target Endangered species in the Auwahi district.

Through field surveys and interviews with Maui botanists, locate all remaining individuals in Auwahi. Map distribution using Global Positioning System (GPS) devices, altimeters, and topographic maps. Photograph and evaluate health of each individual.

Objectives: (1) To provide a realistic assessment on the feasibility of conservation of five endangered tree species based on current, comprehensive distributional information. (2) To evaluate individual trees on immediate threats to their survival.

II. Conduct triage-type protection of trees of Endangered species.

Erect small exclosures to protect target taxa from ungulates, control exotic vegetation, conduct tree surgery if needed.

Objective: To provide mitigation for immediate threats.

III. Establish nurse tree forests around native trees in nine small NHPS exclosures where kikuyu grass has been removed.

Restoration of a forest microenvironment may be a prerequisite for successful regeneration of most of the 30-odd tree species of Auwahi. The original forest probably had a semi-closed canopy, a middle story of small trees and large shrubs, and an understory of ferns and other herbs.

"Nurse forests" would be established by supplemental seeding of quick-growing native species in the nine NHPS exclosures. Native species to be used would include: *Alyxia oliviformis* var. *myrtillifolia*, *Chamaesyce celastroides* var. *lorifolia*, *Cocculus lonchophyllus*, *Coprosma foliosa*, *Dodonea viscosa*, *Myoporum sandwicense*, *Myrsine lanaiensis*, *Myrsine lessertiana*, *Osmanthus sandwicensis*, *Osteomeles anthyllidifolia*, *Peperomia leptostachya*, *Sophora chrysophylla*, and *Wikstroemia monticola*. Some rare species, most notably *Cenchrus agrimoniodes*, would probably be used if propagules are available.

Objective: To recreate the moister, semi-shaded microhabitats necessary for seedling germination and establishment.

IV. Intensively propagate target species and outplant into exclosures.

Gather seeds and experiment with germination and establishment techniques for the five endangered and six rare dryland forest tree species. Technology must be developed to facilitate survival of planted tree seedlings, such as holes drilled into lava rocks, shade cloth exclosures, etc.

Objective: To develop techniques that will maximize germination and survival of the five endangered and six rare dryland forest tree species.

APPENDIX C

HISTORIC AND CURRENT RANGES

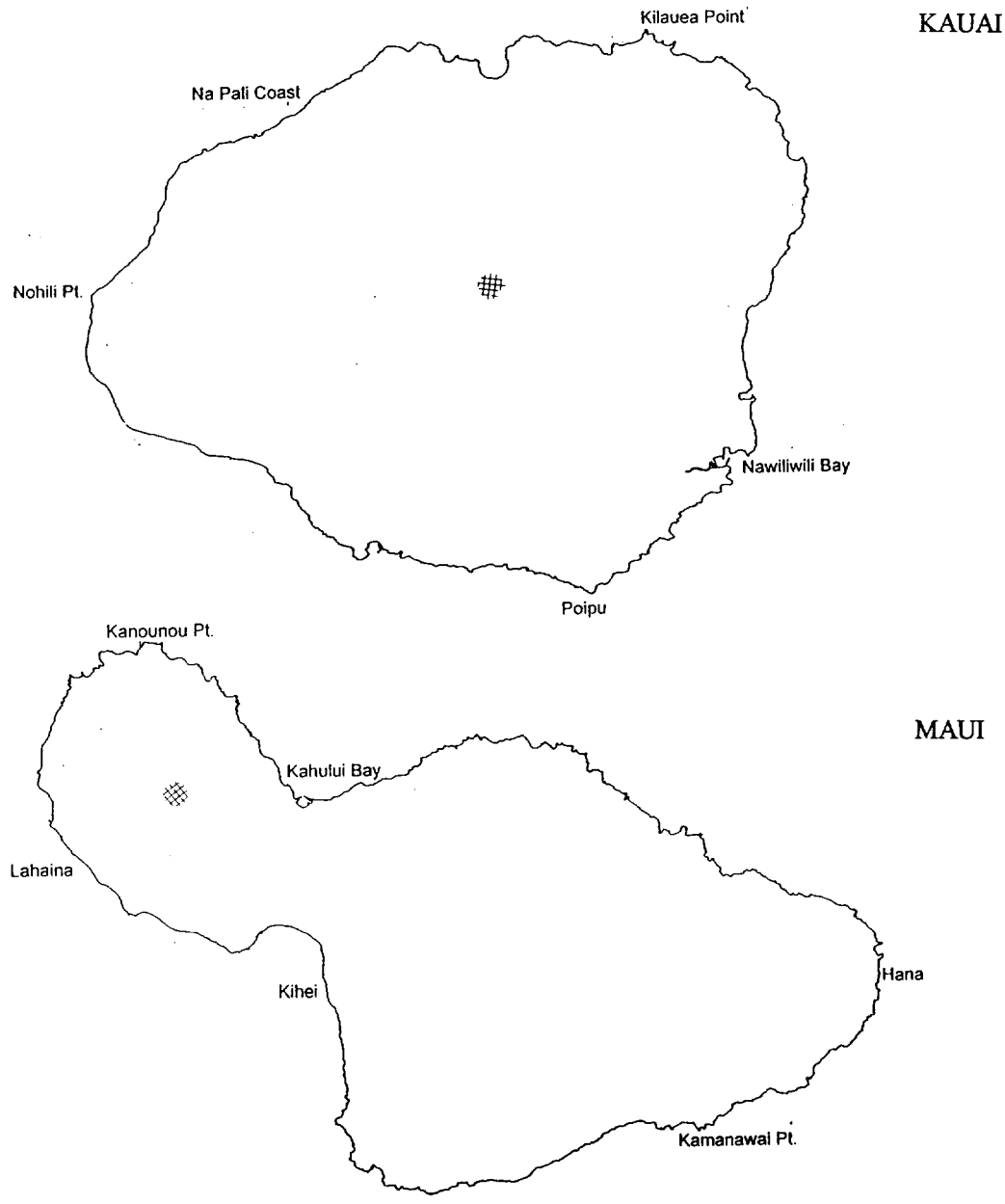


Figure 2. Historic Range of *Acaena exigua* (no extant individuals known).

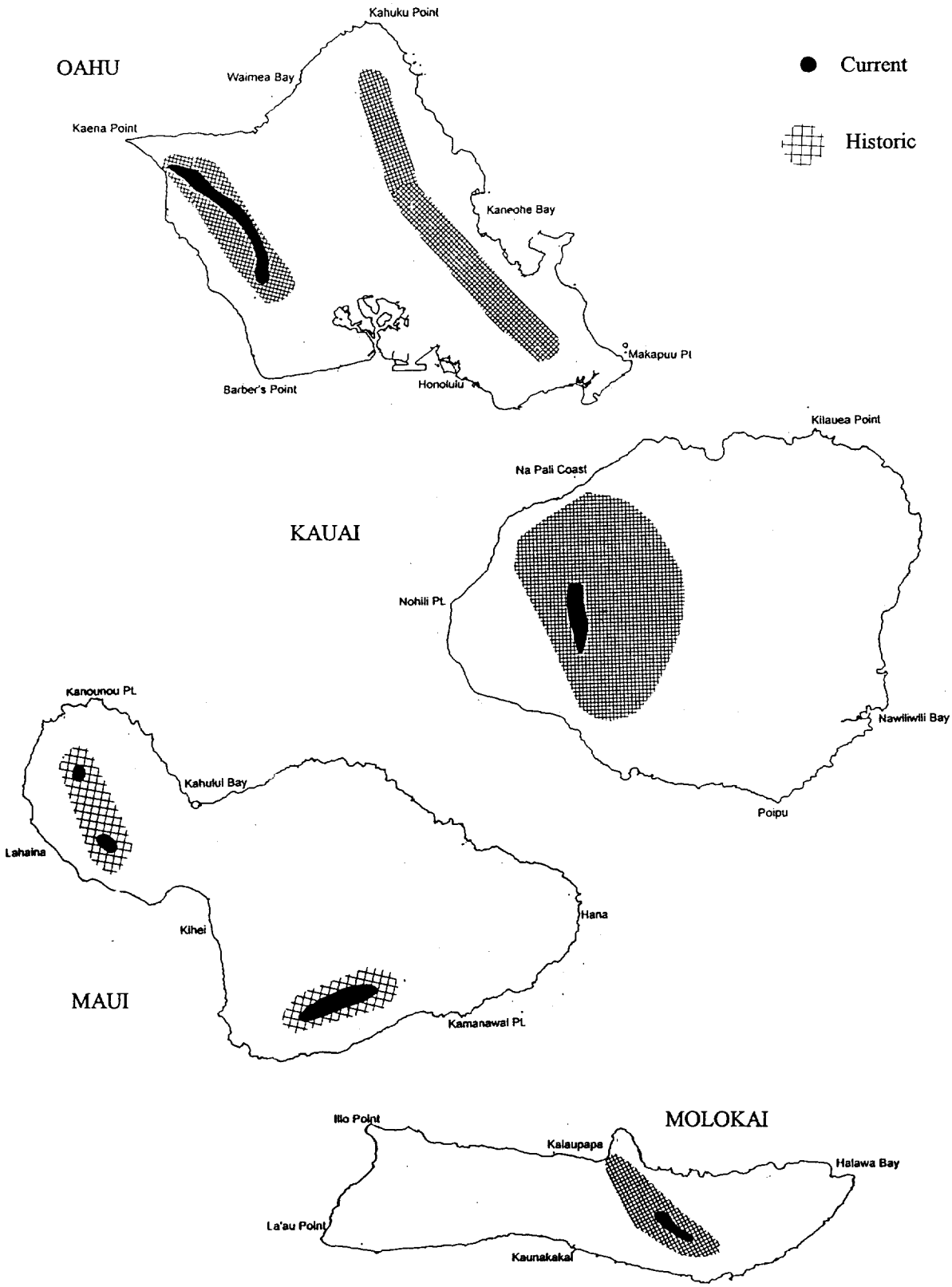


Figure 3. Current and Historic Ranges of *Alectryon macrococcus*.

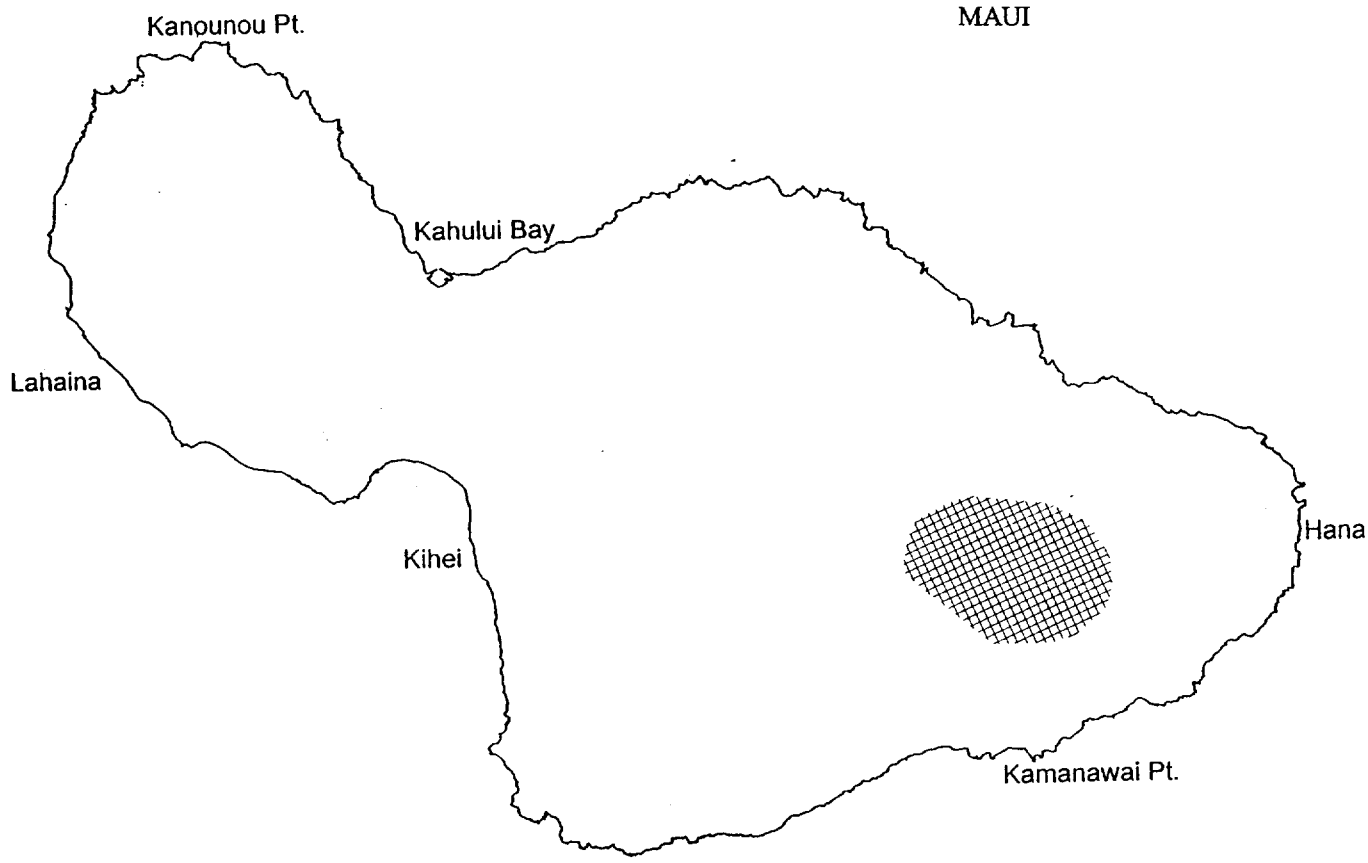


Figure 4. Current (and Historic) Range of *Argyroxiphium sandwicense* ssp. *macrocephalum*.

