U.S. Fish and Wildlife Service

Final Recovery Plan

For Four Species of Hawaiian Ferns

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island Territories under U.S. administration.

RECOVERY PLAN FOR FOUR SPECIES OF HAWAIIAN FERNS

Published by

U.S. Fish and Wildlife Service

Portland, Oregon

Approved: _____
Regional Director, U.S. Fish & Wildlife Service

Date: 4/10/98

DISCLAIMER

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

LITERATURE CITATION:

U.S. Fish and Wildlife Service. 1998. Recovery Plan for Four Species of Hawaiian Ferns. U.S. Fish and Wildlife Service, Portland, OR. 78 pp.

ADDITIONAL COPIES MAY BE PURCHASED FROM:

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814

telephone: 301/492-6403 or 1-800-582-3421
fax: 301/564-4059
e-mail: fwrs@mail.fws.gov

Fees for plans vary depending on the number of pages.

ACKNOWLEDGMENTS

The Recovery Plan for Four Species of Hawaiian Ferns was prepared by Kevin Foster, U.S. Fish and Wildlife Service (USFWS), and Tanya Rubenstein, then of the USFWS, Pacific Islands Ecoregion, Honolulu, Hawaii. Invaluable assistance was provided by Joel Lau of the Nature Conservancy of Hawaii (TNCH), and Marie Bruegmann and Ron Salz (USFWS).

EXECUTIVE SUMMARY
FOR THE FOUR HAWAIIAN FERNS RECOVERY PLAN

Current Species Status: This plan covers four fern taxa that are listed as endangered, with numbers of known remaining individuals as follows (number of populations, number of individuals):
Asplenium fragile var. *insulare* (no common name) (9, 278)
Ctenitis squamigera (pauoa) (10, 100)
Diplazium molokaiense (no common name) (1,1)
Pteris lidgatei (no common name) (7, 33).

Current Distributions: *Diplazium molokaiense* is currently found only on Maui. The three other taxa are currently found on more than one island: *Asplenium fragile* var. *insulare* is on the islands of Hawaii and Maui; *Ctenitis squamigera* is on the islands of Oahu, Lanai, Molokai and Maui; and *Pteris lidgatei* is on Oahu and Maui.

Habitat Requirements: Three of the four endangered fern taxa have been reported from lowland forest habitat. *Ctenitis squamigera* is typically found in lowland mesic forests, and *Pteris lidgatei* appears to be restricted to lowland wet forest. *Diplazium molokaiense* has been reported from lowland to montane forests in mesic to wet settings. The fourth species, *Asplenium fragile* var. *insulare,* has been reported from montane wet, mesic and dry forest habitats as well as subalpine dry forest and shrubland habitat.

Limiting Factors: The four taxa and their habitats have been variously affected or are threatened by one or more of the following: habitat degradation and/or predation by feral or domestic animals (goats, pigs, cattle, sheep and deer); competition for space, light, water, and nutrients from alien plants; human impacts; and fire. In addition, these taxa are subject to an increased likelihood of extinction and/or reduced reproductive vigor from random naturally occurring (stochastic) events due to the small number of existing individuals and their very narrow distributions.

Recovery Objectives: Delisting. Interim and downlisting criteria are also provided to stabilize these taxa and downlist them to threatened status. Recovery efforts for the four fern taxa should focus on the establishment of management units and protection of habitat to make the most efficient use of resources.

Recovery Criteria: The following criteria may be revised as more information is obtained about the life history and population ecology of these taxa.

Interim

The interim objective is to stabilize all existing populations of the four fern taxa. To be considered stable, each taxon must be managed (e.g. by fencing, weeding) to control threats and be represented in an *ex situ* collection (a living collection away from its original site, such as at a botanical garden). In addition, at least three populations of each taxon should be documented on islands where they now occur or occurred historically. Each of these populations must be naturally reproducing and increasing in number, with a minimum of 50 mature individuals per population (minimum of 150 mature plants).

Downlisting

For downlisting, a total of five to seven populations of each taxon should be documented on islands where they now occur or occurred historically. Each of these populations must be naturally reproducing, stable or increasing in number, and secure with a minimum of 300 mature individuals per population. Each population should persist at this level for a minimum of five consecutive years before downlisting is considered.

Delisting

For delisting, a total of 8 to 10 populations of each taxon should be documented on islands where they now occur or occurred historically. Each population must be naturally reproducing, stable or increasing in number, and secure from threats, with a minimum of 300 mature individuals per population. Each population should persist at this level for a minimum of five consecutive years.

Actions Needed:

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

Total Estimated Cost of Recovery ($1,000's):

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	Total
1997	149	0	49	0	0	0	198
1998	191	0	49	0	0	0	240
1999	311	0	49	0	0	0	360
2000	311	2	49	25	0	0	387
2001	292	2	49	25	0	0	368
2002	286	0	17	25	10	15	328
2003	267	0	17	25	10	30	343
2004	267	0	17	25	0	15	318
2005	267	0	17	25	0	0	303
2006	267	0	17	25	0	0	303
2007	267	0	17	25	0	0	303
2008	267	0	17	25	0	0	303
2009	267	0	17	25	0	0	303
2010	267	0	17	25	0	0	303
2011	267	0	17	25	0	0	303
Total	3,943	4	415	300	20	60	4,742

Date of Recovery: Delisting should be initiated in 2011, if recovery criteria are met.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

A. Brief Overview

This recovery plan covers four Hawaiian ferns that were added to the Federal list of endangered and threatened species by a final rule published on September 26, 1994 (U.S. Fish and Wildlife Service [USFWS] 1994a). Much of the background information in this plan was taken directly from the final rule, although portions have been modified to include updated information.

Asplenium fragile var. *insulare* (no common name [NCN]), *Ctenitis squamigera* (pauoa), *Diplazium molokaiense* (NCN), and *Pteris lidgatei* (NCN) are all endemic (restricted) to the Hawaiian Islands (Figure 1). *Diplazium molokaiense* is currently extant only on Maui. The three other species are currently reported from more than one island: *Asplenium fragile* var. *insulare* is found on the islands of Hawaii and Maui; *Ctenitis squamigera* is known from the islands of Oahu, Lanai, Molokai and Maui; and *Pteris lidgatei* is known from Oahu and Maui.

The four taxa[1] and their habitats have been variously affected or are threatened by one or more of the following: habitat degradation and/or predation by feral or domestic animals; competition for space, light, water, and nutrients from alien plants; human impacts; and fire. In addition, these taxa are subject to an increased likelihood of extinction and/or reduced reproductive vigor from randomly occurring (stochastic) events due to the small number of existing individuals and their very narrow distributions.

The land that supports these four ferns is owned by the State of Hawaii, the Federal government, and private entities. State lands are administered by the

---

[1] **Taxon**, plural **taxa**. A term used in biological classification (taxonomy), meaning a group of organisms at any rank (in this recovery plan, the taxa are three species and a variety). Under the Endangered Species Act, subspecies and varieties may be listed as endangered or threatened "species." This plan refers interchangeably to the four fern taxa, four fern "species," or simply four ferns.

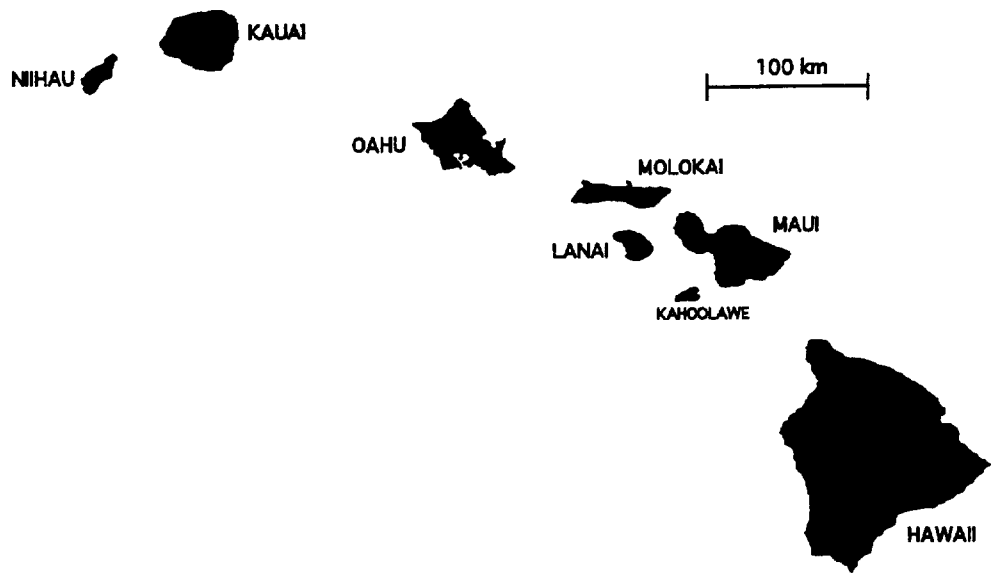

Figure 1. Map of the main Hawaiian islands.

Department of Land and Natural Resources (DLNR) (including the Natural Area Reserves System [NARS], Forest Reserves, and State Parks) and the Department of Hawaiian Home Lands (DHHL). Federally-owned land consists of Hawaii Volcanoes National Park (HAVO), Pohakuloa Training Area (PTA) on the island of Hawaii, and Schofield Barracks Military Reservation on Oahu. The latter two are under the jurisdiction of the U.S. Army.

This plan provides a framework for the recovery of these four ferns so that their protection by the Endangered Species Act (ESA) will no longer be necessary. This plan summarizes available information about each of the four ferns, reviews the threats posed to the ferns' continued existence, and prescribes management actions needed to remove these threats.

Immediate actions needed to prevent the extinction of these ferns include habitat protection through fencing to exclude ungulates, control of alien plants, and protection from fire. *Ex situ* propagation (propagation away from native habitat, as at a botanical garden) and augmentation of some populations may also be needed. Long-term activities necessary to perpetuate these taxa in their natural habitats include long-term monitoring and management and re-establishment of populations within their historic ranges. Research is needed on life history, limiting factors, habitat requirements, and minimum viable population size to help make appropriate management decisions.

B. General Description of Habitat

The vegetation of the Hawaiian Islands varies greatly according to elevation, moisture regime, and substrate. Major vegetation formations include forests, woodlands, shrublands, grasslands, herblands, and pioneer associations on lava and cinder substrates. There are lowland, montane, and subalpine forest types, and these forest types are further subdivided according to annual rainfall (dry, mesic and wet). Coastal and lowland forests are generally dry or mesic and may be open- or

closed-canopied, with the canopy generally less than 10 meters (30 feet) in height. Montane forests, occupying elevations between 500 and 2,700 meters (1,600 and 8,800 feet) are dry to mesic on the leeward (southwest) slopes of Maui and Hawaii. These forests may be open- to closed-canopied, and may exceed 20 meters (65 feet) in stature. On those islands, as well as Oahu and Lanai, mesic to wet montane forests occur on the windward (northeast) slopes and summits. At high montane and subalpine elevations, at elevations above 2,000 meters (6,500 feet), the forests are usually open-canopied, and form a mosaic with surrounding grasslands and shrublands. Subalpine forests and associated ecosystems exist only on East Maui and the island of Hawaii.

Three of the four endangered fern taxa have been reported from lowland forests. *Ctenitis squamigera* is typically found in lowland mesic forests, and *Pteris lidgatei* appears to be restricted to lowland wet forest. *Diplazium molokaiense* has been reported from lowland to montane forests in mesic to wet settings. *Asplenium fragile* var. *insulare* has been reported from montane wet, mesic and dry forest habitats as well as subalpine dry forest and shrubland habitat (Gagné and Cuddihy 1990). Table 1 summarizes the habitats of the four fern taxa and Table 2 summarizes the native and introduced species generally associated with each habitat type. A more detailed description of each taxon's habitat can be found in the individual species accounts.

Table 1. Summary of Habitat Types

Taxon	lowland mesic forest	lowland wet forest	montane dry forest	montane mesic forest	montane wet forest	subalpine dry forest/shrubland
Asplenium fragile var. *insulare*			X	X	X	X
Ctenitis squamigera	X					
Diplazium molokaiense	X	X		X	X	
Pteris lidgatei		X				

Table 2. Habitat Types and Associated Native and Alien Species

E=Endangered; **C**=Candidate - sufficient information is available to propose listing as endangered or threatened; **SOC**=Species of Concern - may require special management in the future but is not presently a candidate for listing. Current and/or former habitats of the four fern species overlap with a majority of other native and alien plant species found in Hawaii, including most other endangered, threatened, and rare species. Associated species listed below are limited to those that best characterize the immediate area of current habitat for the four fern species.

Habitat Type	Recovery Plan Species	Associated Native Species	Associated Alien Species
Lowland Mesic Forest elevation: 15-2,000 meters (50-6,500 feet) rainfall: 1,200-2,500 millimeters (48-100 inches)/year	*Ctenitis squamigera* *Diplazium molokaiense*	*Acacia koa* (koa) *Antidesma platyphyllum* (hame) *Bobea elatior* (ahakea lau nui) *Broussaisia arguta* (kanawao) *Charpentiera obovata* (papala) *Coprosma* spp. (pilo) *Cyrtandra* spp. (haiwale) *Dicranopteris linearis* (uluhe) *Diospyros sandwicensis* (lama) *Hedyotis* spp. (manono) *Hibiscus arnottianus* (kokio keokeo) *Metrosideros polymorpha* (ohia) *Myrsine* spp. (kolea) *Nestegis sandwicensis* (olopua) *Pipturus albidus* (mamaki) *Pisonia* spp. (papala kepau) *Pleomele halapepe* (hala pepe) *Poutaria sandwicensis* (alaa) *Psychotria* spp. (kopiko) © *Psydrax odoratum* (alahee) *Touchardia latifolia* (olona)	*Aleurites moluccana* (kukui) *Clidemia hirta* (Koster's curse) *Cordyline fruticosa* (ti) *Lantana camara* (lantana) *Myrica faya* (firetree) *Nephrolepis multiflora* (sword fern) *Psidium cattleianum* (strawberry guava) *Psidium guajava* (guava) *Rubus rosifolius* (thimbleberry) *Schinus terebinthifolius* (Christmas berry) *Syzygium cumini* (Java plum) *Toona ciliata* (Australian red cedar)

Table 2 (Continued)

Habitat Type	Recovery Plan Species	Associated Native Species	Associated Alien Species
Lowland Wet Forest elevation: 15-2,000 meters (50-6500 feet) rainfall: > 2,500 millimeters (100 inches)/year	*Diplazium molokaiense* *Pteris lidgatei*	*Acacia koa (koa)* *Antidesma platyphyllum* (hame) *Bobea* spp. (ahakea lau nui) *Cheirodendron trygynum* (olapa) *Cibotium* spp. (hapuu) *Cyrtandra* spp. (haiwale) *Dicranopteris linearis* (uluhe) *Diospyros sandwicensis* (lama) *Labordia tinifolia* (kamakahala) *Machaerina angustifolia* (uki) *Melicope* spp. *Metrosideros polymorpha* (ohia) *Myrsine fosbergii* (kolea) *Nestegis sandwicensis* (olopua) *Pisonia umbellifera* (papala kepau) *Psychotria* spp. (kopiko) *Touchardia latifolia* (olona)	*Aleurites moluccana* (kukui) *Clidemia hirta* (Koster's curse) *Cordyline fruticosa* (ti) *Piper methysticum* (awa) *Psidium cattleianum* (strawberry guava) *Rubus rosifolius* (thimbleberry)

Table 2 (Continued)

Habitat Type	Recovery Plan Species	Associated Native Species	Associated Alien Species
Montane Dry Forest elevation: 500 - 2,700 meters (1,600 - 8,800 feet) rainfall: <1,200 millimeters (48 inches)/year	*Asplenium fragile* var. *insulare*	*Chamaesyce* spp. (akoko) *Coprosma* spp. (pilo) *Dodonaea viscosa* (aalii) *Dubautia ciliolata* (naenae) *Exocarpus menziesii* (heau) *Myoporum sandwicense* (naio) *Myrsine lanaiensis* (kolea) *Nestegis sandwicensis* (olopua) *Nothocestrum breviflorum* (aiea) (**E**)* *Osteomeles anthyllidifolia* (ulei) *Melicope hawaiensis* (alani) (**SOC**) *Santalum paniculatum* (iliahi) *Sophora chrysophylla* (mamane) *Stenogyne microphylla* (NCN) *Streblus pendulinus* (aiai) *Styphelia tameiameiae* (pukiawe) *Vaccinium reticulatum* (ohelo) *Wikstroemia* spp. (akia) *Zanthoxylum hawaiiense* (ae) (**E**)*	*Pennisetum clandestinum* (kikuyu grass) *Pennisetum setaceum* (fountain grass)

*Recovery Plan for the Big Island Plant Cluster - September, 1996

Table 2 (Continued)

Habitat Type	Recovery Plan Species	Associated Native Species	Associated Alien Species
Montane Mesic Forest elevation: 500-2,700 meters (1,600-8,800 feet) rainfall: 1,200-2,500 millimeters (48-100 inches)/year	*Asplenium fragile* var. *insulare* *Diplazium molokaiense*	*Acacia koa* (koa) *Bobea elatior* (ahakea lau nui) *Dicranopteris linearis* (uluhe) *Hibiscus arnottianus* (kokio keokeo) *Labordia tinifolia* (kamakahala) *Machaerina angustifolia* (uki) *Metrosideros polymorpha* (ohia) *Microsorum spectrum* (NCN) *Myrsine fosbergii* (kolea) *Pisonia umbellifera* (papala kepau) *Psychotria* sp. (kopiko) *Touchardia latifolia* (olona)	*Aleurites moluccana* (kukui) *Clidemia hirta* (Koster's curse) *Piper methysticum* (awa) *Psidium cattleianum* (strawberry guava) *Schinus terebinthifolius* (Christmas berry)

Table 2 (Continued)

Habitat Type	Recovery Plan Species	Associated Native Species	Associated Alien Species
Montane Wet Forest elevation: 500-2,700 meters (1,600-8800 feet) rainfall: > 2,500 millimeters (100 inches)/year	*Asplenium fragile* var. *insulare* *Diplazium molokaiense*	*Antidesma platyphyllum* (hame) *Bidens sandvicensis* (kookoolau) *Broussaisia arguta* (kanawao) *Cheirodendron trygynum* (olapa) *Cyanea acuminata* (haha) (E)* *Cyrtandra* spp. (haiwale) *Dicranopteris linearis* (uluhe) *Dubautia laxa* (naenae pua melemele) *Hibiscus arnottianus* (kokio keokeo) *Labordia tinifolia* (kamakahala) *Machaerina angustifolia* (uki) *Metrosideros polymorpha* (ohia) *Microsorum spectrum* (NCN) *Myrsine fosbergii* (kolea) *Phyllanthus distichus* (pamakani mahu) *Pisonia umbellifera* (papala kepau) *Psychotria* spp. (kopiko)	*Aleurites moluccana* (kukui) *Casuarina equisetifolia* (common ironwood) *Clidemia hirta* (Koster's curse) *Cordyline fruticosa* (ti) *Paspalum conjugatum* (Hilo grass) *Psidium cattleianum* (strawberry guava) *Schinus terebinthifolius* (Christmas berry)

*Draft Recovery Plan for Oahu Plants - September 1997

Table 2 (Continued)

Habitat Type	Recovery Plan Species	Associated Native Species	Associated Alien Species
Subalpine Dry Forest/Shrubland elevation: 1,700-3,000 meters (5,500-9,800 feet) rainfall: <1,200 millimeters (48 inches)/year	*Asplenium fragile* var. *insulare*	*Asplenium trichomanes* *Carex wahuensis* *Coprosma ernodeoides* *Coprosma montana* *Deschampsia nubigena* *Dianella sandwicensis* *Dodonaea viscosa* (aalii) *Dubautia ciliolata* (naenae) *Gahnia gahniiformis* *Geranium cuneatum* (nohoanu) *Luzula hawaiiensis* *Metrosideros polymorpha* *Pellaea ternifolia* *Polypodium pellucidum* *Sophora chrysophylla* (mamane) *Styphelia tameiameiae* (pukiawe) *Tetramolopium humile* *Vaccinium reticulatum* (ohelo) *Wikstroemia* spp. (akia)	*Holcus lanatus* *Hypochoeris radicata* *Pennisetum setaceum* (fountain grass) *Plantago lanceolata*

C. General Life History

Although each of the four ferns in this plan has unique life history characteristics, little is known about these specific characteristics. This section summarizes general fern life history because this information can be useful for fern recovery efforts and point to future research needs.

Ferns have two distinct free-living stages. The sporophyte (spore-producing plant), is the familiar, conspicuous, and relatively long-lived fern plant, whereas the gametophyte stage (gamete-producing plant) is inconspicuous and usually short-lived. The sporophyte produces large numbers of wind-dispersed spores. Under the right environmental conditions, a spore can germinate to produce a gametophyte (or prothallus) (Cobb 1963, Stern 1988). Although spore production and dispersal may occur frequently, the establishment and persistence of gametophyte populations is strongly influenced by environmental conditions such as substrate moisture content, surface stability and other soil and microclimatic conditions (Peck *et al.* 1990).

Gametophytes produce two kinds of reproductive organ: antheridia (male, producing sperm) and archegonia (female, producing eggs). Ferns, unlike most seed plants, depends on external water for sexual reproduction. The sperm are not released until the antheridia are in contact with moisture, and the sperm swim from the male sex organs to the female organs for fertilization (Cobb 1963, Stern 1988). Most ferns, including the four in this plan, are homosporous, meaning that single spores have the ability to produce self-fertile, bisexual gametophytes under certain conditions, making it possible to have intragametophytic mating (self-fertilization within a single gametophyte) (Peck *et al.* 1990, Wagner 1995). Consequently, a single spore can start a whole colony of plants (Wagner 1995). Although more than one egg can be fertilized, only one zygote (fertilized egg) develops into the young sporophyte on the prothallus. The young sporophyte usually has small, simple

fronds during its first season of growth, but eventually develops into a mature spore-producing plant with full-sized fronds (Stern 1988).

Some ferns form natural soil spore banks where viable spores remain dormant while buried. Although more research is needed, particularly on tropical species, natural soil spore banks may have a role in the conservation of endangered ferns. The conservation possibilities include augmenting surviving populations and increasing genetic diversity, retrieving lost populations and/or stimulating regeneration from spore banks *in situ*. It may also be possible to culture soil samples from sites where survival is threatened. Many of these activities could be done without disturbing surviving plants or natural reproduction (Dyer 1994).

The requirement of external water for sexual reproduction, wind dispersal of spores, the capability of ferns to be homosporous, their two-phased life cycle, and perhaps other general life history characteristics of ferns, are important in designing recovery programs. Research on specific life history characteristics of the four ferns is recommended in this plan. Research is needed on spore dispersal, spore dormancy capability, optimal conditions for storage of spores in artificial spore banks, spore germination and gametophyte growth under natural and culture conditions, whole plant culture, breeding systems, bisexual and selfing potential, gametophyte and sporophyte ecology, and habitat requirements.

D. Overall Reasons for Decline and Current Threats

Native vegetation on all of the main Hawaiian Islands has undergone extreme alteration because of past and present land management practices including ranching, accidental and deliberate animal and plant introductions, and agricultural development (Cuddihy and Stone 1990, Wagner *et al.* 1985). Primary threats to the four endangered fern taxa include ongoing and threatened destruction and modification of habitat by feral animals and competition with alien plants.

1. Feral Ungulates

All four taxa are threatened by feral ungulates. Animals such as pigs (*Sus scrofa*), goats (*Capra hircus*), sheep (*Ovis aries*), cattle (*Bos taurus*) and axis deer (*Axis axis*) have been introduced to the Hawaiian Islands for food, commercial ranching activities, and as game animals. Over the years following introduction of these ungulates, their numbers have increased and their adverse impacts on native vegetation have become increasingly apparent (USFWS 1994a).

Goats were first introduced to Maui in 1793 (Stone and Loope 1987), and became established on other Hawaiian islands by the 1820s (Cuddihy and Stone 1990, Culliney 1988). By the mid-1800s the feral goat population was in the millions, in spite of an active trade in goatskins (Culliney 1988). Goats can reach more remote areas than other ungulates because of their agility (Culliney 1988). Feral goats now occupy a wide variety of habitats, from dry lowland forests to alpine grasslands, where they consume native vegetation, trample roots and seedlings, accelerate erosion, and promote the invasion of alien plants (Cuddihy and Stone 1990, Stone 1985, Stone and Loope 1987). Habitat degradation by goats threatens *Asplenium fragile* var. *insulare*, *Ctenitis squamigera*, and *Diplazium molokaiense* (USFWS 1994a).