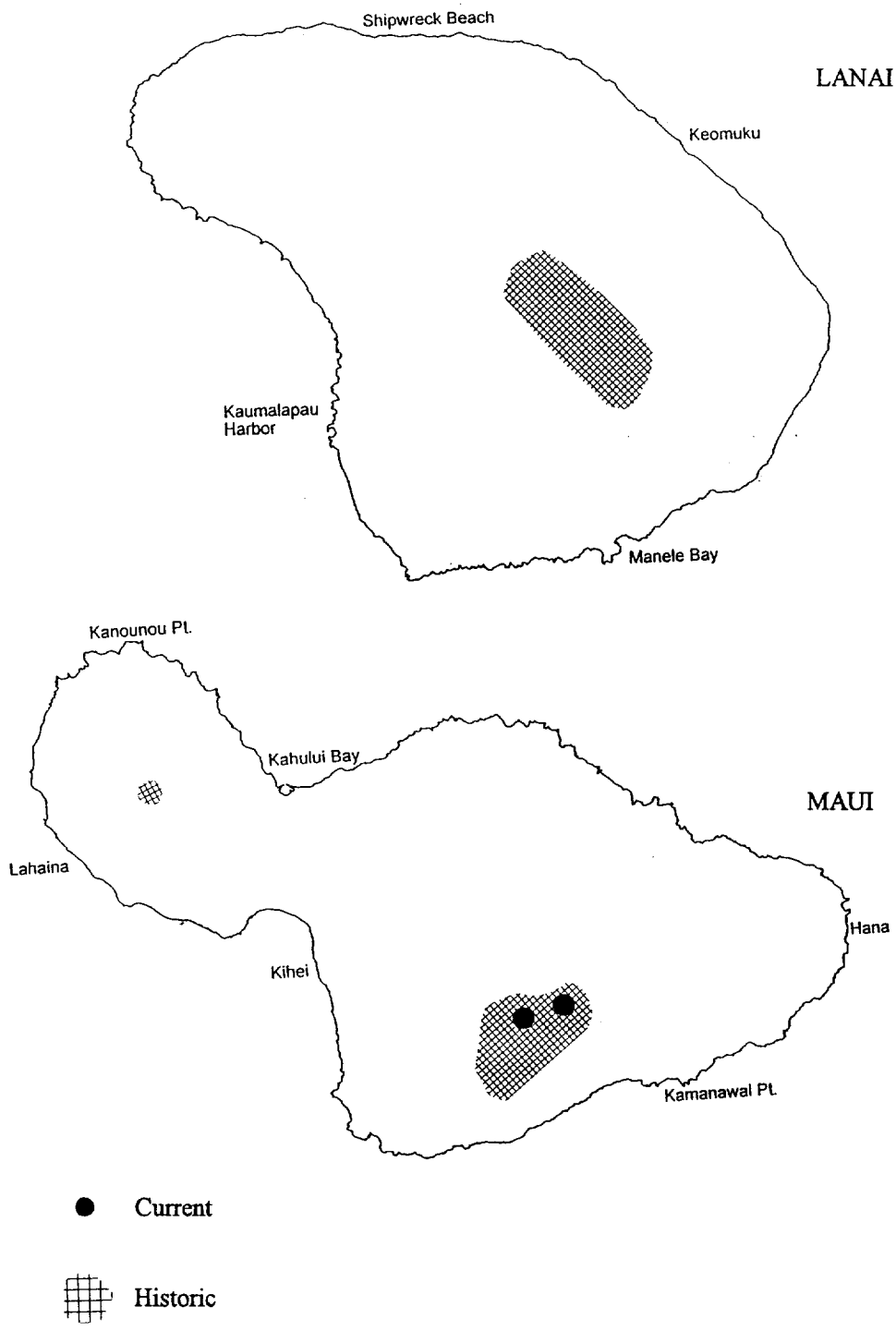


Figure 5. Current and Historic Ranges of *Bidens micrantha* ssp. *kalealaha.*

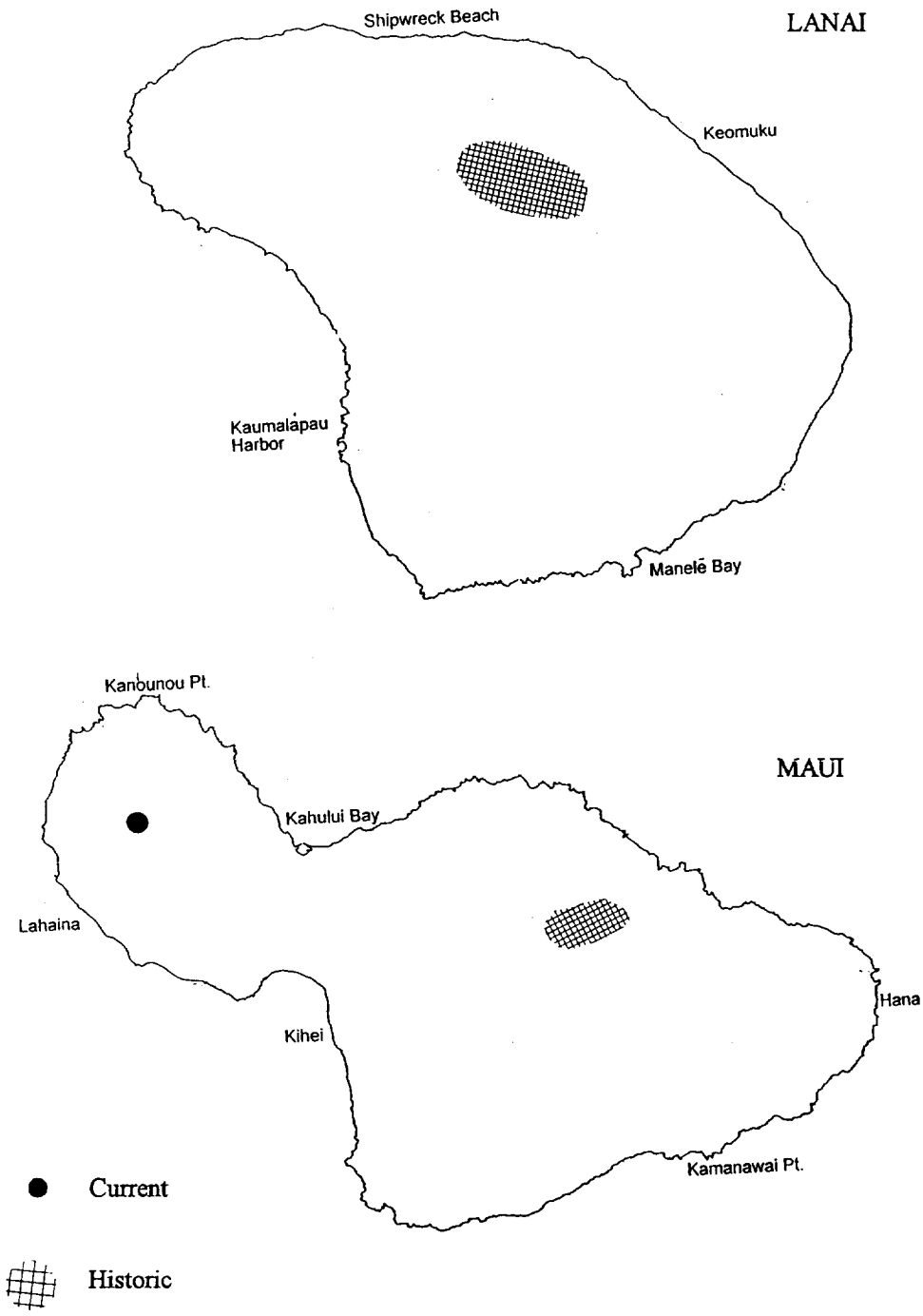


Figure 6. Current and Historic Ranges of *Clermontia oblongifolia* ssp. *mauiensis*.

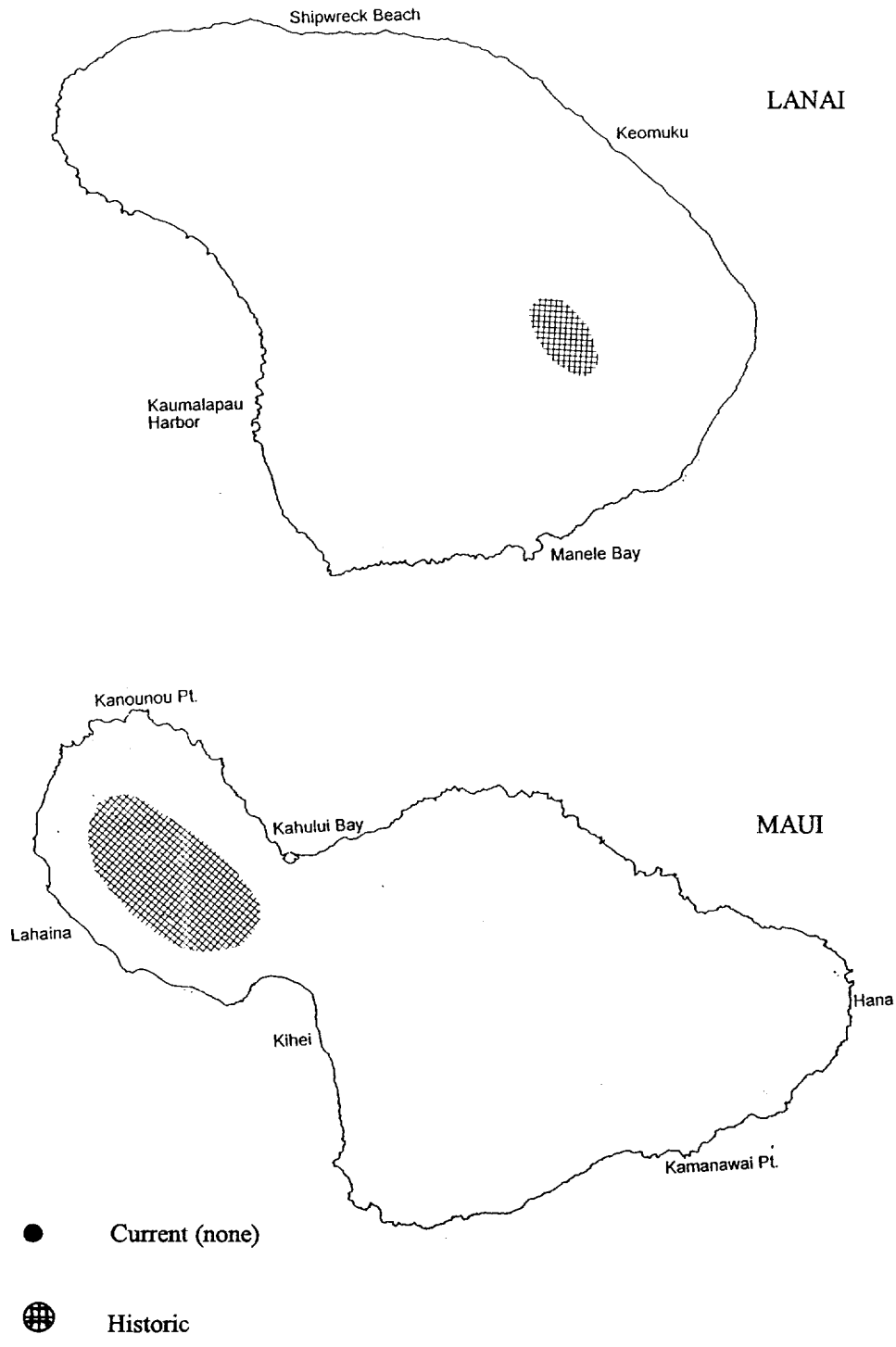


Figure 7. Historic Range of *Cyanea lobata* (no extant individuals are known).

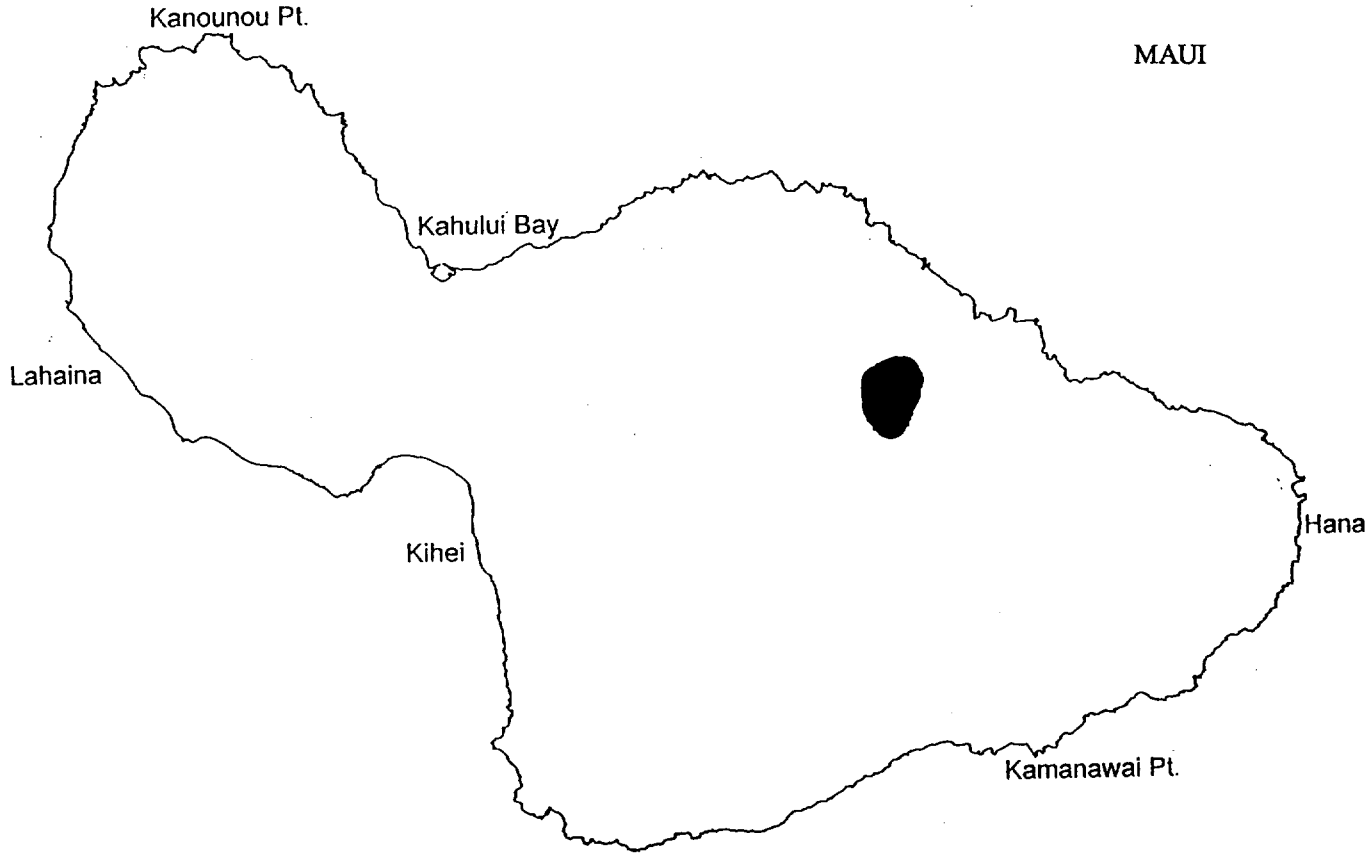


Figure 8. Current and Historic Ranges of *Cyanea mceldowneyi*.

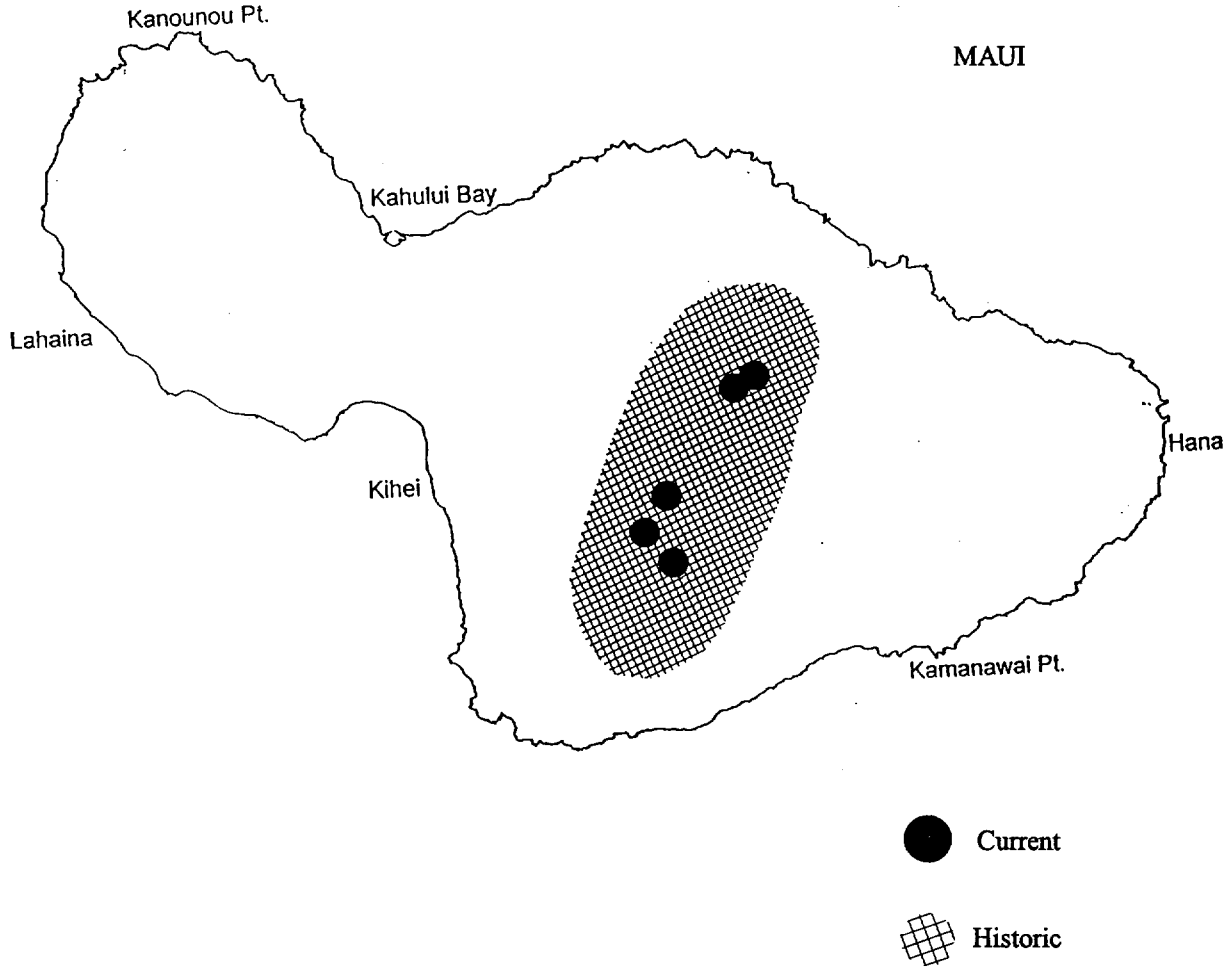


Figure 9. Current and Historic Ranges of *Geranium arboreum*.

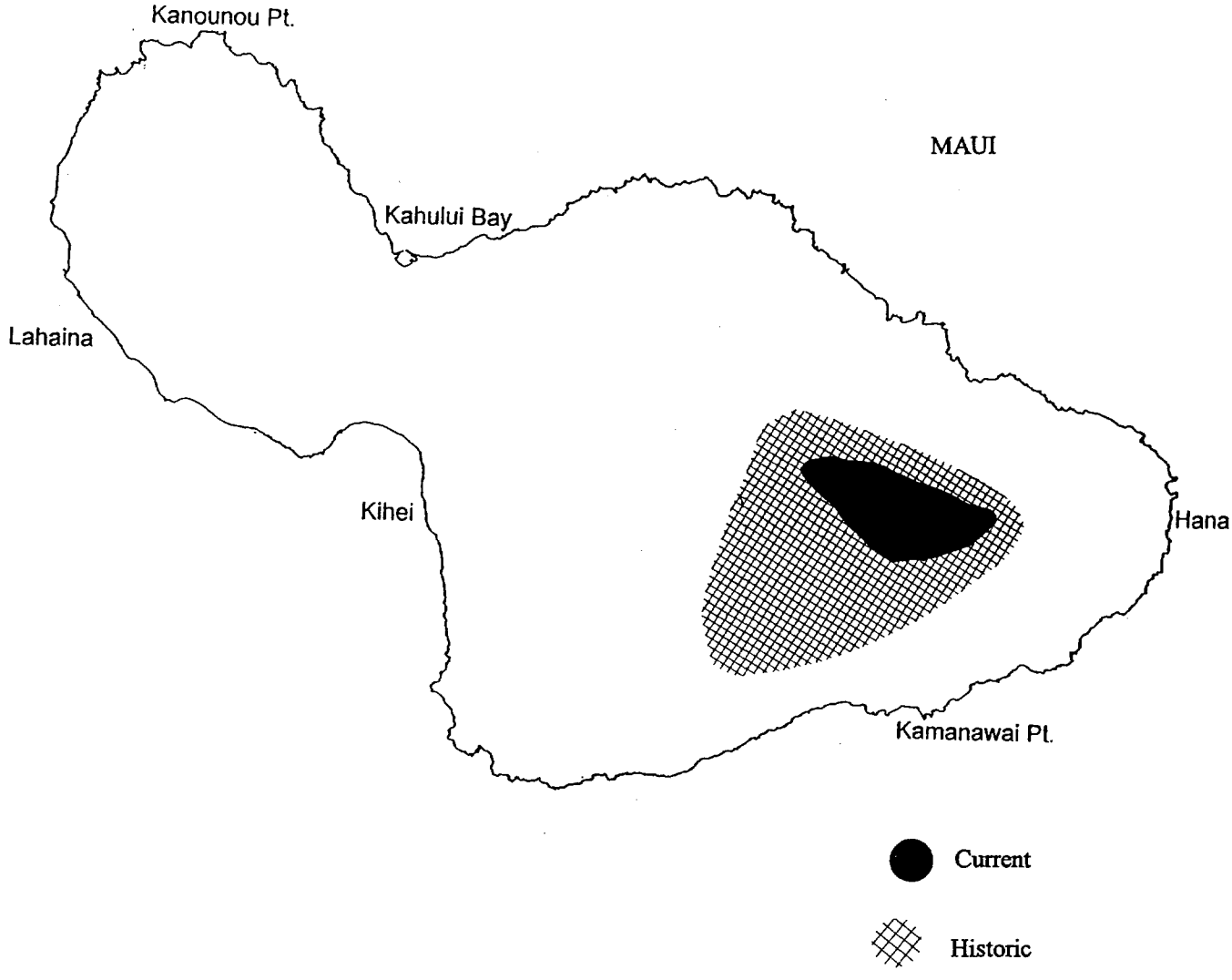


Figure 10. Current and Historic Ranges of *Geranium multiflorum*.