Feral sheep have become firmly established on the island of Hawaii (Tomich 1986) since their introduction almost 200 years ago (Cuddihy and Stone 1990). Sheep roam the upper elevation dry forests of Mauna Kea (above 1,000 meters [3,300 feet]), causing damage similar to that of goats (Stone 1985). The presence of sheep at PTA contributes to the degradation of the habitat of *Asplenium fragile* var. *insulare* (USFWS 1994a).

Large-scale cattle ranching in the Hawaiian Islands began in the middle of the 19th century on the islands of Kauai, Oahu, Maui, and Hawaii. Ranches tens of thousands of acres in size developed on East Maui and Hawaii (Cuddihy and Stone 1990), where most of the State's large ranches still exist. Degradation of native

forests used for ranching activities became evident soon after full-scale ranching began. The negative impact of cattle on Hawaii's ecosystems is similar to that described for goats and sheep (Cuddihy and Stone 1990, Stone 1985). Cattle threaten *Asplenium fragile* var. *insulare* and *Diplazium molokaiense* (USFWS 1994a; R. Hobdy, Division of Forestry and Wildlife (DOFAW), personal communication 1995).

Feral pigs have invaded primarily wet and mesic forests and grasslands of Kauai, Oahu, Molokai, Maui, and Hawaii. Pigs damage the native vegetation by rooting and trampling the forest floor, and encourage the expansion of alien plants in the newly tilled soil (Stone 1985). Pigs also transport alien plant seeds through their feces and on their bodies, accelerating the spread of alien plants through native forest (Cuddihy and Stone 1990, Stone 1985). All four ferns in this plan are threatened by feral pigs.

Axis deer were first introduced to the Hawaiian Islands in 1868 as a game animal on Molokai, later to Oahu and Lanai, and finally to East Maui in 1960. Deer browse on native vegetation, promoting habitat degradation. Their trampling removes ground cover, compacts the soil, promotes erosion, and opens areas, allowing alien plants to invade (Cuddihy and Stone 1990, Culliney 1988, Scott *et al.* 1986, Tomich 1986). Considerable damage has been done to the forests on Molokai and Lanai by deer (Cuddihy and Stone 1990, Culliney 1988, Scott *et al.* 1986, Tomich 1986). Extensive erosional scars caused by decades of deer activity are evident on Lanai. Axis deer are presently actively managed for recreational hunting on Molokai and Lanai by the State Department of Land and Natural Resources, and hunting is allowed only during two months of the year. Axis deer are a threat to populations of *Ctenitis squamigera* on Lanai, and the range of the axis deer is rapidly expanding on East Maui, posing a potential threat to *Diplazium molokaiense* (USFWS 1994a; R. Hobdy, personal communication 1995).

2. Competition from Alien Plant Species

All four endangered ferns are threatened by alien plants. Naturalized, introduced plants compete with native plants for space, light, water and nutrients (Cuddihy and Stone 1990). The alien plants described below are some of the worst threats to native ecosystems.

Clidemia hirta (Koster's curse), a noxious shrub first reported on Oahu in 1941, had spread through much of the Koolau Mountains by the early 1960s, and spread to the Waianae Mountains by 1970 (Cuddihy and Stone 1990). This shrub replaces native plants of the forest understory and poses a serious threat to the population of *Pteris lidgatei* located in the Koolau Mountains and populations of *Ctenitis squamigera* in the Waianae Mountains (HHP 1991; USFWS 1994a).

Schinus terebinthifolius (Christmas berry) has invaded the dry to mesic lowland regions of the Hawaiian Islands. Christmas berry forms dense thickets that shade out and displace other plants (Cuddihy and Stone 1990). It negatively affects both of the Oahu populations of *Ctenitis squamigera*, the West Maui population, and one of the Lanai populations (HHP 1991, USFWS 1994a).

Psidium cattleianum (strawberry guava), a shrub or small tree, has become naturalized on all of the main Hawaiian Islands except Niihau and Kahoolawe. Like Christmas berry, strawberry guava forms dense stands that exclude other plants (Cuddihy and Stone 1990). It grows primarily in mesic and wet habitats and provides food for alien animals, including feral pigs and game birds, which disperse its seeds through the forest (Smith 1985, Wagner et al. 1985). Strawberry guava is one of the greatest alien plant threats to Hawaii's wet forests. It is known to pose a direct threat to the populations of *Ctenitis squamigera* in the Waianae Mountains on Oahu (USFWS 1994a). It also threatens the populations of *Ctenitis squamigera* on Lanai and East Maui (HHP 1991, USFWS 1994a).

Pennisetum setaceum (fountain grass) is a fire-adapted bunch grass that has spread rapidly over bare lava flows and other open areas on the island of Hawaii

since its introduction in the early 1900s. Fountain grass is particularly detrimental to Hawaii's dry forests because it invades areas dominated by native plants, where it interferes with plant regeneration, carries fire, and increases the likelihood of fires (Cuddihy and Stone 1990, Smith 1985). Fountain grass is invading native vegetation at PTA and threatens *Asplenium fragile* var. *insulare* (USFWS 1994a).

Toona ciliata (Australian red cedar) is a fast-growing tree that has been extensively planted and has become naturalized in mesic to wet forests (Wagner *et al.* 1990). This tree threatens populations of *Ctenitis squamigera* in the Waianae Mountains of Oahu (HHP 1991; USFWS 1994a). Those same populations are threatened by *Syzygium cumini* (Java plum), a large evergreen tree that forms a dense cover, excluding other taxa. Java plum is an aggressive invader of undisturbed lowland mesic and dry forests (Smith 1985).

Myrica faya (firetree) has attracted a great deal of attention and concern for its recent explosive increase on several Hawaiian islands. It is capable of forming a dense, nearly monospecific stand (Cuddihy and Stone 1990). Because of its ability to fix nitrogen, it outcompetes native plants and enriches the soil so that other alien plants can invade (Wagner *et al.* 1990). The Lanai populations of *Ctenitis squamigera* are threatened by the invasion of firetree (HHP 1991, USFWS 1994a).

Although not yet widespread in the Hawaiian Islands, *Cinnamomum burmanii* (Padang cassia) could become a dominant component of Hawaiian mesic forests (USFWS 1994a). A dense and enlarging stand of it threatens a population of *Ctenitis squamigera* on Lanai (HHP 1991).

3. Human Impacts

Although it is not currently known to be a factor, unrestricted 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 *Diplazium molokaiense* and *Pteris lidgatei,* each of which numbers fewer than 50

individuals and fewer than 10 populations. Excessive visits by humans could promote erosion and greater ingression of alien plants. Habitat disturbance caused by military activities, such as construction and road building, could also detrimentally affect *Asplenium fragile* var. *insulare* at PTA (Shaw 1992).

4. Small Number of Populations and Individual Plants

The small number of populations and of individual plants of these taxa increases the potential for extinction from random (stochastic) events. The limited gene pool may depress reproductive vigor, or a single human-caused or natural environmental disturbance could destroy a significant portion of the individuals. *Diplazium molokaiense* is currently known from only a single population consisting of one individual. The other three endangered taxa are estimated to number no more than 300 known individuals.

5. Fire

Fire is a potential threat to two of the endangered fern taxa growing in dry to mesic habitats. Because Hawaii's native plants have evolved with only infrequent, naturally occurring episodes of fire, most are not adapted to fire and are unable to recover well after recurring fires. Alien plants are often more fire-adapted than native taxa and will quickly exploit suitable habitat after a fire (Cuddihy and Stone 1990).

On Oahu, fire is a potential threat to the populations of *Ctenitis squamigera* in the Waianae Mountains because of the dry conditions of the forest as well as its proximity to urban areas. In addition, some *Ctenitis* populations are located near an area currently used as a military firing range. Fires originating on the firing range have the potential of spreading into the native forest habitat (USFWS 1994a). On the island of Hawaii, fire is a potential threat to the population of *Asplenium fragile*

var. *insulare* at PTA (USFWS 1994a), where the military conducts exercises using live ammunition. The presence of fountain grass at PTA increases the potential of fire.

E. Overall Conservation Efforts

The four fern taxa included in this plan were listed as endangered on September 26, 1994 (USFWS 1994a). Their Federal listing as endangered has afforded each the protection of the Endangered Species Act. When a species is listed as endangered or threatened under the ESA, it is automatically added to the State of Hawaii's list of protected species (Hawaii Revised Statutes Chapter [HRS] 195D). Hawaii State law prohibits taking of endangered flora and encourages conservation by State government agencies. ("Take" as defined by Hawaii State law means "to harass, harm . . . , wound, kill . . . , or collect endangered or threatened . . . species . . . or to cut, collect, uproot, destroy, injure, or possess endangered or threatened . . . species of . . . land plants, or to attempt to engage in any such conduct" [HRS 195D]). Further, the State may enter into agreements with Federal agencies to administer and manage any area required for the conservation, management, enhancement, or protection of endangered species (HRS, Sect. 195D-5(c)). Funds for these activities could be made available under Section 6 of the Federal Endangered Species Act (State Cooperative Agreements). The ESA reinforces State protection of these taxa. It is a violation of the ESA for any person to remove, cut, dig up, or damage or destroy an endangered plant in an area not under Federal jurisdiction in knowing violation of any State law or regulation or in the course of any violation of a State criminal trespass law [Section 9(a)(2) of the ESA].

Critical habitat was not designated for any of the four Hawaiian fern taxa. Such designation 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 (USFWS 1994a).

Section 7(a) of the Act, as amended, requires Federal agencies to evaluate their actions with respect to any species that is proposed or listed as endangered and with respect to its critical habitat, if any is being designated. Regulations implementing the interagency cooperation provision of the Act are codified at 50 CFR Part 402. Section 7(a)(2) requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of an endangered species or to destroy or adversely modify its critical habitat. If a Federal action may affect a listed species or its critical habitat, the responsible Federal agency must enter into formal consultation with the Service.

Three of this plan's fern taxa are currently found on lands owned or managed by the Federal government, where Federal law protects all plants from damage or removal. One taxon (*Asplenium fragile* var. *insulare*) is found in Hawaii Volcanoes National Park. Three taxa are on lands under the jurisdiction of the U.S. Army (Makua Military Reservation, Schofield Barracks Military Reservation, PTA and Kawailoa Training Area). The Army is aware of the ferns' presence and location on these installations, and any Federal activities that may affect their continued existence will be addressed through the Section 7 consultation process. Preliminary draft management plans have been developed for all of these U.S. Army managed areas. They highlight the specific threats to endangered plants and recommend actions to promote recovery (U.S. Army 1997a, U.S. Army 1997b) (Christina Crooker, USFWS, 1998).

Additional conservation efforts for the four ferns are described in the individual species accounts.

F. Overall Recovery Strategy

Immediate actions must be taken to stabilize the remaining populations of the four fern taxa. These actions include propagation and maintenance of genetic stock *ex situ,* and protection of remaining wild individuals from threats. Current threats to these taxa can be managed through fencing and/or hunting to control ungulates, control of alien plants, protection from fire and human disturbance, and a comprehensive monitoring program. Additional surveys are also needed to find additional individuals and/or populations of these species that may exist in former habitats, or may be present in areas that have not been surveyed recently.

Secondly, landowners and managers should delineate management units to conserve these taxa and preserve as many native species as possible, through threat control and habitat restoration programs.

A program is also needed to augment very small populations and establish new populations within the species' historical ranges. This program will 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 the stock, preparation of sites, and monitoring and maintenance of new individuals and populations as they are established.

To ultimately recover the listed plant taxa in Hawaii, habitat must be protected and managed for natural expansion of existing populations, as well as for reintroduction of these plants into portions of their former ranges. Maps of habitats essential for the recovery of listed species in Hawaii have been published by the Recovery Plan for Multi-Island Plants (U.S. Fish and Wildlife Service 1998). These maps may be used by land owners and managers to identify priority areas for management and restoration and for wide-range planning purposes.

A research program for each taxon is also recommended to study its life history, habitat requirements, limiting factors and parameters of viable populations. The results will be applied to improve management practices.

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

Currently, recovery for certain populations of these four fern taxa is partially addressed by six recovery plans developed for other species. These plans are valuable references, providing additional information about associated species and threats to the habitat as well as needed recovery actions. Eventually, this recovery plan may be combined with other recovery plans to produce coordinated master plans for recovery of plant taxa in particular island ecosystems, including a comprehensive analysis of the threats to those ecosystems and species-by-species analyses of recovery actions needed for stabilization and recovery. Species can then be grouped within ecosystem types, and projects can be developed that will benefit multiple species with a single recovery action. Table 3 summarizes the plant recovery plans that are relevant to current populations of each taxon (USFWS 1994b, 1995b, 1996a, 1996b, 1996c, 1997). Additional information in these plans relevant to specific populations of the four fern taxa is contained in the individual species accounts.

Table 3. Summary of Relevant Plant Recovery Plans

Taxon	Big Island Cluster (1996b)	Lanai Cluster (1995a)	Koolau Cluster (1996c)	Maui Cluster (1997)	Molokai Cluster (1996d)	*Haplostachys haplostachya* and *Stenogyne angustifolia* (1994b)	Waianae Cluster (1995c)
Asplenium fragile var. *insulare*	X			X		X	
Ctenitis squamigera		X		X	X		X
Diplazium molokaiense				X			
Pteris lidgatei			X	X			

G. Species Accounts

1. ***Asplenium fragile* var. *insulare*** - RP# 6C (See Appendix C for a description of the Recovery Priority System)

a. Description and Taxonomy (See Figure 2 for a line drawing of this taxon)

The Hawaiian plants now referred to as *Asplenium fragile* var. *insulare* were considered by William Hillebrand (1888) to be conspecific with *Asplenium fragile* from Central and South America. The Hawaiian plants were subsequently treated as a distinct endemic species, *Asplenium rhomboideum* Brack. (Robinson 1913). However, that species is now considered native to the New World and not present in Hawaii. The name *Asplenium fragile* var. *insulare* was published in 1947, as the Hawaiian plants were considered distinct at the varietal level from the extra-Hawaiian plants (Morton 1947).

Asplenium fragile var. *insulare*, a member of the spleenwort family (Aspleniaceae), is a fern with a short suberect stem. The leaf stalks are 5 to 15 centimeters (2 to 6 inches) long. The main axis of the frond is dull gray or brown, with two greenish ridges. The fronds are thin-textured, bright green, long and narrow, 23 to 41 centimeters (9 to 16 inches) long, 2 centimeters (0.8 inches) wide above the middle, and pinnate with 20 to 30 pinnae (leaflets) on each side. The pinnae are rhomboidal, 0.8 centimeters (0.3 inches) wide, and notched into two to five blunt lobes on the side towards the tip of the frond. The sori (spore-producing bodies) are close to the main vein of the pinna, with one to two on the lower side and two to four on the upper side (Hillebrand 1888, Wagner and Wagner 1992). The Hawaiian fern species most similar to *Asplenium fragile* var. *insulare* is *Asplenium macraei*. The two can be distinguished by a number of characters, including the size and shape of the pinnae and the number of sori per pinna (Wagner and Wagner 1992).

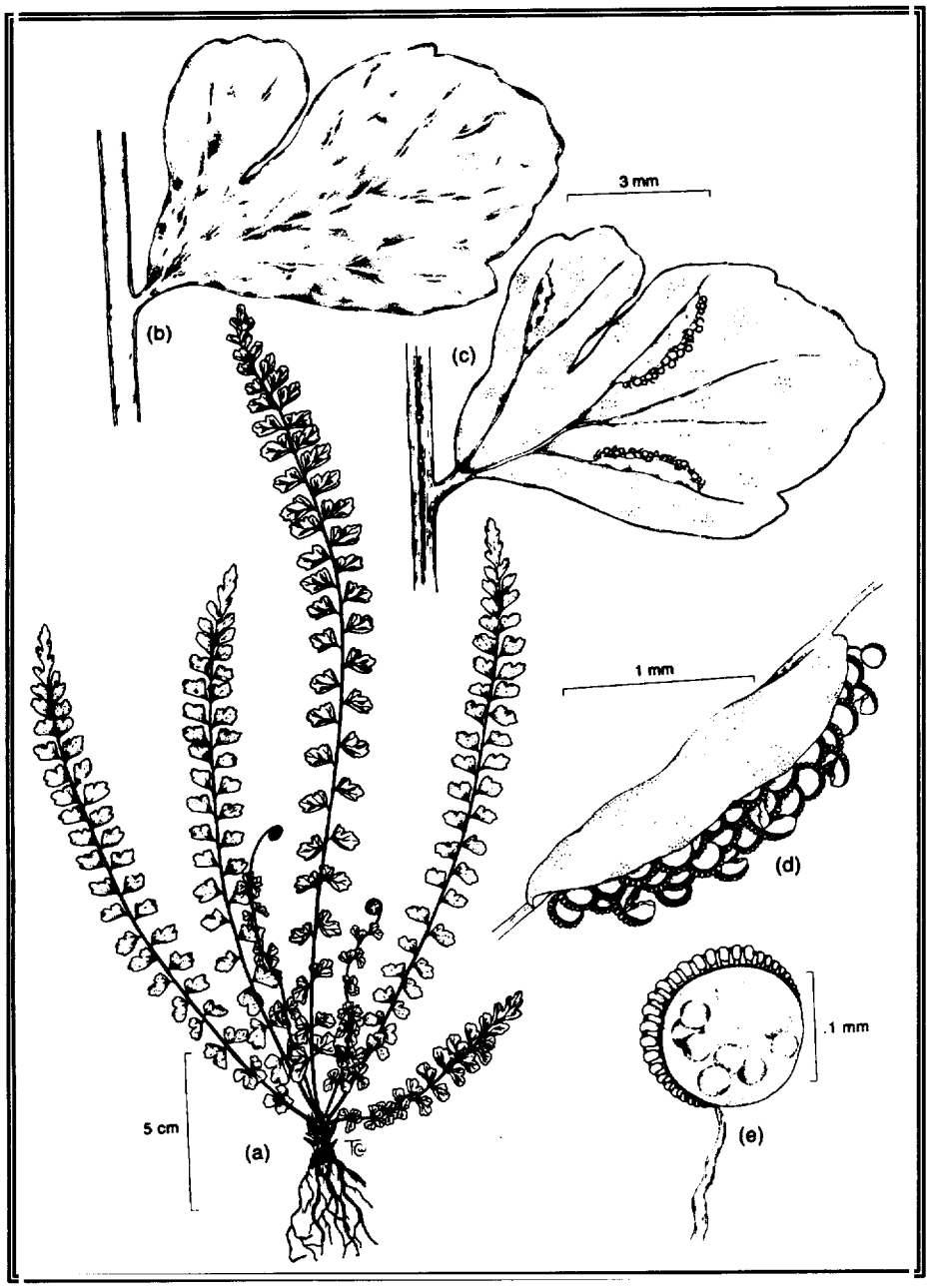

Figure 2. Line drawing of *Asplenium fragile* var. *insulare* (Tracy Wager, Center for Environmental Management of Military Lands, Colorado State University) (Shaw 1992).

b. Life History

Little life history information is available for this taxon. Reproductive cycles, longevity, specific environmental requirements and limiting factors are unknown.

Researchers have sampled plots in six subpopulations at PTA in order to describe the populations (e.g., species composition, extent of cover, age-class structure). No gametophytes were found, and the age-class structure of the populations sampled was determined to be 100 per cent reproductive adults because all the sporophytes had sori on some fronds (Shaw 1992).

c. Historic and Current Ranges and Population Status (See Figure 3 for a map of the historic and current populations of *Asplenium fragile* var. *insulare*).

Asplenium fragile var. *insulare* was known historically from East Maui, where it was recorded from the north slope of Haleakala and Kanahau Hill (HHP 1995a6, Hillebrand 1888). On the island of Hawaii, the taxon was found historically below Kalaieha, Laumaia, Keanakolu and Umikoa on Mauna Kea (HHP 1995a8, 1995a12, 1995a14 and 1995a15), Puuwaawaa on Hualalai (HHP 1995a4), west of Keawewai, above Kipuka Ahiu on Mauna Loa (HHP 1995a3, 1995a5), and near Hilo (HHP 1995a2).

This taxon is currently known from eight populations on Hawaii between 1,600 and 2,380 meters (5,250 and 7,800 feet) elevation (HHP 1995a7, Shaw 1992). An additional population was recently reported from East Maui, in Hanawi NAR (Frederick R. Warshauer, Biological Resources Division, U.S. Geological Survey [BRD], personal communication 1995). The extant populations on the island of Hawaii are located at Puu Huluhulu, Pohakuloa Training Area (nine subpopulations), Kulani Correctional Facility, Keauhou, the Mauna Loa Strip

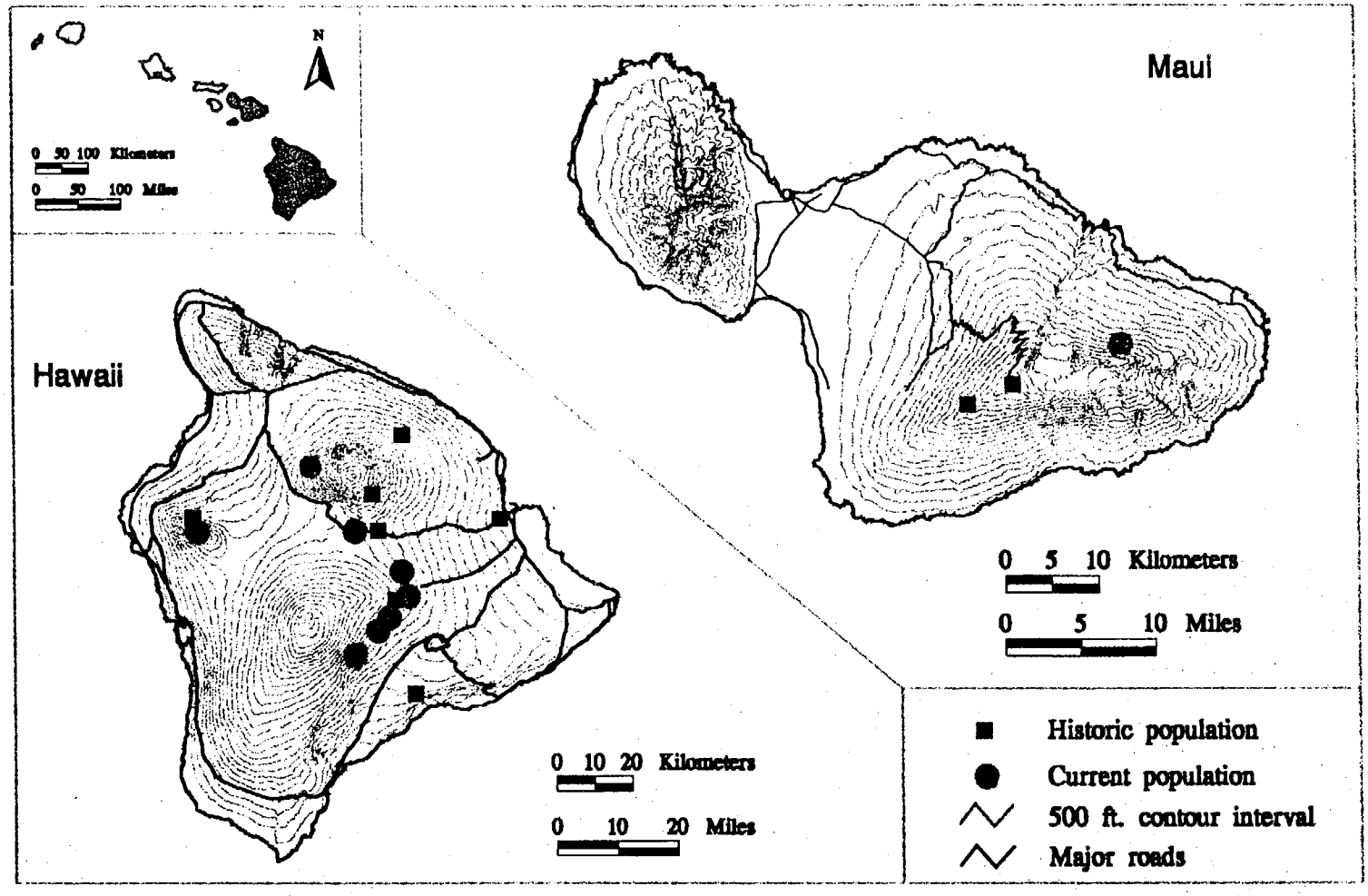

Figure 3. Historic and Current Populations of *Asplenium fragile* var. *insulare* (Islands of Hawaii and Maui).