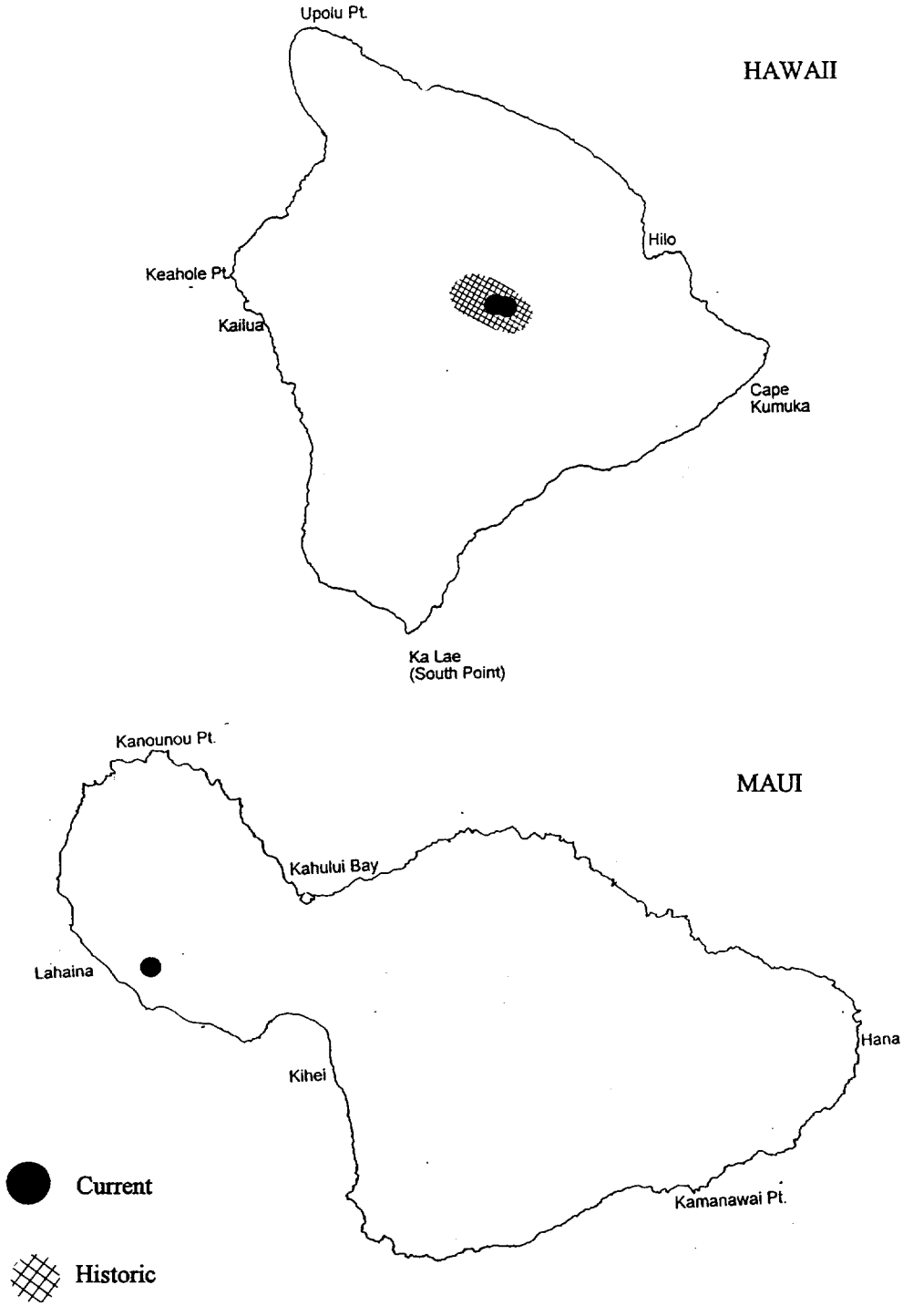


Figure 11. Current and Historic Ranges of *Hedyotis coriacea*.

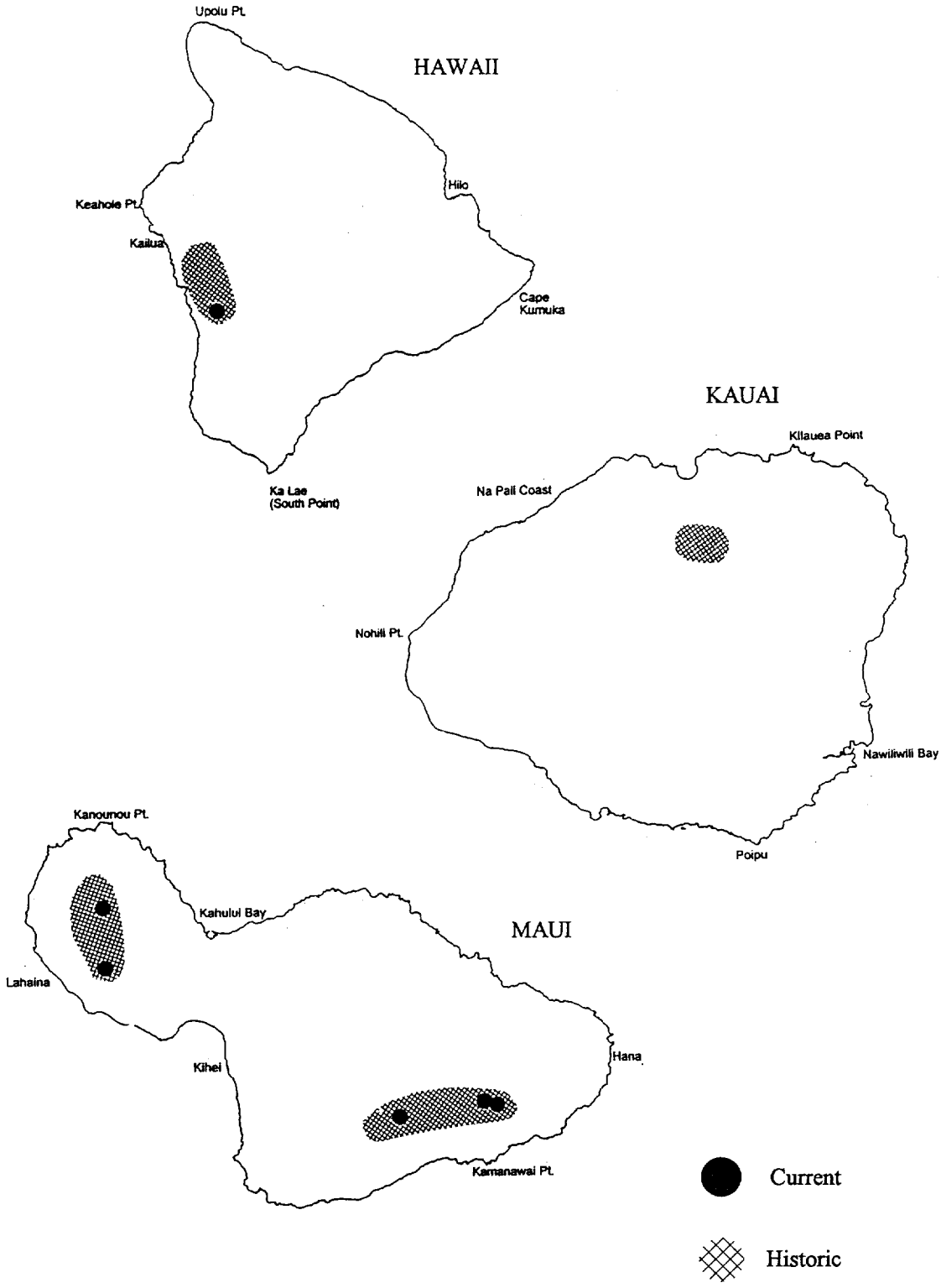


Figure 12. Current and Historic Ranges of *Huperzia mannii*.

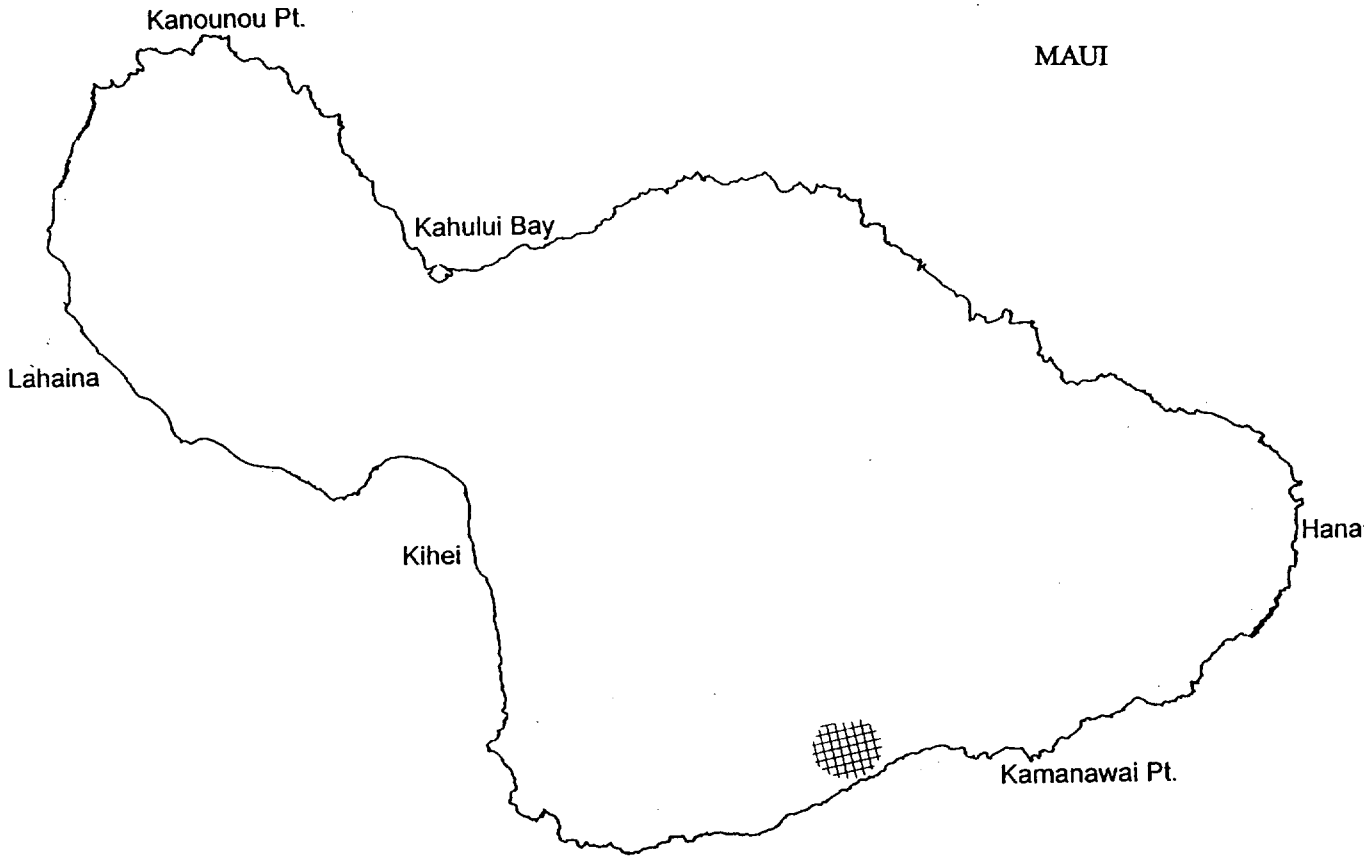


Figure 13. Current and Historic Ranges of *Lipochaeta kamolensis*.

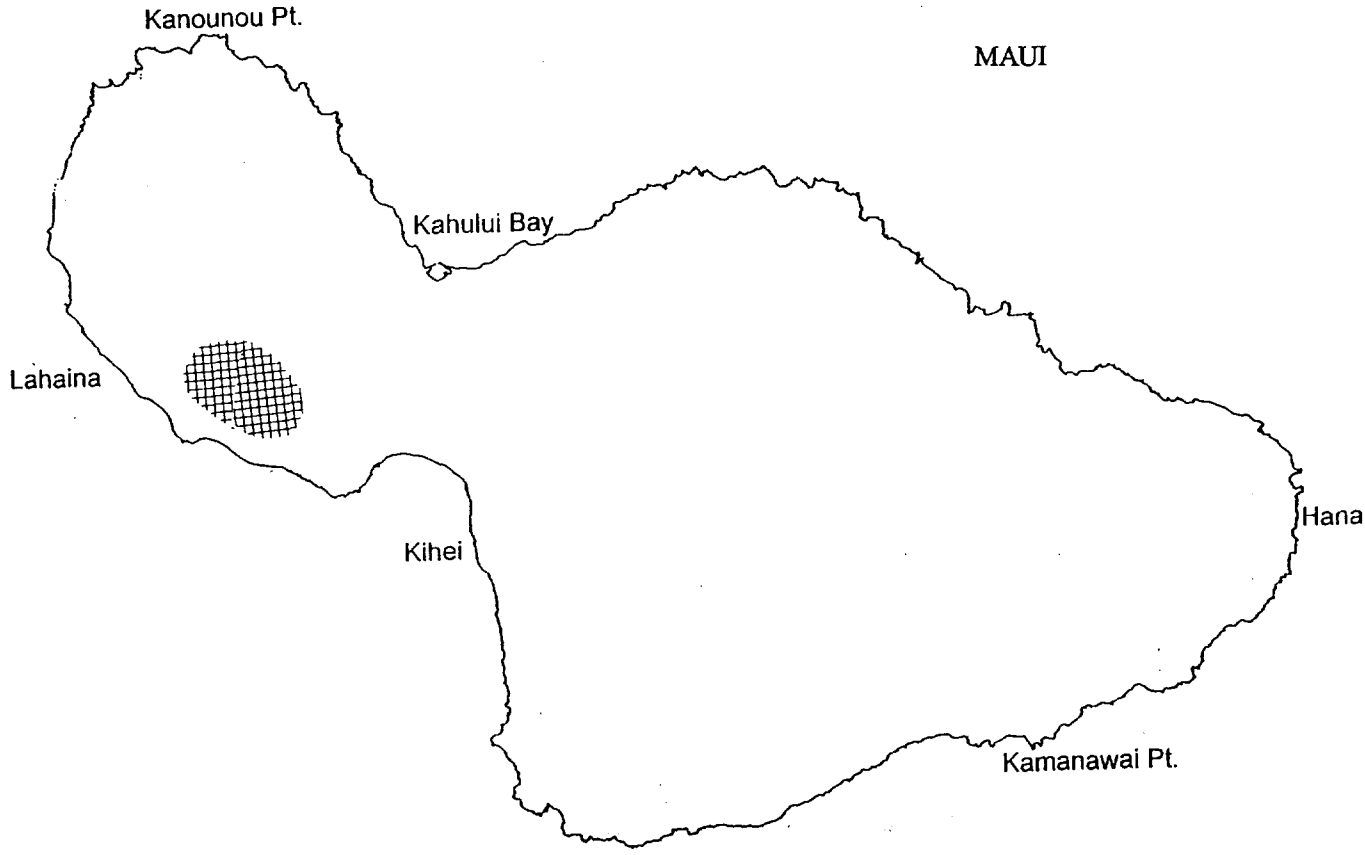


Figure 14. Current and Historic Ranges of *Lysimachia lydgatei*.