Road in Hawaii Volcanoes National Park, Kapapala Forest Reserve, Kau Forest Reserve and the summit area of Hualalai (HHP 1995a1, HHP 1995a7, HHP 1995a9 to HHP 1995a14, HHP 1995a16; Shaw 1992; USFWS 1994a; and Joel Lau, The Nature Conservancy of Hawaii [TNCH], personal communication 1995). The population at PTA is the largest and is currently estimated to be approximately 200 individuals. The most recent monitoring at PTA revealed a slight reduction in numbers from 1992 (Mick Castillo, formerly with the Colorado State University Center for Ecological Management of Military Lands, personal communication 1995). The nine known populations total approximately 278 plants (USFWS 1994a; M. Castillo, personal communication 1995). These populations are on Federal, State, and private land.

d. Habitat Description

On the island of Hawaii, this fern is found in *Metrosideros* (ohia) Dry Montane Forest, *Dodonaea* (aalii) Dry Montane Shrubland, *Myoporum/Sophora* (naio/mamane) Dry Montane Forest (Shaw 1992), Ohia/*Acacia* (koa) Forest (HHP 1995a9) as well as Subalpine Dry Forest and Shrubland (Gagné and Cuddihy 1990). *Asplenium fragile* var. *insulare* grows almost exclusively in lava tubes, pits, deep cracks, and lava tree molds, with at least a moderate soil or ash accumulation, associated with mosses and liverworts. Infrequently, this fern has been found growing on the interface between younger aa lava flows and much older pahoehoe lava or ash deposits (Shaw 1992; F. Warshauer, personal communication 1995). The population recently found on Maui is growing in Montane Wet Ohia Forest in a rocky gulch with other species of ferns (F. Warshauer, personal communication 1995).

Although this taxon is found in habitats with three different moisture regimes (dry, mesic and wet), the microhabitat for *Asplenium fragile* var. *insulare* is fairly consistent. The fern generally occurs in areas that are moist and dark. This

taxon appears to have a naturally patchy distribution because of its relatively specialized habitat requirements (F. Warshauer, personal communication 1995).

e. Reasons for Decline and Current Threats

The primary threats to *Asplenium fragile* var. *insulare* are feral sheep and goats. On the island of Hawaii, feral goats are present in large numbers within PTA in the saddle between Mauna Loa and Mauna Kea, where they threaten *Asplenium fragile* var. *insulare* through habitat degradation as well as direct browsing on the plants (R. Shaw, in litt., 1993; USFWS 1994a). Predation by feral goats and/or sheep has been reported for *Asplenium fragile* var. *insulare* at PTA (Shaw 1992; R. Shaw, in litt., 1993; M. Castillo, personal communication 1995). Because no colonies have been completely decimated by the animals, apparently goats do not seek out this fern. However, further predation may occur if their preferred forage is not available. Predation by feral goats is a potential threat to the other two sizable known populations of this fern at Keauhou and Kulani because goats can feed on the ferns at the entrance to lava tubes (USFWS 1994a). Hawaii Volcanoes National Park is fenced at the 2,330 meter (7,000 foot) level, so goats should not be in the vicinity of the Mauna Loa strip population, which is near 6,500 feet (USFWS 1994a).

At least one population at PTA is threatened by military operations and/or fires resulting from these operations (USFWS 1994a), and construction due to military activities could also affect populations at this military installation (USFWS 1994a). Another threat to *Asplenium fragile* var. *insulare* at PTA is the alien plant fountain grass (USFWS 1994a).

Populations of *Asplenium fragile* var. *insulare* are threatened by the bulldozing of jeep roads and filling in of lava tubes (Linda Pratt, BRD, personal communication 1995). Also of concern is the small number of existing individuals,

which make it possible that random population fluctuations or mortality could result in the extinction of this taxon.

f. Conservation Measures

The Army has prepared a Preliminary Endangered Species Management Plan for PTA (U.S. Army 1997b). The Army is also presently consulting with the USFWS under section 7 of the Endangered Species Act, and negotiations are underway to control threats and promote the recovery of endangered species at PTA (Elizabeth Sharpe, USFWS, personal communication 1995).

The USFWS has a cooperative agreement for the management of Kilauea and Kulani forests with Kamehameha Schools/Bishop Estate, Hawaii Department of Land and Natural Resources, Hawaii Department of Public Safety/Corrections Division, and the National Park Service (Ron Walker, USFWS, personal communication 1996). One portion of Kulani Forest with a population of *Asplenium fragile* var. *insulare* has been fenced and the ungulates removed (Tanya Rubenstein, National Park Service, personal communication 1998).

g. Needed Recovery Actions

The most important recovery action for this taxon is to protect high elevation lava tubes, including removal of feral animals (L. Pratt, personal communication 1995). The areas that are most important for protection include PTA, Keahou and Kulani Forests and portions of Kapapala and Kau Forest Reserves (L. Pratt and F. Warshauer, personal communications 1995). A portion of Kapapala and Kau Forest Reserves important for protection of *Asplenium fragile* var. *insulare* and other native plants has been proposed, but not yet officially recommended, as a potential NAR (Waihaka NAR) (Betsy Gagné, DOFAW, personal communication 1995). The establishment of a NAR at Waihaka and

protection of habitat for *Asplenium fragile* var. *insulare* are much-needed recovery actions for this taxon.

The Army should implement actions proposed in their Preliminary Endangered Species Management Plan for PTA. These actions include controlling feral animals, minimizing the impact of training activities, monitoring of known populations, and controlling fires and fountain grass (U.S. Army 1997b).

Surveys to locate and map additional populations are also important to the recovery of this taxon. For example, many areas at PTA have not been surveyed for biological resources, so the current level of survey coverage should be considered incomplete (U.S. Army 1997b). *Asplenium fragile* var. *insulare* has a very scattered distribution and surveys will help determine the best areas for habitat protection. Optimal survey areas can be determined by considering the age of the substrate and the vegetation type (F. Warshauer, personal communication 1995). Please refer to the Stepdown Narrative section on page 47of this plan for the overall recovery strategy.

2. ***Ctenitis squamigera*** - RP# 8

a. Description and Taxonomy (See Figure 4 for a line drawing of this taxon)

Ctenitis squamigera was first published as *Nephrodium squamigerum* by Hooker and Arnott in 1832. The species was subsequently placed in the genera *Lastraea*, *Aspidium*, and *Dryopteris*. In 1957 it was transferred to the genus *Ctenitis*, resulting in the currently accepted combination *Ctenitis squamigera* (Degener and Degener 1957).

Ctenitis squamigera is a member of the wood fern family (Dryopteridaceae) (Wagner and Wagner 1992). It has a rhizome (horizontal stem) 5 to 10 millimeters (0.2 to 0.4 inches) thick, creeping above the ground and densely covered with scales similar to those on the lower part of the leaf stalk. The leaf stalks are 20 to 60 centimeters (8 to 24 inches) long and densely clothed with tan-colored scales up to

1.8 centimeters (0.7 inches) long and 1 millimeter (0.04 inch) wide. The leafy part of the frond is deltoid to ovate-oblong, dark green, thin, and twice-pinnate to thrice pinnatifid (leaflet sections). The sori are tan-colored when mature and are in a single row one-third of the distance from the margin to the midrib of the ultimate segments (Degener and Degener 1957). The indusium is whitish before wrinkling, thin, suborbicular with a narrow sinus extending about half way, glabrous except for a circular margin which is ciliolate with simple several-celled glandular and nonglandular hairs arising directly from the margin or from the deltoid base (Degener and Degener 1957).

Ctenitis squamigera can be readily distinguished from other Hawaiian species of *Ctenitis* by the dense covering of tan-colored scales on its frond (Wagner and Wagner 1992).

b. Life History

Reproductive cycles, longevity, specific environmental requirements and limiting factors are unknown.

c. Historic and Current Ranges and Populations Status (See Figures 5 and 6 for maps of the historic and current populations of *Ctenitis squamigera*)

Historically, *Ctenitis squamigera* was recorded from above Waimea on Kauai (HHP 1995b3); Kaluanui, southeast of Kahana Bay, Pauoa, Nuuanu, Niu, and Wailupe in the Koolau Mountains of Oahu (HHP 1995b4, 1995b5, 1995b9 to 1995b12); Mt. Kaala NAR and Schofield Barracks in the Waianae Mountains of Oahu (HHP 1995b2, HHP 1995b14); at Kaluaaha Valley on Molokai (HHP 1995b6); in the mountains near Koele on Lanai (HHP 1995b7); in the Honokohau Drainage on West Maui (HHP 1995b1); at Manawainui Stream on East Maui (HHP 1995b8); and at "Kalua" (Kailua?) on the island of Hawaii (HHP 1995b13).

Figure 4. Line drawing of *Ctenitis squamigera* (Degener and Degener 1957)

The 10 populations that have been observed within the last 20 years are in the Waianae Mountains of Oahu, Lanai, East and West Maui and Molokai. The Waianae Mountain populations are in Makaleha Valley, Kaawa Gulch, Maku Valley and Waianae Kai Forest Reserve (HHP 1995b14 to HHP 1995b17; J. Lau, personal communication 1995). On Lanai, *Ctenitis squamigera* is known from the Waiapaa-Kapohaku area on the leeward side of the island, and Lopa Gulch and Waiopa Gulch on the windward side (HHP 1991; HHP 1995b18 to HHP 1995b20). The West Maui populations are in Iao Valley and Kapunakea Preserve (J. Lau, personal communication 1995). The Molokai populations is in Wawaia Gulch (J. Lau, personal communication 1995). The 10 populations are on State, Federal, and private land and total approximately 100 individuals (J. Lau, personal communication 1995).

d. Habitat Description

This species is found in the forest understory at elevations of 380 to 915 meters (1,250 to 3,000 feet) (HHP 1991, 1995b8), in Ohia/*Diospyros* (lama) Mesic Forest and Diverse Mesic Forest (HHP 1991). Associated native plants include *Myrsine* (kolea), *Psychotria* (kopiko), and *Xylosma hawaiiense* (maua) (HHP 1991, USFWS 1994a).

e. Reasons for Decline and Current Threats

The primary threats to *Ctenitis squamigera* are habitat degradation by feral pigs, goats, and axis deer; competition with alien plants, especially strawberry guava and Christmas berry; fire; and stochastic extinction due to the small number of existing populations and individuals.

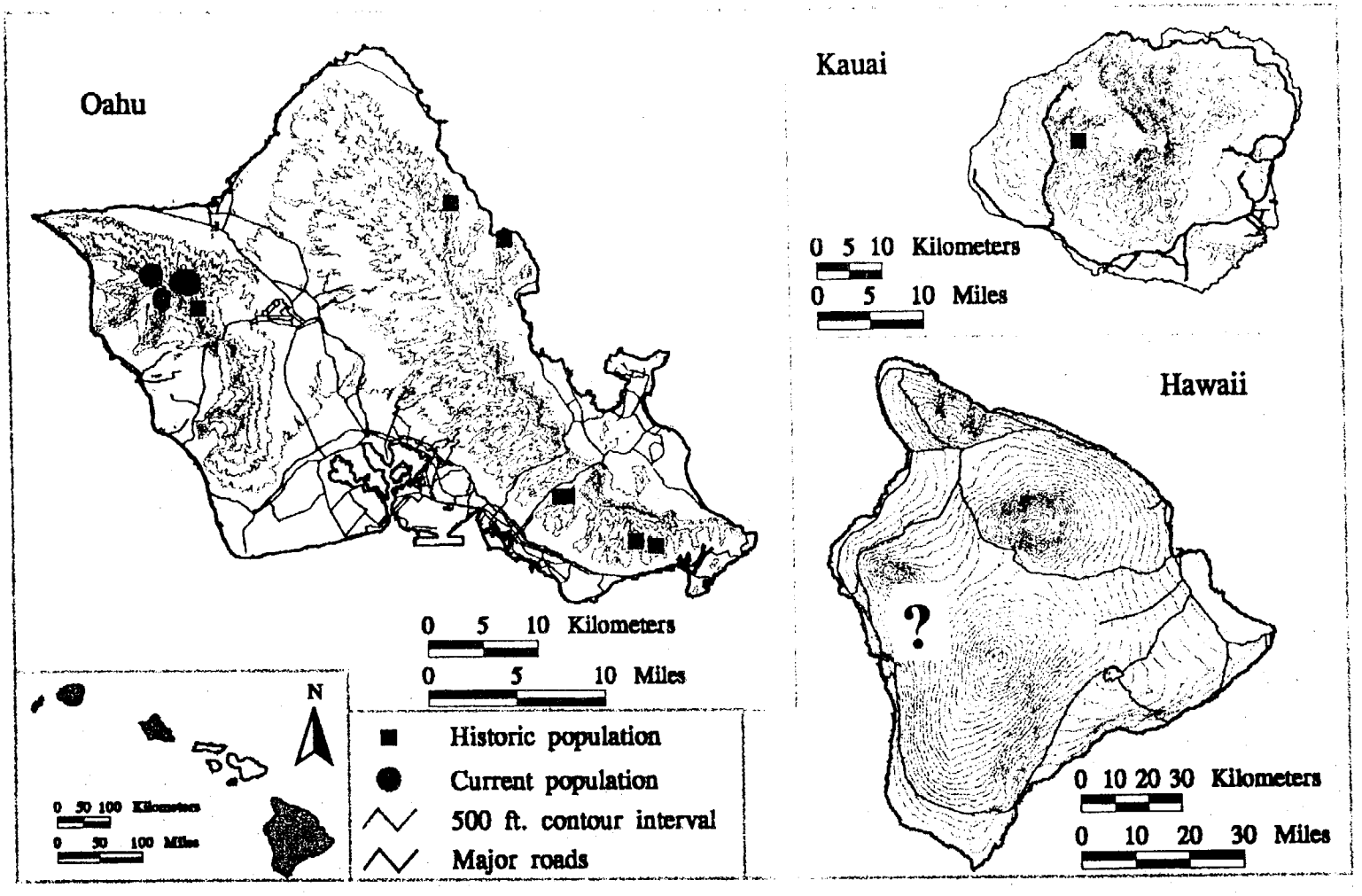

Figure 5. Historic and Current Populations of *Ctenitis squamigera* (Islands of Kauai, Oahu and Hawaii)

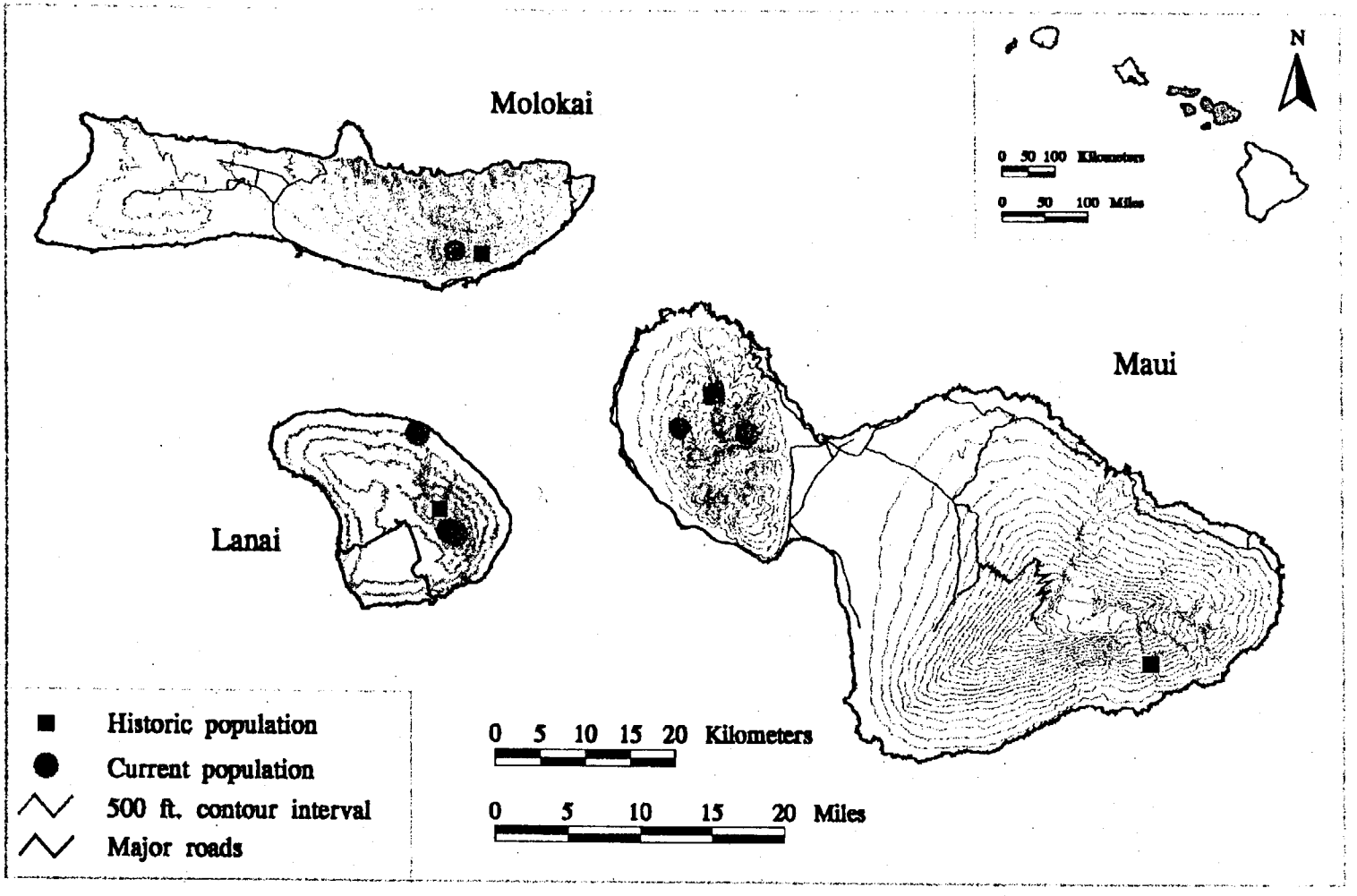

Figure 6. Historic and Current Populations of *Ctenitis squamigera* (Islands of Maui, Molokai and Lanai)

Habitat degradation caused by axis deer is now considered a major threat to the forests of Lanai (Culliney 1988). All three of the Lanai populations of *Ctenitis squamigera* are negatively affected to some extent by axis deer (HHP 1991).

f. Conservation Measures

The Army is preparing Endangered Species Management Plans for training areas on the island of Oahu. These plans will highlight specific threats to endangered plants and recommend actions to promote recovery (U.S. Army 1997a).

g. Needed Recovery Actions

On Lanai, building exclosures around some of the most intact portions of native forest in conjunction with hunting would provide good protection for endangered species, including *Ctenitis squamigera* (R. Hobdy, personal communication 1995).

Oahu populations of *Ctenitis squamigera* would benefit from the proposed expansion of the Mt. Kaala NAR to include Waianae-Kai Forest Reserve and Makaleha Valley Forest Reserve (Talbert Takahama, DOFAW, personal communication 1995). Please refer to the Stepdown Narrative section on page 47 of this plan for the overall recovery strategy.

3. ***Diplazium molokaiense*** - RP# 5

a. Description and Taxonomy (There is no line drawing available for this taxon)

Diplazium molokaiense was published by Winifred Robinson (1913) as a new name for the Hawaiian plants that had previously been assigned to the extra-Hawaiian species, *Asplenium arboreum* Willd., by Hillebrand (1888).

Diplazium molokaiense, a member of the woodfern family (Dryopteridaceae), has a short prostrate rhizome. The leaf stalks are 15 to 20 centimeters (6 to 8 inches) long and green or straw-colored. The frond is thin-textured, ovate-oblong, 15 to 50 centimeters (6 to 20 inches) long and 10 to 15 centimeters (4 to 6 inches) wide, truncate at the base, and pinnate with a pinnatifid apex. The sori are 0.8 to 1.3 centimeters (0.3 to 0.5 inches) long and lie alongside the side veins of the pinnae (Hillebrand 1888, Wagner and Wagner 1992). *Diplazium molokaiense* can be distinguished from other species of *Diplazium* in the Hawaiian Islands by a combination of characters, including venation pattern, the length and arrangement of the sori, frond shape, and the degree of dissection of the frond (Wagner and Wagner 1992).

b. Life History

Reproductive cycles, longevity, specific environmental requirements and limiting factors are unknown.

c. Historic and Current Ranges and Population Status (See Figures 7 and 8 for maps of the historic and current populations of *Diplazium molokaiense*)

Historically, *Diplazium molokaiense* was found at Kaholuamano on Kauai (HHP 1995c7); Makaleha and Schofield Barracks on Oahu (HHP 1995c2, 1995c3);

Kalae, Kaluaaha, Mapulehu, and the Wailau Trail on Molokai (HHP 1995c5, 1995c11 to 1995c13); Mahana Valley and Kaiholena on Lanai (HHP 1995c8, 1995c9); and Ainahou Valley and Maliko Gulch (East Maui) and Wailuku (Iao) Valley and Waikapu on West Maui (HHP 1995c1, 1995c4). However, within the last 20 years, only 1 population of 1 individual has been recorded from Waiopai Gulch, East Maui on DHHL land (R. Hobdy and M. Bruegmann, USFWS, personal communications 1995).

A population of ferns on the Makawao side of East Maui may belong to this species; however, the population's identity needs to be confirmed (F. Warshauer, personal communication 1995).

d. Habitat Description

Recently known populations of *Diplazium molokaiense* were between 850 and 1,680 meters (2,800 and 5,500 feet) in elevation (HHP 1995c6, 1995c10) in lowland to montane habitat, including Montane Mesic Ohia/Koa Forest (USFWS 1994a).

e. Reasons for Decline and Current Threats

The primary threats to *Diplazium molokaiense* are habitat degradation by feral goats, cattle, and pigs; competition with alien plants; and stochastic (random) extinction. On Maui, large populations of feral goats persist on the south slope of Haleakala outside of Haleakala National Park, where they threaten the population of *Diplazium molokaiense* at Waiopai (USFWS 1994a). Goats have reduced the species' habitat there to small remnants. Cattle ranching was once the primary economic activity on the west and southwest slopes of East Maui where the population of *Diplazium molokaiense* can be found (USFWS 1994a). Although this area is no longer actively ranched, feral cattle threaten *Diplazium molokaiense*. Axis deer are also moving into the area (R. Hobdy, personal communication 1995).

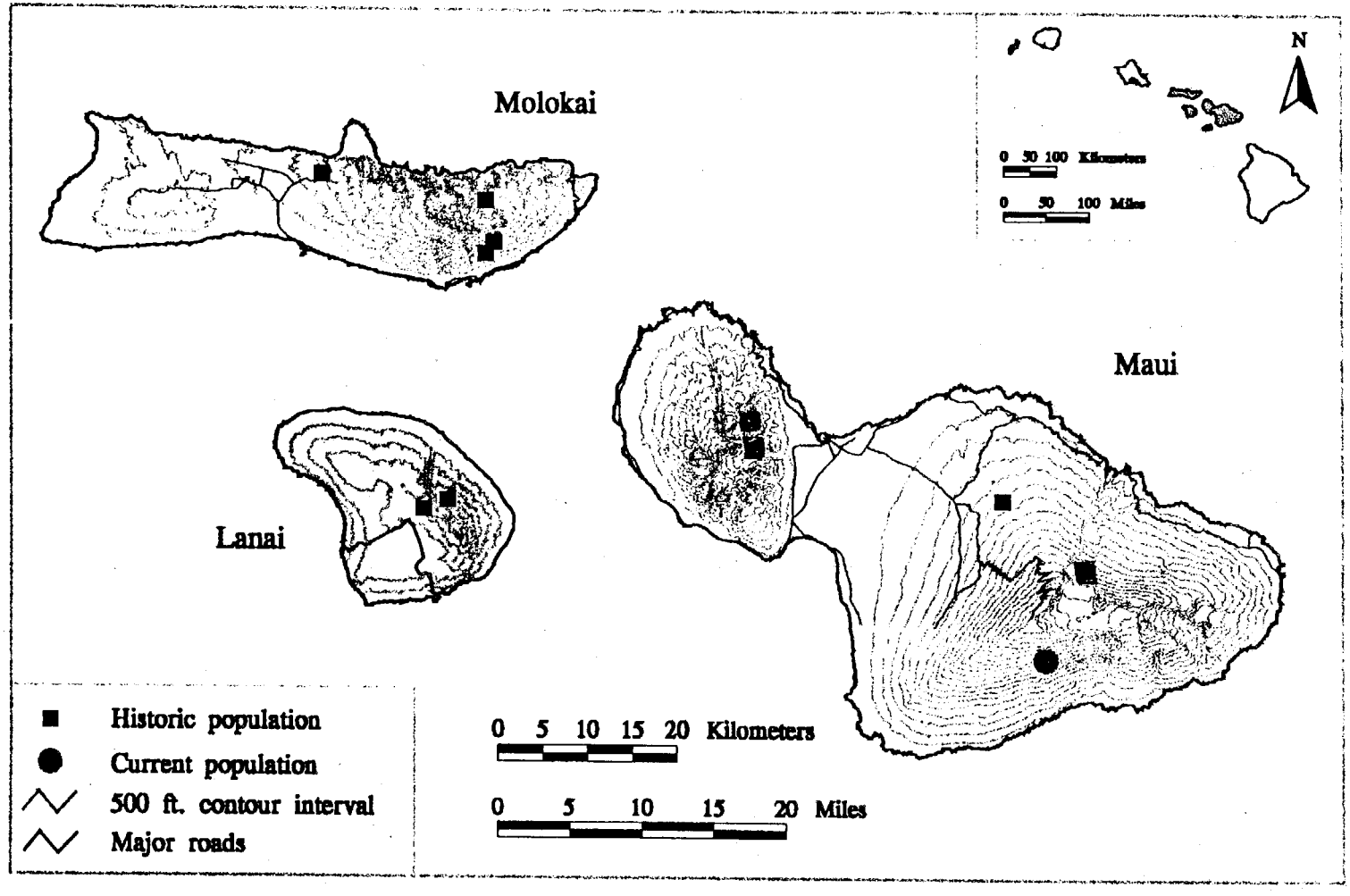

Figure 7. Historic and Current Populations of *Diplazium molokaiense* (Islands of Maui, Molokai and Lanai)