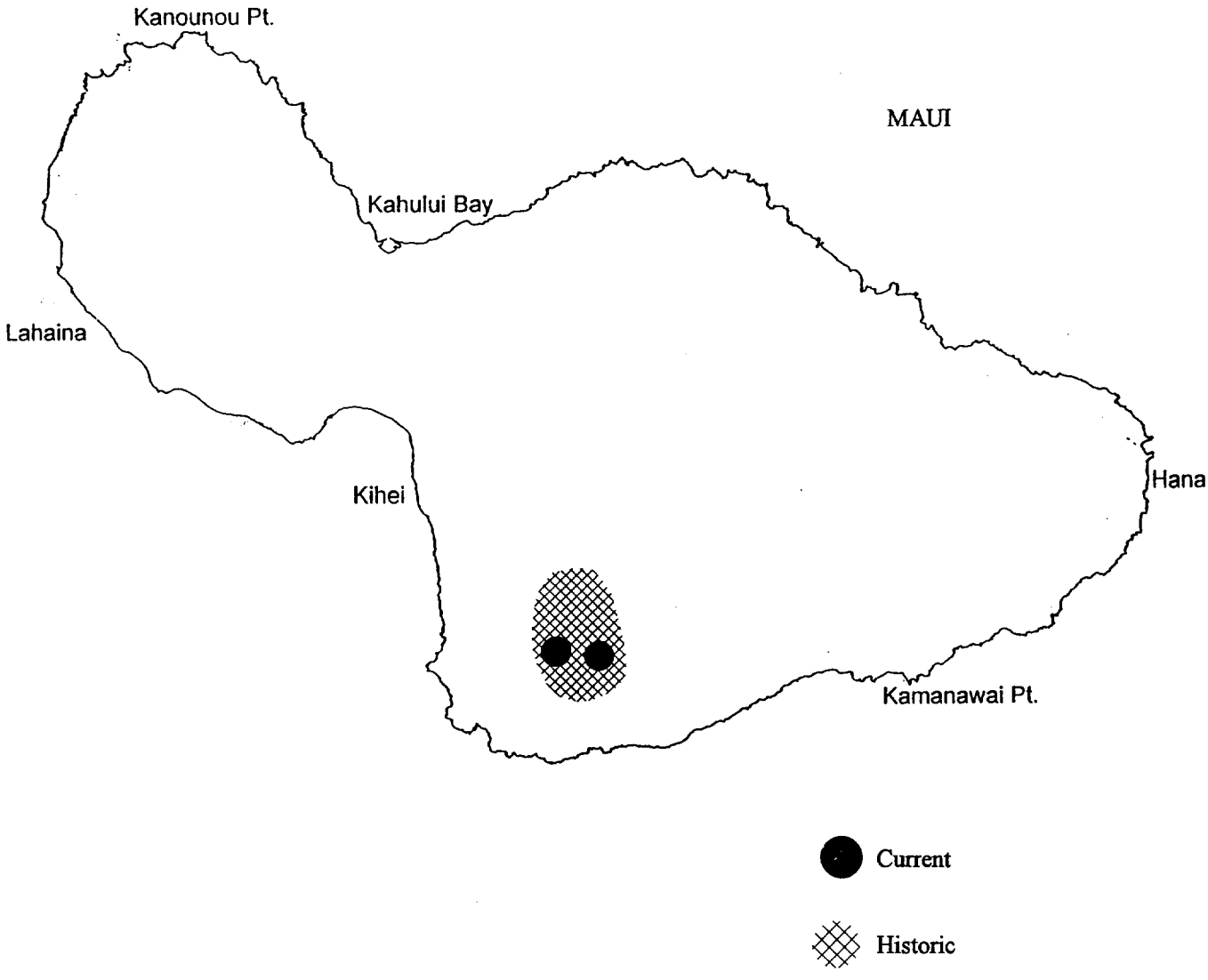


Figure 15. Current and Historic Ranges of *Melicope adscendens*.

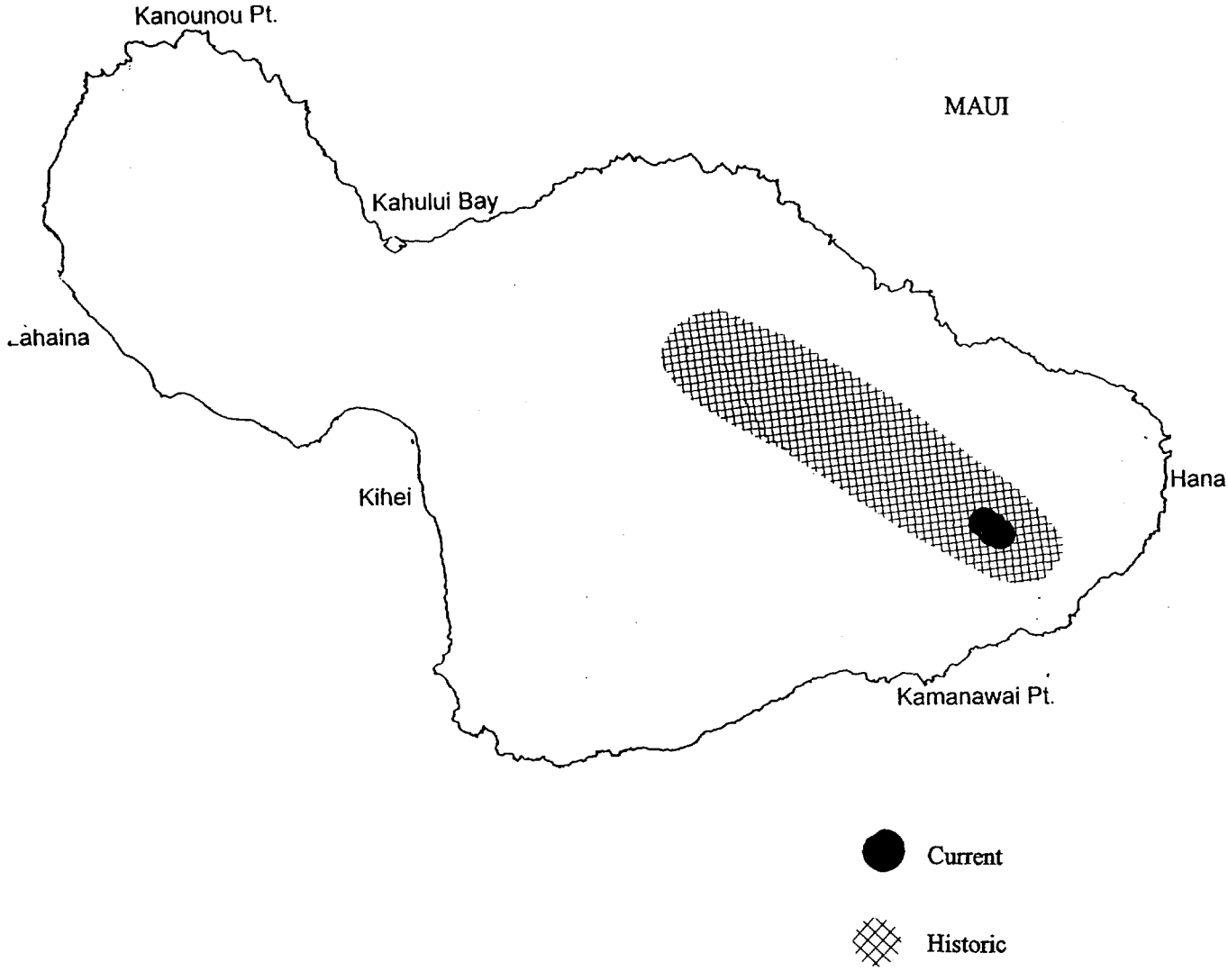


Figure 16. Current and Historic Ranges of *Melicope balloui*.

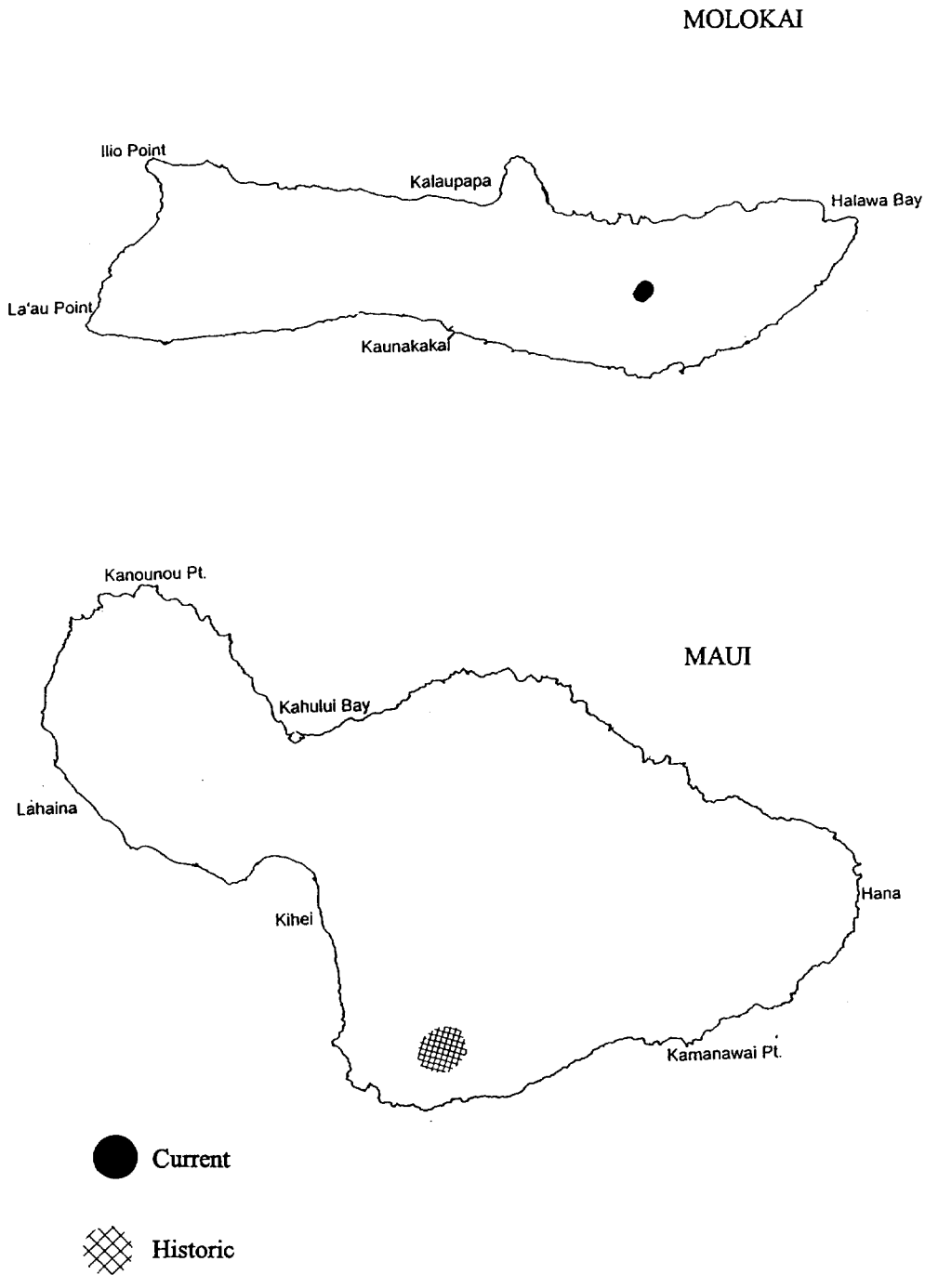


Figure 17. Current and Historic Ranges of *Melicope mucronulata.*

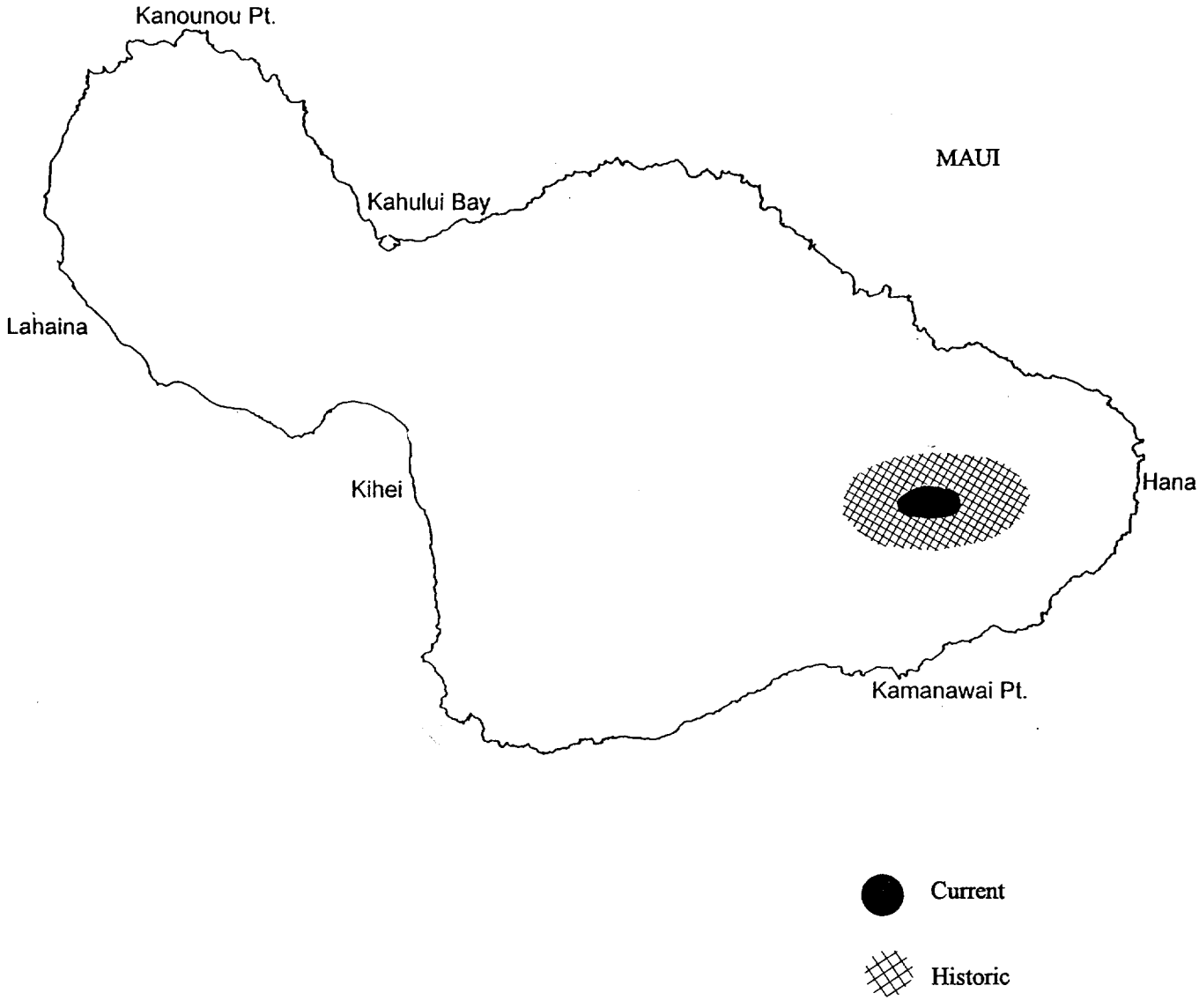


Figure 18. Current and Historic Ranges of *Melicope ovalis*.

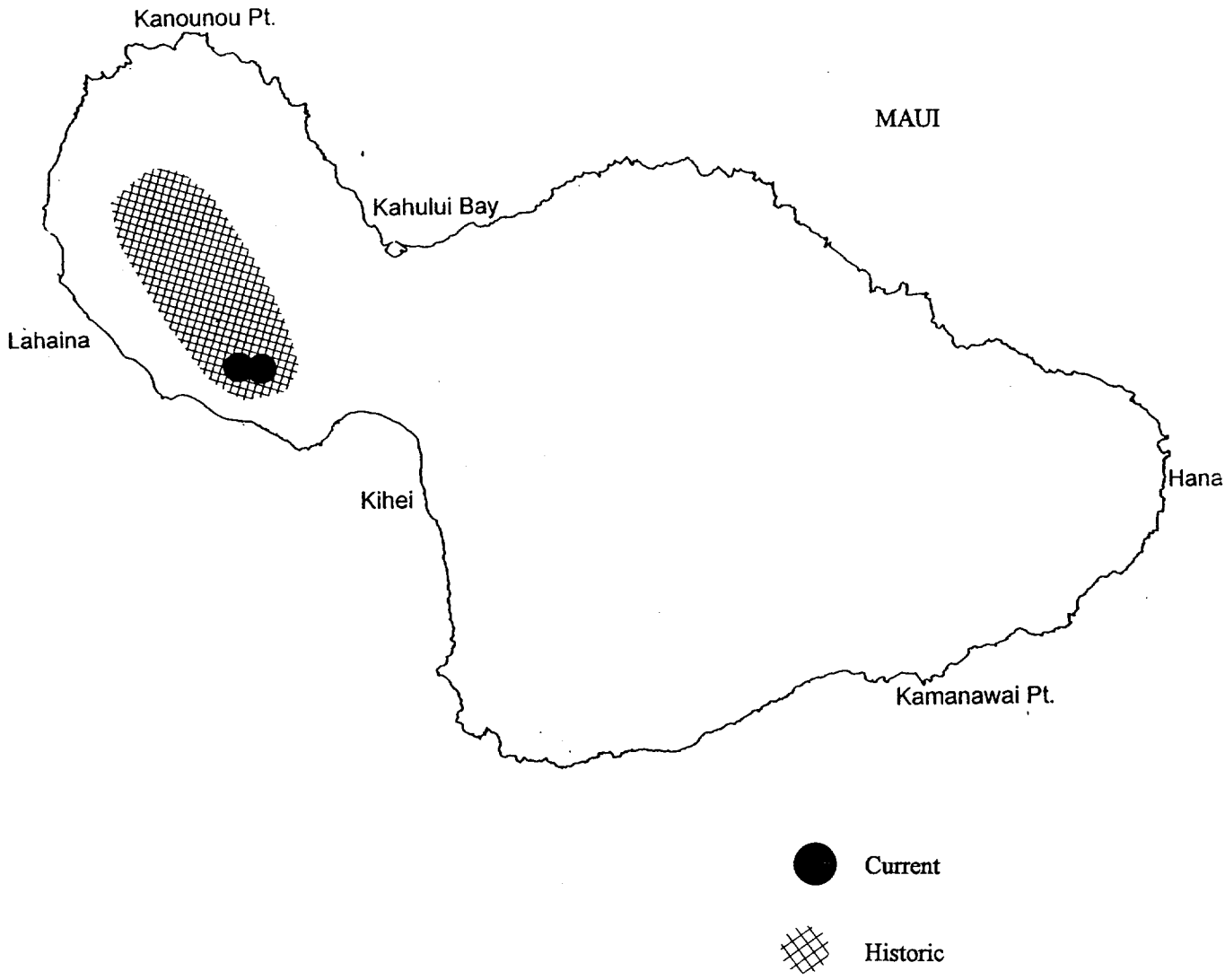


Figure 19. Current and Historic Ranges of *Remya mauiensis*.