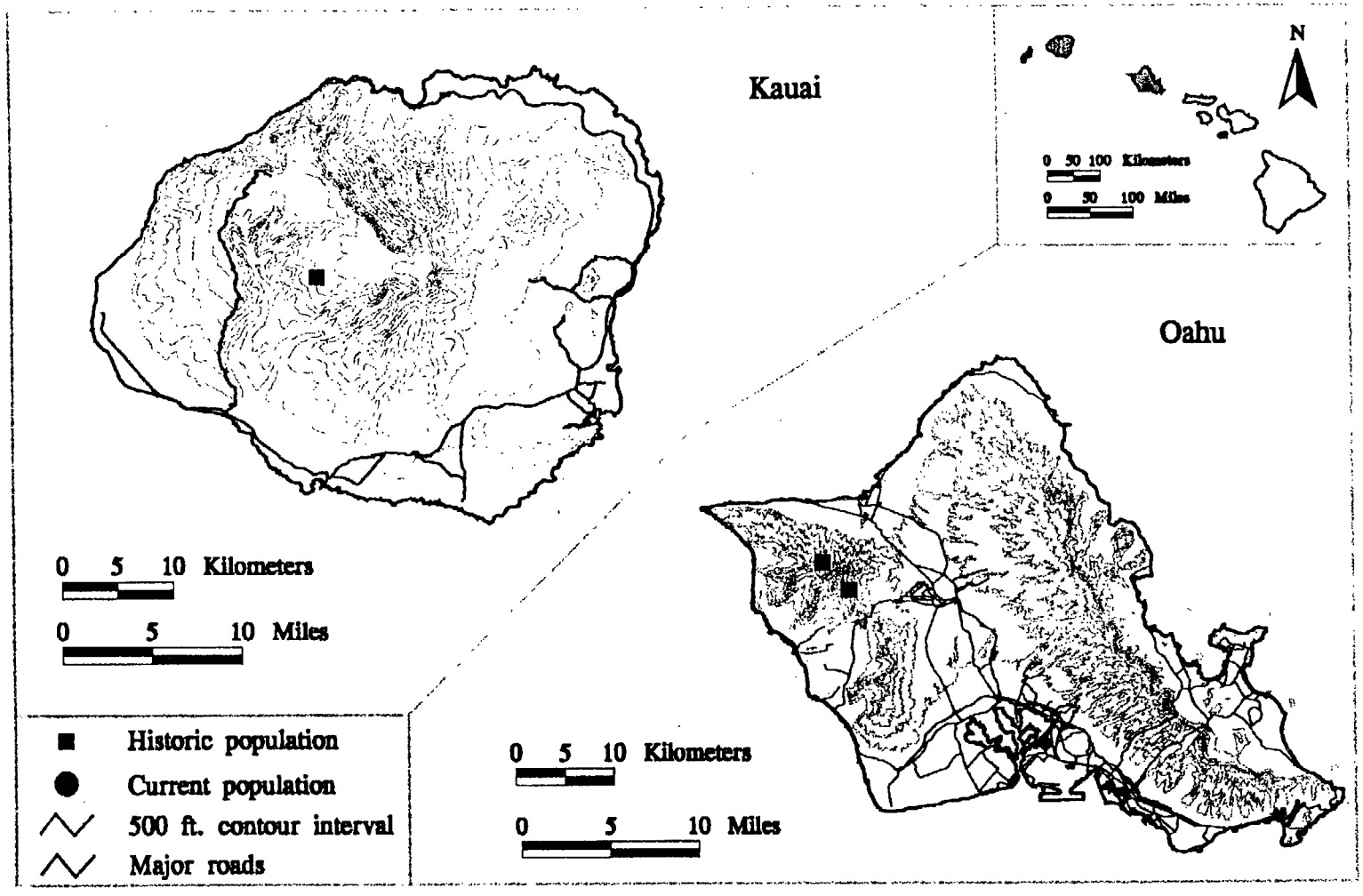

Figure 8. Historic and Current Populations of *Diplazium molokaiense* (Islands of Kauai and Oahu)

f. Conservation Measures

The Living Indigenous Forest Ecosystems (LIFE) organization is working to restore the native vegetation of Kahikinui Forest and is currently fencing a portion of the forest reserve (R. Hobdy, personal communication 1995). Although the Waiopai Gulch population of *Diplazium molokaiense* is not within the section of forest currently being fenced, forest management work in the area will benefit the habitat of this taxon (M. Bruegmann, personal communication 1995).

g. Needed Recovery Actions

Priority recovery actions for this taxon are: fencing and removal of ungulates from its habitat; control of competing alien plant species; *ex situ* propagation; and protection and enhancement of the wild population. Surveys are also needed to locate new populations of this taxon and determine the status of populations that have not been seen in over 20 years (e.g., Ainahou on the island of Maui). The exclosure built by LIFE at Kahikinui Forest may be a good location for establishing new populations of this taxon.

4. ***Pteris lidgatei*** - RP# 5

a. Description and Taxonomy (There is no line drawing available for this taxon)

Cheilanthes lidgatei was described in 1883 on the basis of a specimen collected on Oahu. Hillebrand (1888) erected the genus *Schizostege* for this anomalous species. In 1897 it was placed in the genus *Pteris* by H. Christ, resulting in the currently accepted combination *Pteris lidgatei* (Wagner 1949).

Pteris lidgatei, a member of the maidenhair fern family (Adiantaceae), is a coarse herb, 0.5 to 1 meters (1.6 to 3.3 feet) tall. It has a horizontal rhizome 1.5 centimeters (0.6 inches) thick and at least 10 centimeters (3.9 inches) long when mature. The fronds, including the leaf stalks, are 60 to 95 centimeters (24 to 37 inches) long and 20 to 45 centimeters (8 to 18 inches) wide. The leafy portion of the frond is oblong-deltoid to broadly ovate-deltoid, thick, brittle, and dark gray-green. The sori are apparently marginal in position, either fused into long linear sori, or more typically separated into distinct shorter sori, with intermediate conditions being common (Wagner 1949). *Pteris lidgatei* can be distinguished from other species of *Pteris* in the Hawaiian Islands by the texture of its fronds and the tendency of the sori along the leaf margins to be broken into short segments instead of being fused into continuous marginal sori (Wagner and Wagner 1992).

b. Life History

Reproductive cycles, longevity, specific environmental requirements and limiting factors are unknown.

c. Historic and Current Ranges and Population Status (See Figure 9 for a map of the historic and current populations of *Pteris lidgatei*)

Historically, *Pteris lidgatei* was found at Olokui on Molokai (HHP 1995d4) and Waihee on West Maui (HHP 1995d5). The species was also recorded historically at four locations in the Koolau Mountains of Oahu: Waiahole, Lulumahu Stream, Kaluanui and Wailupe (HHP 1995d1, HHP 1995d2, HHP 1992d5 and HHP 1995d6). Currently, seven populations totaling approximately 33 individuals are known. On Oahu, this taxon is reported from five locations: Kawaiiki Stream, North Waimano Gulch (two populations), Kawainui Drainage, and S. Kaukonahua Gulch (HHP 1995d7, HHP 1995d8, HHP 1995d9, HHP 1995d10 and HHP 1995d11). Two populations were recently discovered on West

Maui at Kauaula Valley (12 individuals) and Kahakuloa Stream (8 individuals) (USFWS 1994a; R. Hobdy and J. Lau, personal communications 1995).

The extant populations of *Pteris lidgatei* are on Federal, State and private land. Three of the Oahu populations are located on lands under the jurisdiction of the U.S. Army.

d. Habitat Description

This taxon is found in lowland wet forest ranging from 530 to 910 meters (1,750 to 3,000 feet) in elevation. It is generally found on streambanks and next to waterfalls with mosses and other species of ferns. Ohia is the dominant native overstory tree species (HHP 1993).

e. Reasons for Decline and Current Threats

The primary threats to *Pteris lidgatei* are the alien plant Koster's curse, habitat destruction by feral pigs (HHP 1992d3, USFWS 1994a), and stochastic extinction.

f. Conservation Measures

Feral pig control efforts by TNCH at Kapunakea Preserve have helped keep pigs from spreading into the Kauaula Valley population of *Pteris lidgatei* on Maui (R. Hobdy, personal communication 1995).

The Army is preparing endangered species management plans for Oahu Training Areas; these plans highlight specific threats to endangered plants and recommend actions to promote recovery (U.S. Army 1997a).

The USFWS is studying the environmental effects of establishing a National Wildlife Refuge in the Koolau Mountains (Phyllis Ha, USFWS, personal communication 1998).

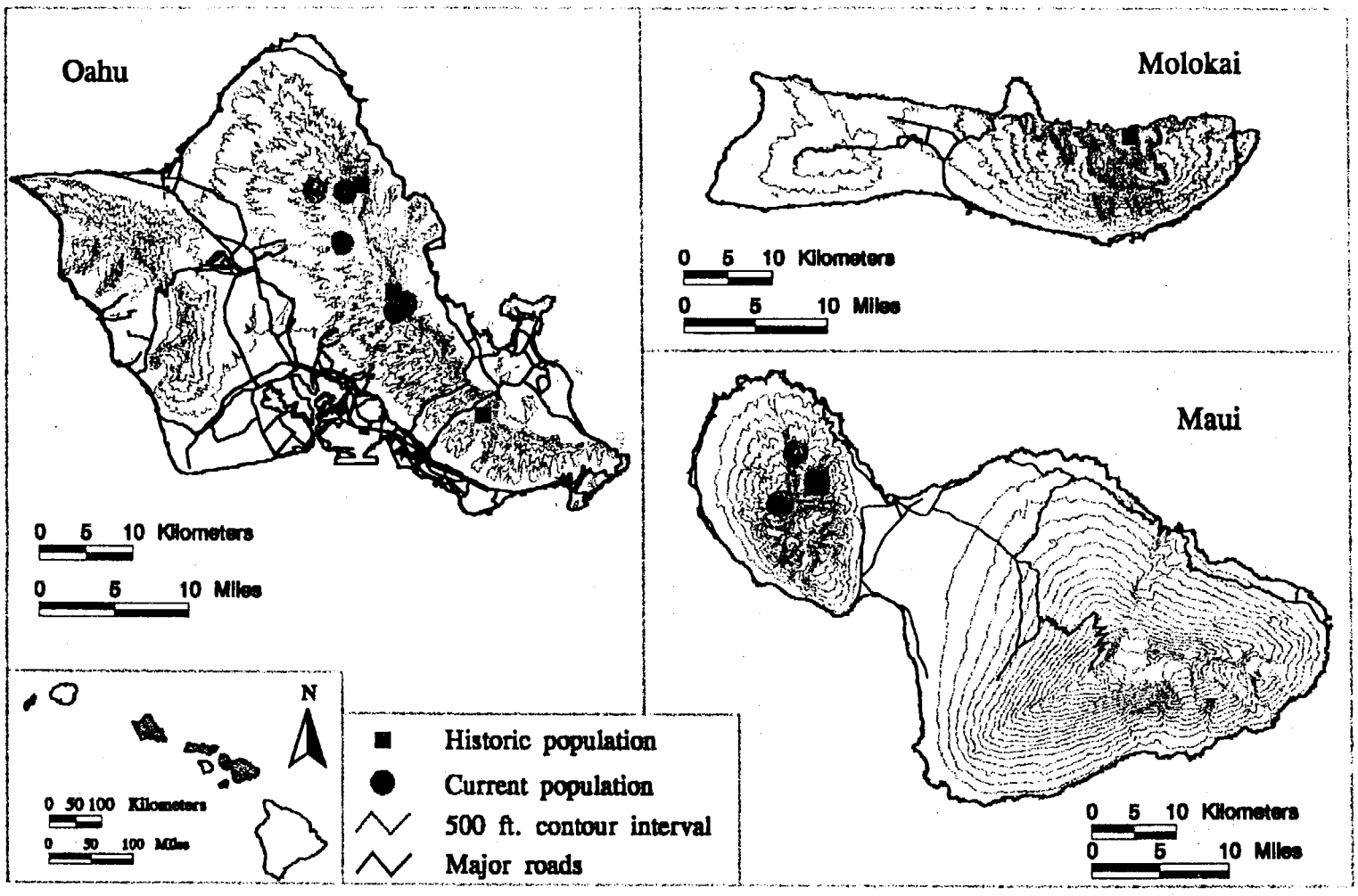

Figure 9. Historic and Current Populations of *Pteris lidgatei* (Islands of Maui, Oahu and Molokai)

g. Needed Recovery Actions

The priority recovery actions for this taxon are control of feral ungulates and alien weeds. Although this species is presently very rare, the number of known plants is expected to rise slowly as botanists become more familiar with the plant and its preferred habitats (HHP 1993). Additional populations should be carefully documented as they are discovered so that important habitat can be protected. The Koolau Mountains and West Maui Mountains should be targeted for protection. Recovery actions for other rare plants in these areas are described in the Koolau Plant Cluster Recovery Plan, The Maui Plant Cluster Recovery Plan and the Recovery Plan for Oahu Tree Snails of the genus Achatinella (USFWS 1996c, 1997, 1993, respectively).