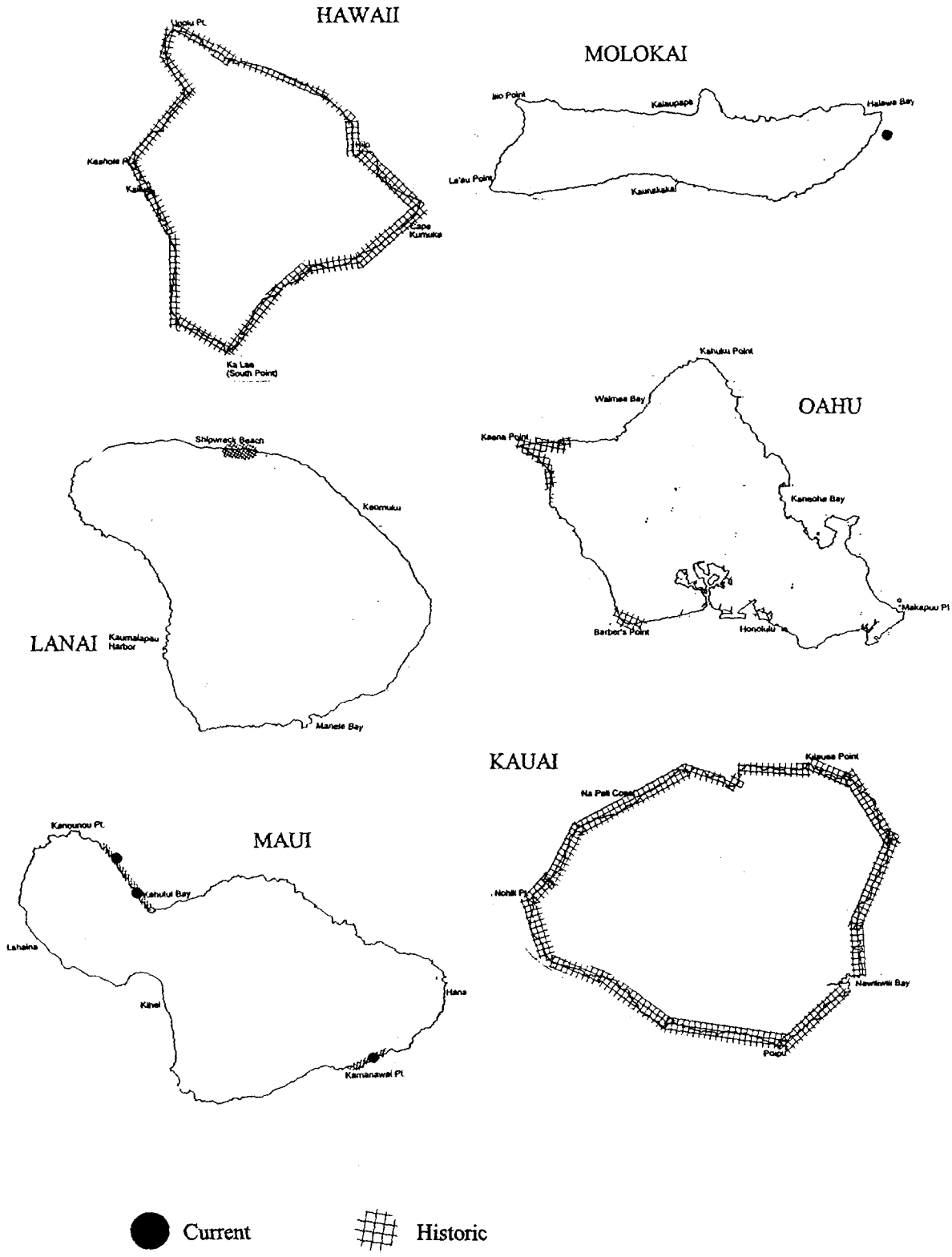


Figure 20. Current and Historic Ranges of *Scaevola coriacea*.

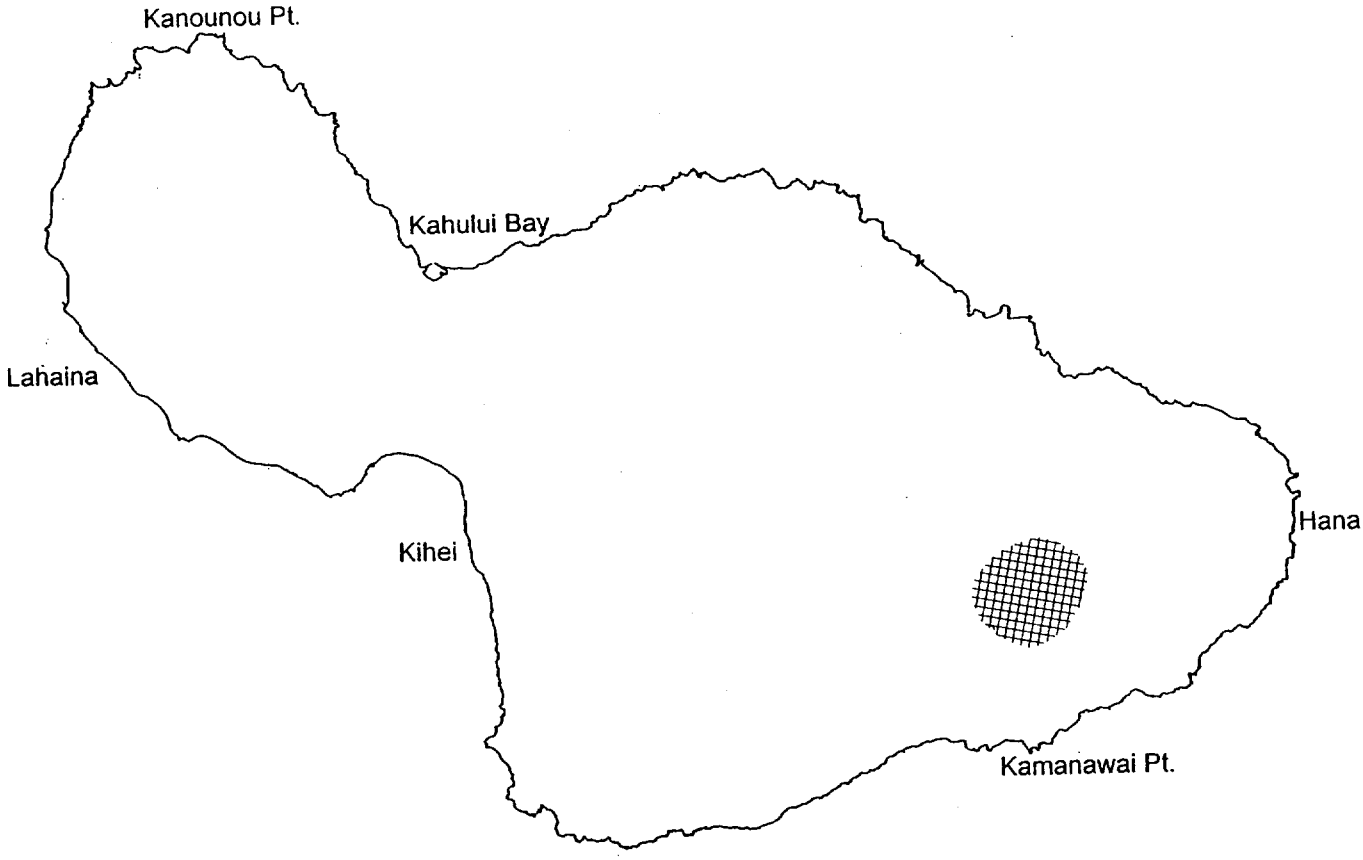


Figure 21. Current and Historic Ranges of *Schiedea haleakalensis*.

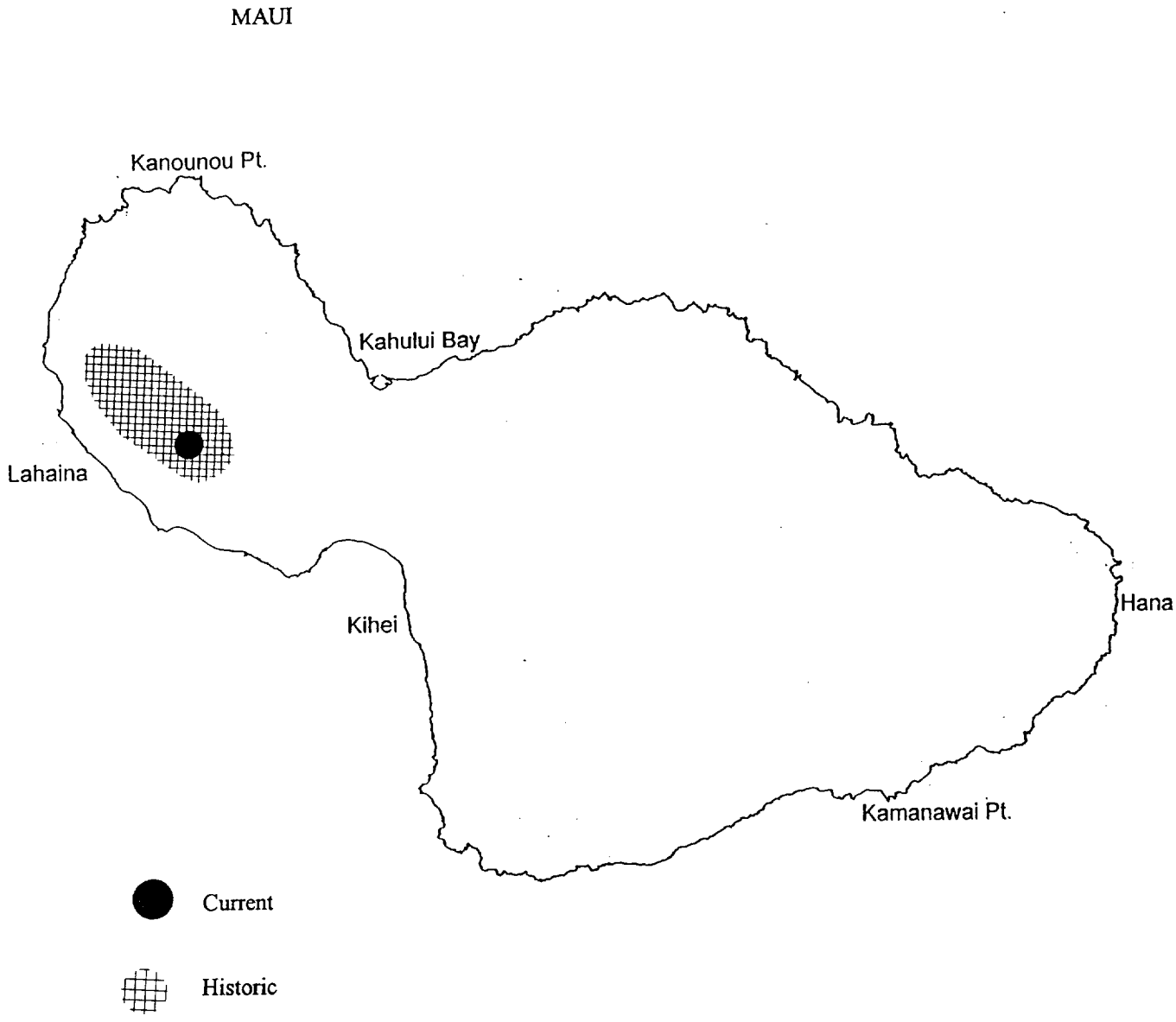
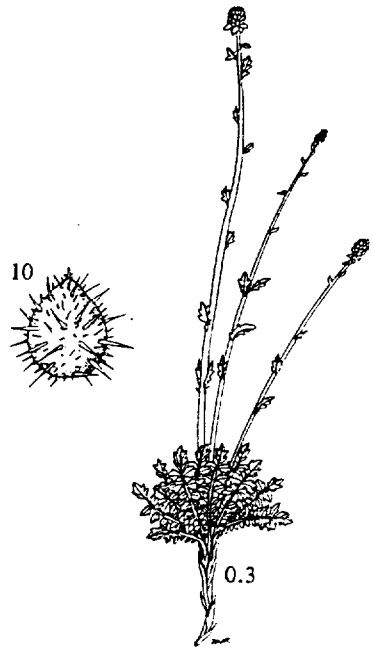


Figure 22. Current and Historic Ranges of *Tetramolopium capillare*.

APPENDIX D

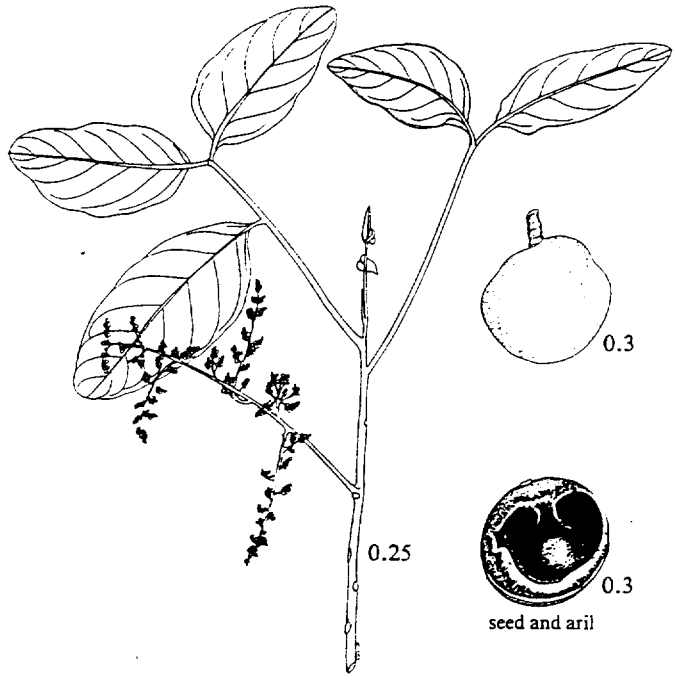
FIGURES OF PLANTS

(Numbers indicate multiplication factor for figure.)



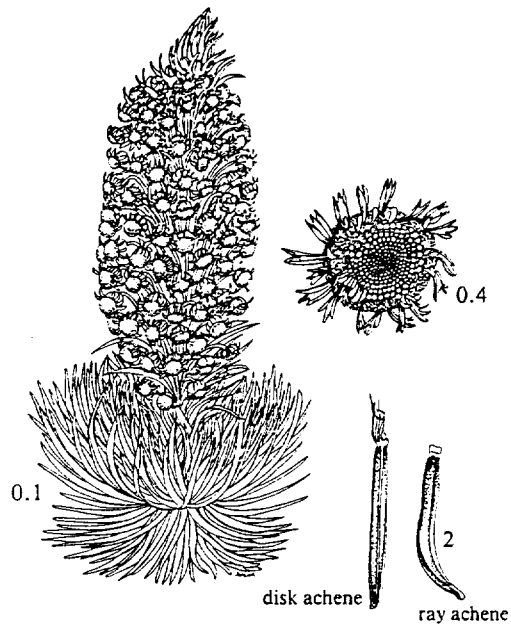
Acaena exigua

Figure 23. Line drawing of *Acaena exigua* (Wagner et al. 1990).



Alectryon macrococcus var. macrococcus

Figure 24. Line drawing of *Alectryon macrococcus* var. *macrococcus* (Wagner *et al.* 1990).



Argyroxiphium sandwicense subsp. macrocephalum

Figure 25. Line drawing of *Argyroxiphium sandwicense* ssp. *macrocephalum* (Wagner *et al.* 1990).

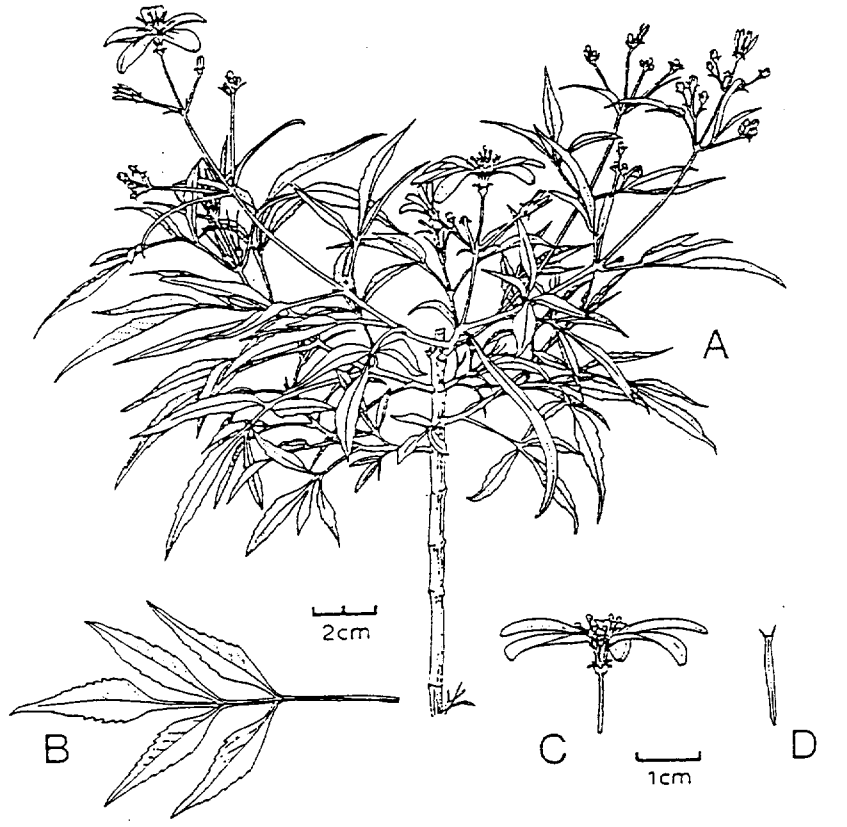


Figure 26. Line drawing of *Bidens micrantha* ssp. *kalealaha* (Ganders & Nagata 1983).

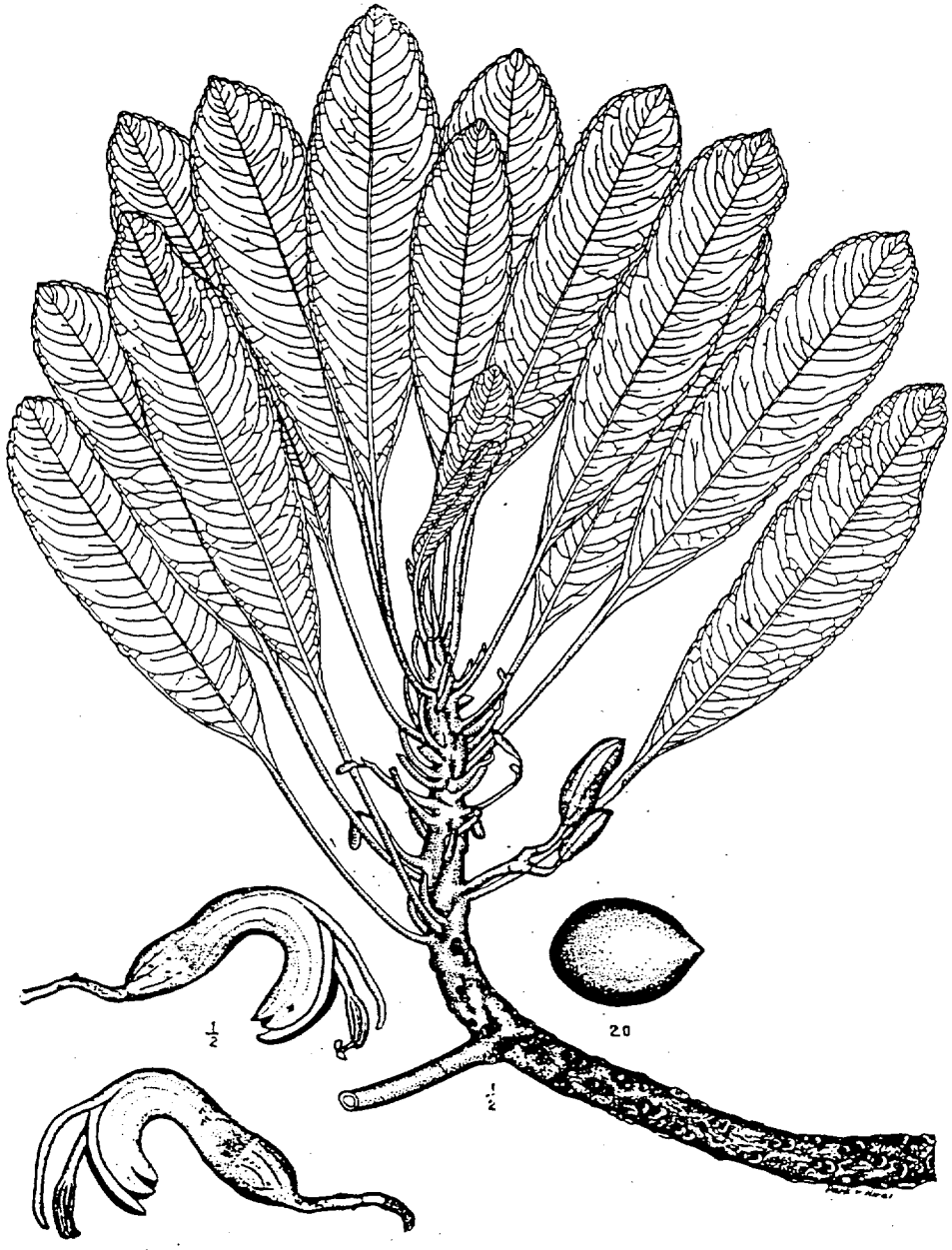
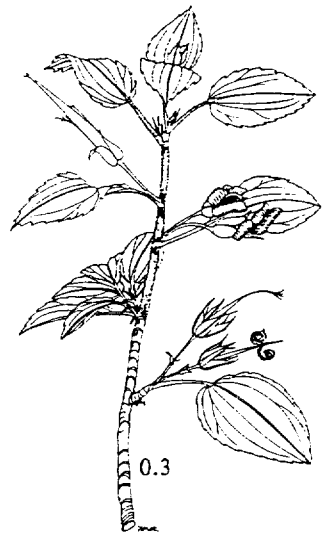


Figure 27. Line drawing of *Clermontia oblongifolia* (Degener 1937).



Geranium arboreum

Figure 28. Line drawing of *Geranium arboreum* (Wagner *et al.* 1990).

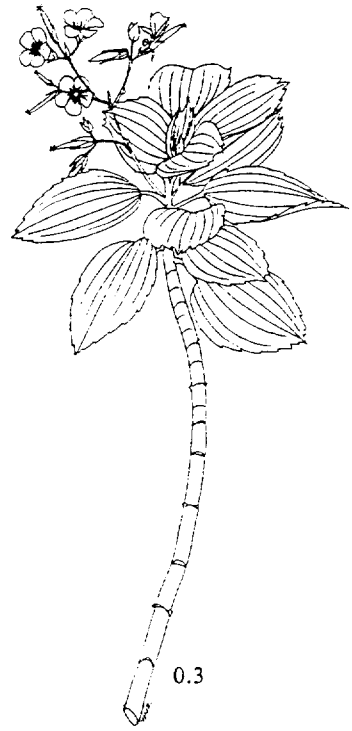


Figure 29. Line drawing of *Geranium multiflorum* (Wagner *et al.* 1990).

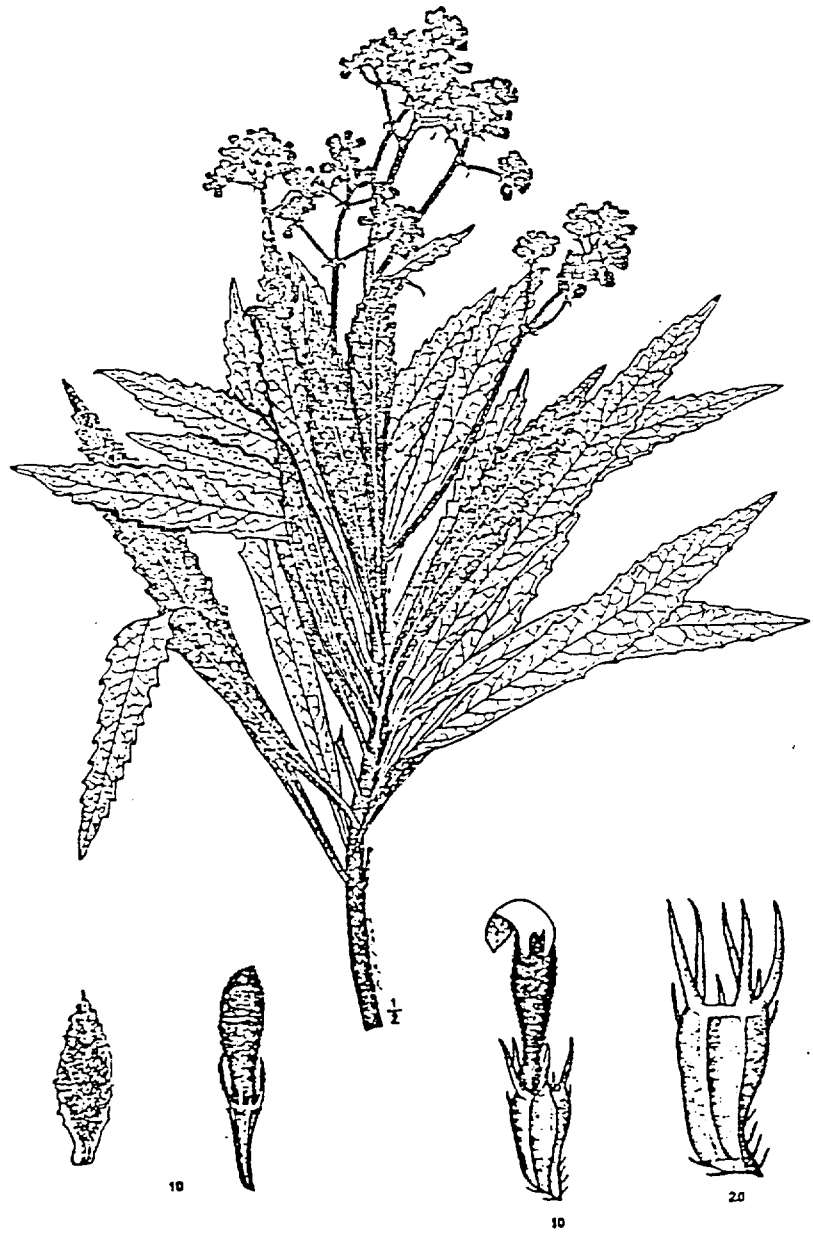
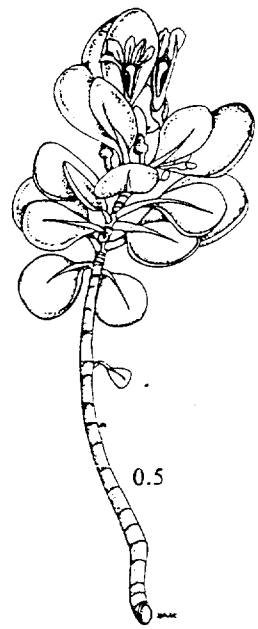


Figure 30. Line drawing of *Remya mauiensis* (Degner 1936).



Scaevola coriacea

Figure 31. Line drawing of *Scaevola coriacea* (Wagner *et al.* 1990).

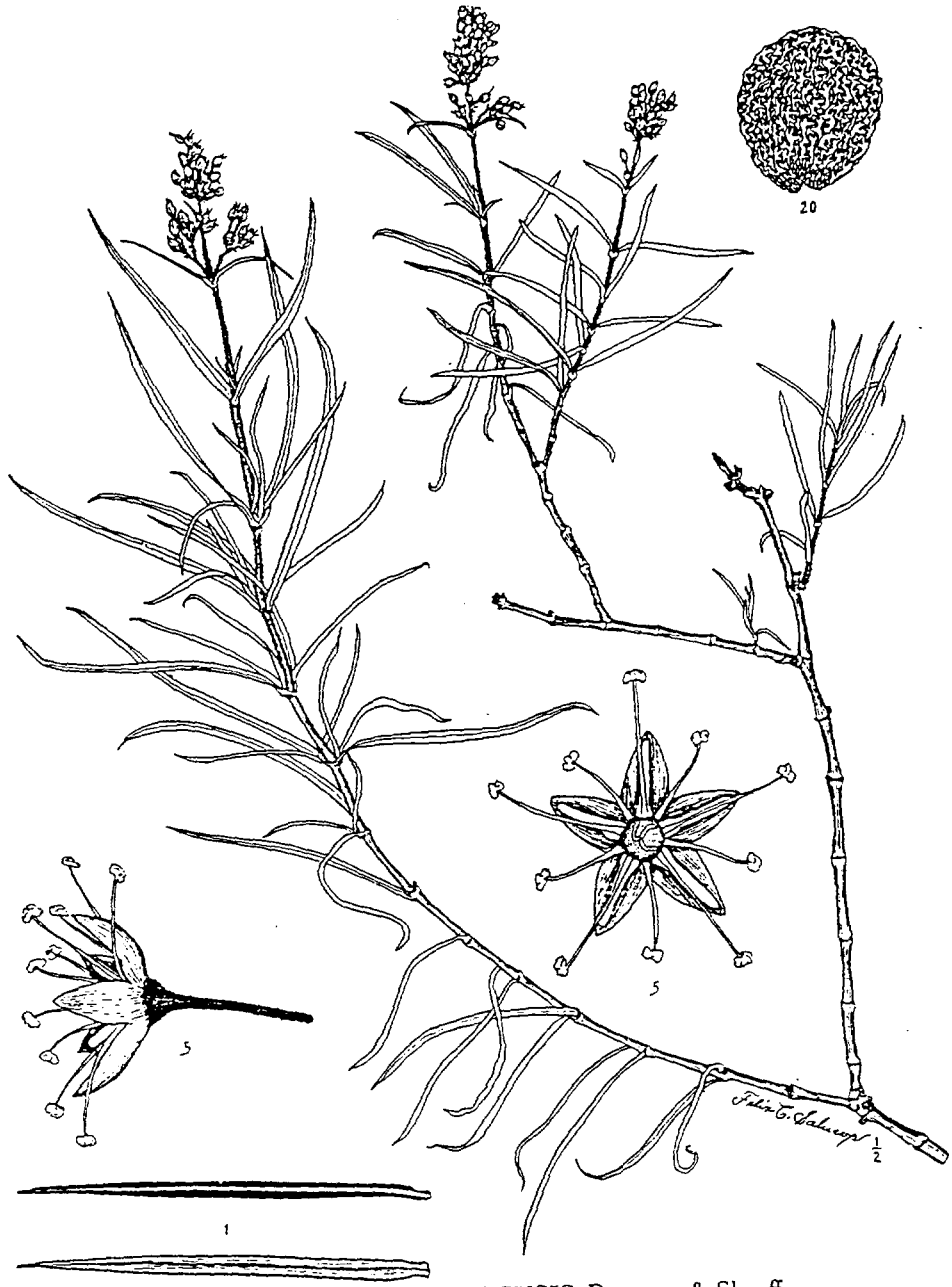


Figure 32. Line drawing of *Schiedea haleakalensis* (Degener & Greenwell 1956).

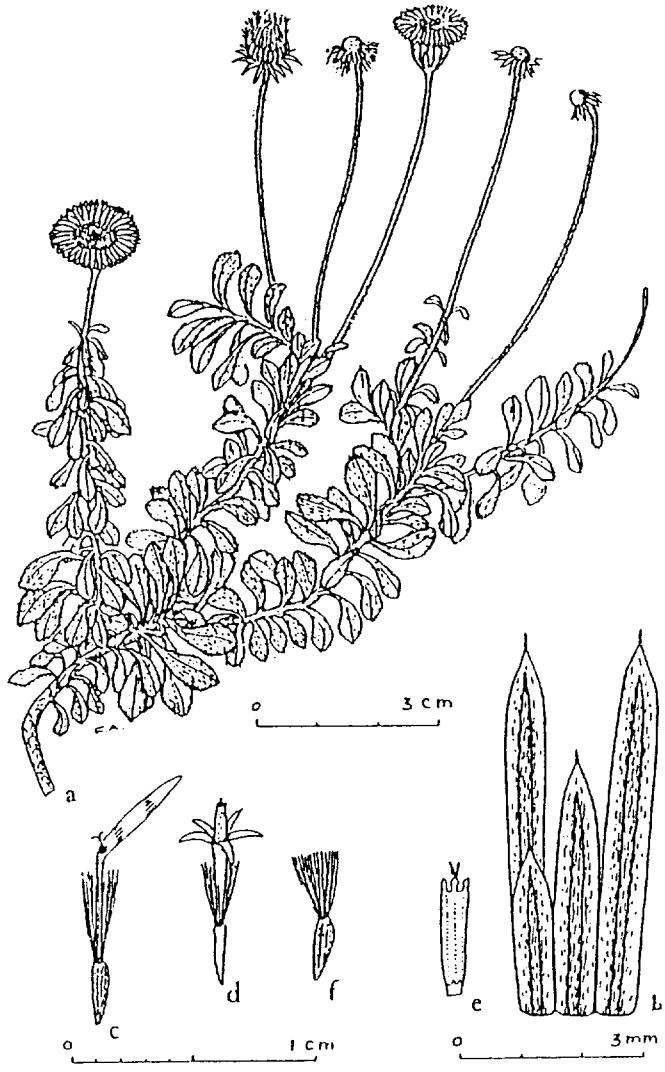


Figure 33. Line drawing of *Tetramolopium capillare* (St. John 1974).

APPENDIX E
SUMMARY OF ASSOCIATED SPECIES

COASTAL SHRUBLAND
Elevation: 0-300 meters (0-990 feet)
Rainfall: <120 centimeters/year (47 inches)

Maui Cluster Taxa

Scaevola coriacea

Associated Listed Species (Recovery Plan in which addressed)[1]

Cenchrus agrimonioides var. *agrimonioides*–E (Multi-island)
Centaurium sebaeoides–E[2] (Waianae)
Ischaemum byrone–E (Big Island)
Mariscus pennatiformis ssp. *pennatiformis*–E (Multi-island)
Panicum fauriei var. *carteri*–E (Carter's)
Peucedanum sandwicense–T[2] (Kauai)
Sesbania tomentosa–E (Multi-island)

Associated Candidate and Species of Concern

Capparis sandwichiana –sc[2]
Chamaesyce skottsbergii var. *vaccinioides*–s
Hedyotis littoralis–sc
Portulaca molokiniensis–sc
Portulaca villosa–sc

Associated Native Species

Bidens mauiensis, *Boerhavia* spp., *Fimbristylis cymosa*, *Gnaphalium sandwicensium*, *Heliotropium curassavicum*, *Jacquemontia ovalifolia*, *Lipochaeta integrifolia*, *Nama sandwicensis*, *Osteomeles anthyllidifolia*, *Scaevola sericea*, *Sida fallax*, and *Waltheria indica*

Associated Alien Species

Casuarina equisetifolia, *Cynodon dactylon*, *Ficus microcarpa*, *Heterotheca californica*, *Leucaena leucocephala*, *Macroptilium lathyroides*, *Sonchus oleracea*, *Stachytarpheta*, *Verbensina encelioides*, *Wedelia trilobata*

DRY FOREST
Elevation: 5-760 meters (17-2,510 feet)
Rainfall: 100-200 centimeters/year (39-78 inches)

Maui Cluster Taxa

Alectryon macrococcus
Bidens micrantha ssp. *kalealaha*
Hedyotis coriacea
Lipochaeta kamolensis
Melicope adscendens
Melicope mucronulata
Tetramolopium capillare

Associated Listed Species

Abutilon menziesii–E (Lanai)
Bonamia menziesii–E (Multi-island)
Caesalpinia kavaiensis–E (Kona)
Flueggea neowawraea–E (Multi-island)
Gardenia brighamii–E (Gardenia)
Gouania hillebrandii–E (Gouania)
Haplostachys haplostachya–E (Pohakuloa)
Hibiscus brackenridgei ssp. *brackenridgei*–E (Multi-island)
Isodendrion pyrifolium–E (Big Island)
Melicope knudsenii–E (Kauai)
Neraudia sericea–E (Multi-island)
Nototrichium humile–E (Waianae)
Santalum freycinetianum var. *lanaiense*–E (Lanai)
Solanum incompletum–E (Multi-island)
Stenogyne angustifolia–E (Pohakuloa)
Tetramolopium arenarium–E (Big Island)
Tetramolopium remyi–E (Lanai)
Vigna o-wahuensis–E (Multi-island)
Zanthoxylum hawaiiense–E (Big Island)

Associated Candidate and Species of Concern

Acacia koaia–sc
Bobea timonioides–sc
Canavalia pubescens–sc
Chamaesyce olowaluana–sc
Hibiscus kokio ssp. *kokio*–sc
Schiedea salicaria–sc

Associated Native Species

Metrosideros polymorpha, Aleurites moluccana, Diospyros sandwicensis, Nestegis sandwicensis, Psychotria, Pisonia, Xylosma, Streblus, Hibiscus, Antidesma, Pleomele, Acacia, Melicope knudseni, Hibiscus waimeae, Pteralyxia, Zanthoxylum, Doodia, Blechnum, Kokia kavaiensis, Bobea timonioides

Associated Alien Species

Lantana, Setaria, Triumfetta, Melia azedarach, Bocconia frutescens, Melinis minutiflora, Psidium cattleianum, Schinus terebinthifolius, Pennisetum clandestinum

DIVERSE MESIC FOREST
Elevation: 30-1,600 meters (99-5,280 feet)
Rainfall: 120-380 centimeters/year (47-149 inches)

Maui Cluster Taxa

Geranium multiflorum
Huperzia mannii
Lysimachia lydgatei
Melicope ovalis
Remya mauiensis
Schiedea haleakalensis

Associated Listed Species

Asplenium fragile var. *insulare*–E (Ferns)
Bonamia menziesii–E (Multi-island)
Brighamia rockii–E (Molokai)
Clermontia lindseyana–E (Big Island)
Ctenitis squamigera–E (Ferns)
Cyanea grimesiana ssp. *grimesiana*–E
Cyrtandra munroi–E (Lanai)
Delissea undulata ssp. *undulata*–E (Big Island)
Diellia erecta–E (Multi-island)
Gardenia mannii–E (Oahu)
Gouania vitifolia–E (Waianae)
Hedyotis mannii–E (Molokai)
Hesperomannia arbuscula–E (Waianae)
Mariscus pennatiformis ssp. *pennatiformis*–E (Multi-island)
Melicope knudsenii–E (Kauai)
Neraudia sericea–E (Multi)
Phyllostegia mollis–E (Waianae)
Platanthera holochila–E
Schiedea hookeri–E (Multi-island)
Solanum incompletum–E (Multi-island)
Spermolepis hawaiiensis–E (Multi-island)

Tetramolopium arenarium–E (Big Island)

Associated Candidate and Species of Concern

Asplenium schizophyllum–sc
Bidens campylotheca–sc
Thelypteris boydiae–sc
Dubautia plantaginea ssp. *humilis*–C[2]
Eurya sandwicensis–sc
Exocarpos gaudichaudii–sc
Festuca hawaiiensis–sc
Gardenia remyi–sc
Hibiscus kokio ssp. *kokio*–sc
Peperomia subpetiolata–sc
Phyllostegia imminuta–sc
Ranunculus hawaiensis–sc
Ranunculus mauiensis–sc
Stenogyne haliakalae–sc
Tetraplasandra kavaiensis–sc
Torulinium odoratus ssp. *auriculatum*–sc

Associated Native Species

Acacia koa, Cibotium chamissoi, Cibotium glaucum, Diplazium sandwichianum, Melicope clusiifolia, Metrosideros polymorpha, Sadleria pallida, Astelia menziesii, Coprosma spp., *Cheirodendron trigynum, Ilex anomala, Metrosideros polymorpha, Myrsine, Sophora chyrsophylla, Vaccinium reticulatum, Vaccinium calycinum, Metrosideros polymorpha, Coprosma, Styphelia tameiameiae, Sadleria cyatheoides*

Associated Alien Species

Dactylis glomerata, Holcus lanatus, Hypochoeris radicata, Juncus planifolius, Rubus argutus, Paspalum conjugatum, Paspalum urvillei, Psidium cattleianum, Psidium guajava, Rhychospora caduca, Youngia japonica

WET FOREST
Elevation: 550-670 meters (1,810-2,210 feet)
Rainfall: >250 centimeters/year (98 inches)

Maui Cluster Taxa

Acaena exigua
Clermontia oblongifolia ssp. *mauiensis*
Cyanea lobata
Cyanea mceldowneyi
Geranium arboreum
Geranium multiflorum
Huperzia mannii
Melicope balloui

Associated Listed Species

Clermontia peleana ssp. *singulifolia*–E (Big Island)
Cyanea grimesiana ssp. *grimesiana*–E (Multi-island)
Diplazium molokaiense–E (Ferns)
Hesperomannia arborescens–E (Koolau)
Hesperomannia arbuscula–E (Waianae)
Phyllostegia mannii–E (Molokai)
Phyllostegia mollis–E (Waianae)
Plantago princeps var. *laxiflora*–E (Multi-island)
Pteris lidgatei– E(Ferns)
Sanicula purpurea–E (Multi-island)

Associated Candidate and Species of Concern

Bidens campylotheca–sc
Bidens conjuncta–sc
Calamagrostis expansa–sc
Cyanea copelandii ssp. *haleakalaensis*–C
Cyanea glabra–C
Cyanea hamatiflora ssp. *hamatiflora*–C
Cyanea kunthiana–sc
Cyanea longissima–sc
Cyrtandra filipes–sc
Cyrtandra lydgatei–sc
Cyrtandra oxybapha–sc
Dubautia plantaginea ssp. *humilis*–C
Geranium humile–sc
Hedyotis elatior–sc
Hedyotis formosa–sc
Hibiscus kokio ssp. *kokio*–sc
Joinvillea ascendens ssp. *ascendens*–sc
Mariscus kunthianus–sc
Melicope haleakalae–sc
Myrsine vaccinioides–sc
Phyllostegia bracteata–sc
Ranunculus mauiensis–sc
Rubus macraei–sc
Sanicula sandwicensis–sc
Sicyos cucumerinus–sc
Tetraplasandra kavaiensis–sc
Wikstroemia bicornuta–sc
Wikstroemia villosa–sc

Associated Native Species

Sophora chrysophylla, Vaccinium reticulatum, Dodonaea, Styphelia, Rubus hawaiiensis, Dryopteris wallichiana, Metrosideros, Myrsine lessertiana, Coprosma, Acacia koa, Cibotium chamissoi, Cibotium glaucum, Diplazium sandwichianum, Melicope clusiifolia, Metrosideros polymorpha, Sadleria pallida

Associated Alien Species

Cyathea cooperi, Paspalum conjugatum, Psidium cattleianum, Rubus rosifolius, Ageratina adenophora, Holcus lanatus

ALPINE CINDER FIELDS

Elevation: 2,100-3,000 meters (6,890-9,840 feet)
Rainfall: 75-125 centimeters (29.6-49.3 inches)

Maui Cluster Taxa

Argyroxiphium sandwicense ssp. *macrocephalum*

Associated Listed Species

none

Associated Candidate and Species of Concern

none

Associated Native Species

Agrostis sandwicensis
Deschampsia nubigena
Dubautia menziesii
Silene struthioloides
Styphelia tameiameiae
Tetramolopium humile
Trisetum glomeratum

Associated Alien Species

Hypochoeris radicata
Heterotheca grandiflora
Rumex acetosella

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[1]Waianae—Recovery of this taxon will be addressed in the Waianae Plant Cluster Recovery Plan
Big Island—Recovery of this taxon is addressed in the Big Island Plant Cluster Recovery Plan (1996)
Carter's—Recovery of this taxon iwill be addressed in the Carter's Panicgrass Recovery Plan
Kauai—Recovery of this taxon is addressed in the Kauai Plant Cluster Recovery Plan (1995)
Multi-island—Recovery of this taxon will be addressed in the Multi-island Plant Cluster Recovery Plan
Lanai—Recovery of this taxon is addressed in the Lanai Plants Recovery Plan (1995)
Kona—Recovery of this taxon is addressed in the Kona Drylands Plants Recovery Plan (1994)
Gardenia—Recovery of this taxon is addressed in the *Gardenia brighamii* Recovery Plan (1993)
Gouania—Recovery of this taxon is addressed in the *Gouania hillebrandii* Recovery Plan (1990)
Pohakuloa—Recovery of this taxon will be addressed in the Pohakuloa Plant Recovery Plan
Ferns—Recovery of this taxon will be addressed in the Ferns Recovery Plan
Oahu—Recovery of this taxon will be addressed in the Oahu Plants Recovery Plan

[2]E—Taxon is listed as endangered
T—Taxon is listed as threatened
PE—Taxon has been officially proposed for listing as endangered
C—Taxon is a candidate for Federal listing
sc—Taxon is a species of concern

APPENDIX F
SUMMARY OF LAND OWNERSHIP/MANAGEMENT

National Park Service

Argyroxiphium sandwicense ssp. *macrocephalum*, *Bidens micrantha* ssp. *kalealaha*, *Geranium arboreum*, *Geranium multiflorum*, *Huperzia mannii*, *Melicope balloui*, *Melicope ovalis*, *Schiedea haleakalensis*

Department of Defense (Army)

Alectryon macrococcus, *Hedyotis coriacea*

Department of Defense (Navy)

Alectryon macrococcus

State of Hawaii

Alectryon macrococcus, *Bidens micrantha* ssp. *kalealaha*, *Clermontia oblongifolia* ssp. *mauiensis*, *Geranium arboreum*, *Geranium multiflorum*, *Hedyotis coriacea*, *Huperzia mannii*, *Lysimachia lydgatei*, *Remya mauiensis*, *Scaevola coriacea*, *Tetramolopium capillare*

The Nature Conservancy of Hawaii

Geranium arboreum, *Geranium multiflorum*, *Melicope mucronulata*

City and County of Honolulu

Alectryon macrococcus

Hawaiian Home Lands

Huperzia mannii
Lipochaeta kamolensis

Private Landowners

Alectryon macrococcus, *Cyanea mceldowneyi*, *Geranium arboreum*, *Huperzia mannii*, *Lipochaeta kamolensis*, *Melicope adscendens*, *Scaevola coriacea*, *Tetramolopium capillare*

APPENDIX G

SUMMARY OF COMMENTS

The U.S. Fish and Wildlife Service received comments on the Draft Recovery Plan for the Maui Plant Cluster from the City and County of Honolulu, Fire Department; the U.S. Department of the Navy; the Hawaii Division of Forestry and Wildlife; S.H. Sohmer, President and Director, Botanical Research Institute of Texas, Inc.; Warren L. Wagner, Curator of Pacific Botany and Chairman, Department of Botany, National Museum of Natural History, Smithsonian Institution; and Richard Nakagawa.

Editorial changes and comments providing additional information on numbers of populations/individuals, distribution of certain taxa, and ongoing conservation actions have been incorporated into the final plan. Additional comments are addressed below:

Comment 1: The Haleakala silversword has 64,000 individuals listed. Its habitat is protected and stable and its numbers have increased in recent years. USFWS should consider delisting this variety from its present threatened status.

Service Response: The Service acknowledges the efforts afforded to protect this species as one of the most dramatic conservation success stories of the Hawaiian Islands. Nevertheless, due to the highly restricted distribution of the Haleakala silversword and the susceptibility of its pollinators to the Argentine ant, the Service believes it will be prudent to consider delisting of this species only if the threat to its pollinators is controlled through management action and the single population continues to exceed 50,000 individuals

Comment 2: Two other species that inhabit Haleakala Crater have also rebounded in the last decade. Both Schiedea haleakalensis and Bidens micrantha ssp. kalealaha seem to be multiplying and spreading since the removal of goats. While we don't presently recommend any change in their proposed status, we do think their numbers should be adjusted upward.

Service Response: Population estimates for these two species were based on information provided by knowledgeable local botanists. The recovery plan acknowledges that continued monitoring of these species is needed, although in some cases accessability of these species' habitats presents difficulties in accomplishing adequate surveys.

Comment 3: The genus Melicope in the Rutaceae is a highly technical genus in critical need of intensive taxonomic study. Verification is needed for the identification of the four species included in the recovery plan. If recovery plans are to be developed, resolution of the taxonomic problem is needed. Management issues can be addressed only with an understanding of the numbers of populations and what they represent.

Service Response: We foresee that further investigation of this issue will be necessary, but believe that it is prudent to use the identifications provided by the local botanists referenced until sufficient evidence is presented otherwise. Because of the rarity of these species, the final identifications of these individuals will not significantly affect this recovery plan. Delaying the distribution of a final

version of the plan until this issue is resolved would delay recovery efforts for these species and the 17 other taxa covered by this plan.

Comment 4: Concern was expressed for including species, such as *Acaena exigua* that are not known to be extant, in a recovery plan. Specifically, the individual questioned the development of actions to recover species for which no known populations exist.

Service Response: The recovery plan acknowledges that *Acaena exigua* has not been collected since 1957, although botanists have been searching for this species on an *ad hoc* basis for years. A complete search of former habitats is needed. Including this species in a recovery plan provides a method for the Service to seek or support funding for such surveys. The recovery plan states that delisting due to extinction may be proposed if the species is not relocated after extensive searches.

Comment 5: New DNA evidence indicates that *Clermontia oblongifolia* and its subspecies are in fact viable hybrids of *C. arborescens* and *C. kakeana*. If this is confirmed, it would be prudent not to list this subspecies since hybrids have no special status.

Service Response: This information has been noted in the recovery plan. If it is confirmed, the Service would determine whether a proposal to delist the affected subspecies is appropriate. Delaying the distribution of a final version of the plan until this issue is resolved would delay recovery efforts for all of the other species covered by this plan.

Comment 6: Scaevola coriacea has been found to be very easy to propagate and grows vigorously once established. This species should be focused on as one that can yield quick and dramatic results at a very reasonable expenditure.

Service Response: The Service appreciates this information and will take it into consideration when seeking funding or support to implement the recovery actions identified in this plan.

APPENDIX H

DETAILED DESCRIPTIONS OF ALIEN PLANTS AND ANIMALS

1. ALIEN PLANTS

CURRENT THREATS

Kikuyu grass (*Pennisetum clandestinum*)

Kikuyu grass is an aggressive, mat-forming perennial grass that spreads by stolons and rhizomes. In many locations between 915-1,525 meters (3,000-5,000 feet) on leeward East Maui and at lower elevations on windward exposures, this species grows so densely and luxuriantly that it often displaces all other plant species—both native and exotic—and consistently prevents reproduction of native species (Medeiros, Loope, and Holt 1986). Introduced to Maui as a pasture grass in the 1920's-1940's, kikuyu grass (from East Africa) has flourished on the ranchlands of East Maui and has spread over a wide range of habitats from near sea level to 3,050 meters (10,000 feet). Periodic freezing temperatures damage it and generally prevent it from competing well at high elevations. Kikuyu grass flowers and sets seed in Hawaii only when closely cropped; it spreads readily, however, by vegetative means. Kikuyu grass presents a particularly serious problem to conservation efforts on Maui in the Auwahi area (Ulupalakua Ranch) and Kaupo Gap of Haleakala National Park (Medeiros, Loope, and Holt 1986).

Kikuyu grass can be readily killed by application of glyphosphate (a non-persistent organophosphate herbicide) at a sufficiently low concentration that native species are not harmed (Gardner and Kageler 1983). The potential therefore exists for gradually favoring reestablishment of natives in areas infested with kikuyu grass. In practice, extreme caution must be exercised since success depends on carefully regulating the quantities of spray applied to mixed stands of the alien grass and natives.

Molasses grass (*Melinis minutiflora*)

This African species spread rapidly over Maui during the 1970s-1990s. In Kaupo Gap of Haleakala National Park, it has greatly increased after elimination of goat grazing in the 1980s. Scowcroft and Hobdy (1986) found that it increased greatly inside the Healani feral (this term is used for both feral and escaped domestic animals in this document) ungulate exclosure at 1,280 meters (4,200 feet) elevation in the Kipahulu Forest Reserve, and inhibited continued reproduction of *Acacia koa*. Smith (1985) gives its potential upper elevation limit in the Hawaiian Islands as 1,500 meters (5,000 feet). It also occurs in lower elevation areas, such as Kanaio Natural Area Reserve (NAR) (Medeiros, Loope, and Chimera 1993).

Among the Maui cluster group, the taxon particularly vulnerable to invasion by molasses grass (with associated fire hazard) is *Lipochaeata kamolensis*. Others potentially threatened by molasses grass invasion are *Melicope adscendens* and *M. mucronulata*.

Velvetgrass (*Holcus lanatus*)

This perennial grass from Europe is abundant in most open shrubland habitats of East Maui at 1,830-2,740 meters (6,000-9,000 feet). It is particularly dense in the lower elevation subalpine shrubland of Haleakala National Park near Hosmer Grove. Wherever it grows it at least partially displaces seedling establishment by such relatively hardy native species as *Sophora chrysophylla* (Loope, Nagata, and Medeiros 1992). Velvetgrass is tolerant of flooding and is the major introduced species invading pig-damaged montane bogs of northeastern Haleakala (Medeiros *et al.* 1991). Velvetgrass' displacement of seedling establishment by other species adversely affects survival of many rare species in Haleakala National Park, including *Pelea hawaiiensis*, *Planchonella sandwicensis*, *Pleomele auwahiensis*, *Sanicula sandwicensis*, and *Zanthoxylum kauaense*. Among the Maui cluster taxa, velvetgrass inhibits reproduction of *Geranium arboreum*.

Palmgrass (*Setaria palmifolia*)

As of 1994, palmgrass (*Setaria palmifolia*) is rapidly spreading, unchecked, into the habitat of *Cyanea mceldowneyi*. Palmgrass invades the stream banks where *C. mceldowneyi* grows, forming dense stands and displacing native vegetation.

Kahili ginger (*Hedychium gardnerianum*) and other ginger species

The large (up to 2 meters or 6 feet tall) Kahili ginger with bright golden-yellow flowers, is an aggressive invader of low-to-middle elevation rainforest of windward Maui. It is dispersed by birds, which eat its large, fleshy, orange fruits. Once Kahili ginger establishes at a site, it spreads vegetatively, forming large, continuous clumps that displace nearly all other understory vegetation. It has the reputation of being one of the most aggressive and destructive invaders of Hawaiian rainforests (Smith 1985). An incipient population in Kipahulu Valley of Haleakala National Park (Anderson *et al.* 1992) is targeted for control by the park's resource management crew.

Glycine wightii

Glycine wightii, a relative of soybean, is an aggressive perennial vine from the neotropics, introduced to Maui near Ulupalakua for pasture improvement about 1970. Populations exploded in the late 1980s and early 1990s. *Glycine* grows in thick mats over fences and smothers trees and shrubs on the roadside. Cattle browsing keeps it out of pastures. Medeiros, Loope, and Chimera (1993) considered it a potentially serious threat to Kanaio NAR and other dryland forest sites on leeward East Maui.

Spanish needle (*Bidens pilosa*)

Spanish needle, from tropical America but now widespread in the Hawaiian Islands, is an annual herb up to about 1 meter (3 feet) tall. Its germination and growth depends on winter rains; it dries up and dies with summer drought. It seasonally dominates understories of native trees in leeward forests, thereby displacing seedling establishment (Medeiros, Loope, and Holt 1986; Medeiros, Loope, and Chimera 1993). At the same time that climatic conditions are ideal for germination and growth of native dry forest tree seedlings, Spanish needle is thriving and taking up space, nutrients, and water.

Blackberry (*Rubus argutus*)

Spread of this prickly species native to the southern U.S. presents potentially severe problems in high-elevation grasslands and rainforests of Maui. It becomes established primarily in areas of pig activity. Birds disperse it also, and once established in an area its primary method of spread is vegetative, through rooting of aerial shoots where they become prostrate (Smith 1985). Backcountry personnel in Haleakala have been combating blackberry for years in the Paliku pasture and have

succeeded in keeping it localized. A large infestation occurs in the Koolau Forest Reserve below Puu Alaea, and there are scattered occurrences in rainforests of Haleakala National Park. Extensive stands occur along the lower edge of the Kalapawili grasslands between Puu Alaea and Flattop Bog.

Raspberries (*Rubus niveus* and other *Rubus* species)

Aggressive *Rubus* species other than *R. argutus* pose threats to natural areas on Maui. Gerrish *et al.* (1992) mapped the distributions on Maui and other islands. The situation is complex, involving *Rubus discolor*, *R. glaucus*, and *R. niveus*. The most immediate threat appears to involve *R. niveus* in the upper Kula-Keokea area.

German ivy (*Senecio mikanioides*)

German ivy, native to South Africa, is believed to have been introduced to Hawaii on the Kona side of the Big Island sometime around 1909 (Haselwood and Motter 1983). Jacobi and Warshauer (1992) found this species to be highly invasive, spreading rapidly on the Big Island, in communities ranging from dry shrubland to rainforest at elevations between 500 meters (1,640 feet) and 2,500 meters (8,200 feet), where mean annual rainfall is less than 2,500 millimeters (100 inches).

Wagner *et al.* (1990) report that although *Senecio mikanioides* occurs primarily on the Big Island, it is also found sparingly on Maui. It is known to be invading at least three sites on Maui, one in Kula, one near Makawao, and one at Olowalu. At the Kula site, the species has established within the past 10 years (Sandy Stoner, Kula resident, personal observation 1993) and spread rapidly along a gulch where it forms a nearly continuous mat over several acres. This species could invade large areas of leeward East and West Maui. In June 1994, A.C. Medeiros found that this species was being sold at a local garden store. Although the store and the supplier agreed to stop selling it, it appears that an organized campaign will be needed to prevent *Senecio mikanioides* from becoming irreversibly established and spreading on Maui.

Strawberry guava (*Psidium cattleianum*)

A shrub, small tree, or large tree, depending on density of stocking and habitat conditions, strawberry guava establishes dense stands from primarily pig-dispersed seed (Diong 1983) and tends to displace native species. Its elevation range in Haleakala National Park's Kipahulu Valley is 90-1,190 meters (300-3,900 feet), but it is currently abundant only up to about 975 meters (3,200

feet). It is moderately shade-tolerant and grows in nearly impenetrable thickets in Kipahulu at 460-760 meters (1,500-2,500 feet). Strawberry guava potentially threatens numerous middle-to low-elevation rainforest plant species with extirpation through displacement of reproduction. Species of Haleakala National Park that are particularly threatened in this way include *Antidesma platyphyllum*, *Claoxylon sandwicense*, *Joinvillea gaudichaudiana*, *Nothocestrum* cf. *longifolium*, *Psychotria mariniana*, *Sicyocarya umbellata*, and *Strongylodon ruber*. Most of these species are very near extinction (Loope, Nagata, and Medeiros 1992).

Strawberry guava reaches what is probably its current maximum development on Maui below Puu Ahulili (Southwestern portion of East Maui) where it occurs as high as 1,400 meters (4,600 feet). At 1,000-1,190 meters (3,300-3,900 feet) in this area, *P. cattleianum* occupies over 25% of the forest understory; up to 1,000 meters (3,270 feet), it occupies over 75% of the understory and rises into the canopy, attaining diameters of 30 centimeters (12 inches) and heights of 59 meters (18 meters) (James Jacobi, USFWS, personal communication 1980). On Haleakala's north slope, *P. cattleianum* reaches 1,190 meters (3,900 feet) below Puu o Kakai near Waikamoi Stream, and occurs above 970 meters (3,000 feet) at several other localities between there and Hana (J. Jacobi, personal communication 1986).

Australian tree fern (*Cyathea cooperi*)

Cyathea tree ferns have been in cultivation in the Hawaiian Islands at least since the 1960s as ornamentals at homes and botanical gardens. The widely cultivated species, *Cyathea cooperi*, is native to Queensland and New South Wales in eastern Australia. It is widely planted in Hawaii since it is a hardy, attractive species and is faster growing than native Hawaiian tree ferns (*Cibotium* spp.).

It has been recently discovered that populations of *C. cooperi* are invasive in ohia (*Metrosideros polymorpha*) and koa (*Acacia koa*) rainforests in Kipahulu Valley of Haleakala National Park (Medeiros *et al.* 1992). There are four known populations comprising over 1,000 individuals at 610-1,040 meters (2,000-3,410 feet) elevation. Even in nursery and house lot situations, *Cyathea cooperi* has a tendency to escape, often becoming established several hundred meters from the parent populations, especially in wet areas. This species is planted and locally naturalized at several tropical botanical nurseries near Hana, approximately 12 kilometers (7.5 miles) from the Kipahulu Valley populations. The species is also escaping from cultivation on Kauai (Medeiros *et al.* 1992).

The greatest threat that *C. cooperi* poses to Hawaiian forests is its displacement of native species where the fern has achieved high densities and local dominance of communities. Unlike native *Cibotium* tree ferns, *Cyathea* does not support the dense colonies of epiphytic native species that

often colonize the trunks of tree ferns (Medeiros, Loope, & Anderson 1993). Where *Cyathea* forms dense stands in Kipahulu, the understory is conspicuously open and lacking many characteristic native species. This lack of epiphytic natives is apparently due to exclusion of other species by the thick layering of fibrous roots that forms at the soil surface surrounding a growing tree fern. On large tree ferns of this species, this dense layer of near-surface roots may extend out over a diameter of 3.0-4.6 meters (10-15 feet), effectively excluding most other vegetation (Medeiros *et al.* 1992).

Within Haleakala National Park, an attempt is being made to control this alien species before it becomes extensively established. The known populations of *Cyathea cooperi* are being removed, cutting the taller ferns with chain saws and removing the growing tips of shorter-statured individuals. To date, this method appears highly effective in killing individuals of *C. cooperi*.

Miconia calvescens

Miconia calvescens (Melastomataceae), native to New World tropical forests at 300-1,800 meters (980-5,910 feet) elevation, is now known to be an unusually aggressive invader of moist island habitats. Introduced to Tahiti in 1937, dense thickets of *M. calvescens* had replaced the native forest over most of the island by the 1980s, with dramatic reduction of biological diversity. After the late F.R. Fosberg saw this species in Tahiti in 1971, he reported that "it is the one plant that could really destroy the native Hawaiian forest." Because of its attractive purple and green foliage, it was innocently introduced to Hawaii as an ornamental in the 1970s. After its detection on Maui by conservation agencies in 1990, an alarm was raised. Nearly 20,000 individuals of *M. calvescens* were removed from private lands by agency staff and volunteers in 1991-93, and control appeared feasible. However, in September 1993, an aerial vegetation survey discovered a previously undetected *Miconia* population on State land— far larger (over 100 hectares [250 acres]) than all previously known populations on Maui (R.W. Hobdy, personal communication 1993). An interagency working group, the Melastome Action Committee, was developed and began implementation of a containment strategy in January 1994, initially involving helicopter herbicide (Garlon 4) spraying of individual emergent *Miconia* trees and monitoring of results (see also Conant et al. 1997 and Medeiros et al. 1997).

Clidemia hirta

This densely branching shrub (up to 4 meters or 13 feet tall) is native to the Neotropics (southern Mexico and West Indies to Argentina). It has become an aggressive alien in many parts of Africa,

Asia, and the Pacific Islands. A particularly severe invasion in Fiji was controlled by the intentional introduction of a thrips (*Liothrips urichi*), which is native to Trinidad (Wester and Wood 1977). This same organism has been introduced to Hawaii but has proven effective in controlling *Clidemia* only in open (non-shaded) habitats. Other biological control agents, more recently brought to Hawaii, show promise of increased control (Smith 1992; Nakahara *et al.* 1992).

Clidemia was first introduced in the Hawaiian Islands on Oahu in 1941. Since then it has become very widespread on that island, dominating large areas of rainforest understories. It was first recognized as a pest in the Islands in the 1950s, at which time *Liothrips* was introduced. However, the severity of the problem was not generally recognized by government agencies until the 1970s. *Clidemia* seeds are believed to be dispersed by the abundant alien Japanese white-eye (*Zosterops japonicus*) (Wester and Wood 1977) and probably by other alien birds, but mongooses (*Herpestes auropunctatus*) disperse it as well (A.C. Medeiros, personal communication 1986). *Clidemia* was first noted on northern East Maui in 1977 (Nahiku District) and 1980 (Makaiwa District) on lands owned by the State of Hawaii and East Maui Irrigation Company. By 1988, *Clidemia* had spread along watercourses and established along the main Hana highway in numerous drainages (Medeiros *et al.* 1989). A single plant was found (and destroyed) by L. Cuddihy and G. Santos at 850 meters (2,800 feet) in Kipahulu Valley of Haleakala National Park in October 1988 (Anderson *et al.* 1992). By 1994, *Clidemia* was being controlled by hand-pulling in several sites within Kipahulu Valley. *Clidemia* can be expected to provide a major threat to rainforests below about 1,525 meters (5,000 feet) in the future, unless biocontrol agents are effective in limiting its aggressiveness.

Glorybush (*Tibouchina herbacea*)

This wet forest weed from South America grows to 3 meters (10 feet) tall and rapidly fills openings created by disturbance, crowding out any native species present. It is considered one of the worst threats to biological diversity in reserves of the West Maui Mountains where it invaded in the 1980s (Randall Bartlett, Maui Land and Pineapple, personal communication 1992; Paul Higashino, TNCH, personal communication 1992). As of early 1994, it was beginning to establish in Haleakala National Park's Kipahulu Valley, with potentially ominous consequences.

Firetree (*Myrica faya*)

One of the worst invaders in Hawaii Volcanoes National Park (Whiteaker and Gardner 1992), this tree from the Azores, Madeira, and the Canary Islands fixes nitrogen in root nodules and has

great potential for massive alteration of ecosystems (Vitousek 1992). A large infestation occurs on Haleakala's western slope, particularly in the Kula Forest Reserve at 975-1,950 meters (3,200-6,400 feet) elevation (Whiteaker and Gardner 1992).

Gorse (*Ulex europeus*)

On East Maui, this spiny shrub from Europe is abundant in the Olinda area, gets into the edge of Waikamoi Preserve, and reaches its upper elevation limit on Maui near the Haleakala National Park Headquarters at 2,140 meters (7,000 feet). Seed weevils and a flower-feeding caterpillar introduced for biocontrol reduce the reproductive potential of gorse by 73% on Maui (Markin 1984), but persistence of dormant seeds in the soil makes its control crucial before it becomes well-established in an area. A major gorse biocontrol program is underway. The high-elevation gorse population near the Haleakala National Park Headquarters is the only site on Maui where the biocontrol moth *Agonopterix ulicitella*, an eater of young shoots, is thriving (G. Markin, personal communication 1994). Three additional biocontrol agents were released in 1994.

Plum (*Bocconia frutescens*)

This bird-dispersed species in the family Papaveraceae is a large-leaved, soft-wooded shrub/tree (up to 6 meters or 20 feet tall) native to the neotropics. It has been on Maui at least since 1920 (Medeiros, Loope, and Chimera 1993), but is locally in a rapid phase of expansion. It thrives in the leeward 610-1220 meter (2,000-4,000 foot) elevation zone. Medeiros, Loope, and Chimera (1993) consider it a significant threat to Kanaio NAR on leeward East Maui.

Chinese banyan (*Ficus microcarpa*)

Chinese banyan is a strangling, aggressive invader on rocky walls of low-elevation stream courses, banks of irrigation ditches, and sea cliffs of windward Maui. It has become highly invasive in coastal East Maui relatively recently. Each of the world's 900+ *Ficus* species require a species-specific wasp for pollination (Ramirez 1970). The invasiveness of *F. microcarpa* on Maui is made possible by introduction to Hawaii of the agaonid wasp (*Pampristina verticillata*) which pollinates it in its native range in Asia. This specific pollinator was purposely introduced into Hawaii from the Philippines in 1920-21 as part of a reforestation scheme (Condit 1969; McKey and Kaufmann 1991).

APPENDIX I- 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, in preparation of recovery plans 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) (48 Federal Register 43098.

Degree of Threat	Recovery Potential	Taxonomy	Priority	Conflict
High	High	Monotypic genus	1	1/1C
		Species	2	2/2C
		Subspecies	3	3/3C
	Low	Monotypic genus	4	4/4C
		Species	5	5/5C
		Subspecies	6	6/6C
Moderate	High	Monotypic genus	7	7/7C
		Species	8	8/8C
		Subspecies	9	9/9C
	Low	Monotypic genus	10	10/10C
		Species	11	11/11C
		Subspecies	12	12/12C
Low	High	Monotypic genus	13	13/13C
		Species	14	14/14C
		Subspecies	15	15/15C
	Low	Monotypic genus	16	16/16C
		Species	17	17/17C
		Subspecies	18	18/18C