PART II. RECOVERY

1. Objectives

Objectives are provided for stabilizing, downlisting, and delisting the four fern taxa. The order in which tasks are listed in the step-down outline and narrative does not necessarily designate the order in which these tasks should be implemented. The tasks are prioritized and time-frames are recommended in the plan's Implementation Schedule.

An endangered species is defined in section 3 of the ESA 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 regularly exchange genetic material through spore dispersal. Mature individuals are defined as either known or believed to be capable of reproduction.

Because we have only limited knowledge of the life history of the four fern taxa with respect to specific requirements for their short-term and long-term survival, this plan establishes only tentative criteria for stabilizing, downlisting, and delisting. These criteria were formulated based on recommendations by the Hawaii and Pacific Plants Recovery Coordinating Committee, as well as the International Union for Conservation of Nature and Natural Resources' (IUCN's) draft red list categories (Version 2.2) and the advice and recommendations of various biologists and knowledgeable individuals. The four Hawaiian fern taxa have the same general criteria as short-lived perennials in other Hawaii plant recovery plans because these ferns are known or believed to have life spans greater than one year but less than 10 years.

Additional information is needed about each of the four fern taxa so that more meaningful recovery objectives can be quantified.

Interim Objectives

The interim objective is to stabilize all existing populations. To be considered stable, each taxon must be managed to control threats (e.g., fencing, weeding) and be represented in an *ex situ* collection. In addition, a minimum total of three populations of each taxon should be documented on islands where they now occur or occurred historically. Each of these populations must be naturally reproducing and increasing in number, with a minimum of 50 mature individuals per population (minimum of 150 mature plants).

Downlisting Objectives

For downlisting, a total of five to seven populations of each taxon should be documented on islands where they now occur or occurred historically. Each of these populations must be naturally reproducing, stable or increasing in number, and secure with a minimum of 300 mature individuals per population. Each population should persist at this level for a minimum of five consecutive years before downlisting is considered. A particular taxon may be eligible for downlisting even if all five to seven 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 the taxon is not in danger of extinction throughout all or a significant portion of its range.

Delisting Objectives

A total of 8 to 10 populations of each taxon should be documented on islands where they now occur or occurred historically. Each of these populations must be naturally reproducing, stable or increasing in number, and secure from threats, with a minimum of 300 mature individuals per population. Each population should persist at this level for a minimum of five consecutive years. As

with downlisting, in certain cases a particular taxon may be eligible for delisting even if all 8 to 10 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 the taxon is not in danger of extinction throughout all or a significant portion of its range.

2. Stepdown Outline

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

3. Stepdown Narrative

1. Protect habitat and control threats.

Given the altered nature of the four ferns' habitat, their low numbers, and the severity of the threats, the highest priority recovery actions must be aimed at protection of existing individuals and populations, and managing their habitats to control the threats to their survival. *Diplazium molokaiense* is currently known from only one individual, so surveys for this species should begin immediately. A monitoring program (task 4) is essential to track the status of the populations, and to assess the effectiveness of threat management.

11. Identify and map all extant wild populations.

Protection of extant populations will involve locating all extant individuals, mapping their precise locations, and providing this information to land managers. Priority should be given to populations that have not been observed in recent years.

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

12. Delineate management units.

Management units should be identified for the four fern taxa covered by this recovery plan. In most cases, the ranges of the four ferns overlap with those of other listed taxa, and management units including multiple listed taxa from several recovery plans can be delineated and managed under a single management plan. Management units should include areas adequate for buffer zones and fire breaks and for expansion of existing populations and establishment of new populations for recovery. Similar areas for newly discovered populations of each taxon should be identified and targeted for protection and management when necessary for recovery. The Hawaii and Pacific Plants Recovery Coordinating Committee and appropriate Plant Recovery Teams may assist the USFWS, Department of Land and Natural Resources, and other landowners and managers in identifying these management units.

13. Ensure long-term protection of habitat.

Protection of the management units is a primary concern. The protection currently provided to these ferns by various landowners should be continued and enhanced.

Federal lands containing populations of the four fern taxa include U.S. Army and National Park Service lands. Federal agencies are required under the Endangered Species Act to utilize their authorities in furtherance of the Act's purposes by carrying out programs for the conservation of listed species. The Army and the NPS should be encouraged to develop and implement Endangered Species Management Plans for areas that are not already covered by a plan. These agencies also need to be aware of the value to them of developing biological data for any actions likely to affect the four fern taxa on their lands in order to expedite possible consultations with the USFWS under section 7 of the Act.

The State of Hawaii should ensure that all State departments responsible for land zoning, development projects, forestry projects, recreational programs, and other activities are aware of the presence of the four fern taxa on their lands. In addition, the State should establish procedures to ensure that all State activities contemplated in these areas are reviewed with respect to their potential impact on listed plant taxa and that measures are taken to minimize or preclude negative impacts. In addition, the Division of Forestry and Wildlife should develop and implement long-term management plans for each of the four ferns on their lands.

Populations of the four ferns also occur on lands owned or managed by various private landowners. Steps should be taken to ensure that all such landowners are aware of the presence of the listed taxa on their lands, and every effort should be made by DOFAW and/or the USFWS to assist the landowners, as necessary, in developing and implementing long-term management plans for these taxa on their lands.

14. Identify and control threats.

For each population of the four fern taxa, threats must be identified and prioritized, and steps taken to protect the ferns from those threats. Many of these threats have already been well documented, and others need to be further defined. Additional threats may become apparent if additional populations are located. Known threats include feral ungulates, alien plants, fire, and human disturbance.

Threat control plans should be developed for each area in which these fern taxa are found. When such an area has more than one owner, threat control plans should be developed cooperatively. Management units (task #12) should be delineated to allow for the cooperative management of logical groupings of populations. Threat control plans should be as all-encompassing as possible, possibly incorporating several management units and other taxa that are listed, proposed or candidates for listing, or of special concern into one overall plan for restoration and management.

141. Control feral ungulates.

Hawaiian forests have vast numbers of goats, pigs, cattle, and other introduced ungulates. Controlling these ungulates to the point where they no longer impact native vegetation is absolutely imperative. None of the ferns included in this plan can afford to wait many years for protection from ungulates.

The most effective method presently known for providing immediate protection from introduced ungulates in Hawaii is to fence discrete management units, accompanied by the removal of ungulates from within the fenced areas. Although costly, this approach is a feasible solution for introduced ungulate control in Hawaii, as demonstrated at Hawaii Volcanoes and Haleakala National Parks and elsewhere. Eradication of introduced animals may sometimes be an option, given public support, and should also be considered.

1411. Construct and maintain fencing.

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

Fences should include, if possible, the target populations and a buffer area of good-quality, similar habitat, for potential replanting efforts (and/or native buffer habitat, if present, that is resistant to invasion of alien species). To reduce maintenance costs, fences should be

constructed along ridge lines and tied into stream courses at natural barriers (such as the tops of waterfalls) as much as possible.

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

When each fence is completed, all ungulates from within should be removed. Eradication options may include baited hunting, snaring, and poisoning. Hunting from helicopters is also highly effective, particularly in steep, inaccessible areas. It is important to realize that ungulate removal (and other management activities) can cause detrimental impacts. Soil and vegetation disturbance by managers can create open areas for new alien species invasions, and direct damage can result from inappropriate or careless activities. Hunters and others who will be working in the habitat of the four fern taxa should be apprised of the existence of the plants so they do not inadvertently damage them.

Ongoing monitoring for ungulates within the large fenced areas is necessary to ensure their continued absence. Monitoring should also include determining the effects of the exclusion of ungulates, since their herbivory may have a more dramatic impact on invasive alien plants than on the endangered taxa. It is possible that without browsing by ungulates (until other management efforts can be devised and implemented) the present abundance of alien plants could quickly overwhelm some of the endangered taxa.

1412. Consider control of ungulates through eradication programs or establishment of game preserves.

Ideally, island-wide programs to eradicate introduced ungulates should be initiated and supported. Fences are maintenance-intensive, cannot be built in all areas due to topography, and are not altogether a foolproof method of protecting habitats necessary for the perpetuation of the four fern taxa. Ultimately, island-wide eradication of introduced ungulate populations is the only way to eliminate ungulate damage. Such removal of introduced animals will also slow the degradation of watershed lands. However, public support of hunting is fervent, and the likelihood of island-wide acceptance of ungulate eradication programs is remote. Therefore,

development of game preserves, where areas are set aside for hunting of game animals, should be a high priority within the State.

142. Conduct alien plant control.

One of the most important aspects of habitat management for the four fern taxa is the control of invasive alien weeds. This may become even more important for some species if the removal of ungulates relieves grazing and browsing pressure on alien plants. Management activities may also exacerbate the alien plant threat. Soil and vegetation disturbance by managers can create open areas for new alien species invasions, and direct damage can result from inappropriate or careless activities. Steps should always be taken to minimize these effects. Alien plants threaten all four fern taxa in this plan.

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

Control efforts should be supervised by personnel experienced in safe control methods to assure 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 endangered species, during weed removal.

Introduction of alien plants and other species to the State of Hawaii, and between islands within the State, must be halted to prevent further threats to the four fern 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.

143. Provide necessary fire protection.

Protection from fire is critical to the survival of *Asplenium fragile* var. *insulare* and *Ctenitis squamigera*. These plants are not well-adapted to survive fire, particularly fires fed by unnatural buildup of fuel (such as from the growth of alien grasses). In addition, many introduced plant species are better adapted to recovery after fires and often invade burned areas, permanently changing the habitat. Both local and larger-scale protection is needed to prevent fires from spreading to areas where the plants grow.

Plans to protect each site from fire should be developed and implemented. Plans are being developed for areas owned and/or managed by the military. "Fire-free" zones should be established, with hunters and other land users apprised of the dangers of smoking and open flames in sensitive areas. Firebreaks with a minimum width of 6 meters (20 feet) should be constructed around fire-prone populations wherever feasible. This minimum width is a guideline only and may not be sufficient to protect populations from fire in especially dry conditions.

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

Although cultivation of these plants is no substitute for their preservation in the wild, cultivated populations of each of the four fern taxa should be maintained in order to establish pools of genetic resources for reintroduction to appropriate sites and to safeguard against loss of genetic material due to catastrophe in wild populations. Additionally, the existence of cultivated plants may reduce any demand for field-collected specimens of these rare taxa by providing a propagated source to satisfy any horticultural and/or research demand.

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

Spores of each taxon should be collected and entrusted to spore banks for long-term storage using the best available techniques for preservation. Collected spores should be germinated and grown to ensure effective cultivation techniques are developed for all three phases of the fern life

cycle (from spore to gametophyte to mature sporophyte). Spores in long-term storage should be periodically tested for viability and re-collected as necessary.

145. Protect areas from human disturbance.

Human disturbance is believed to be a threat to *Diplazium molokaiense*, *Pteris lidgatei* and *Asplenium fragile* var. *insulare*. These taxa should be protected as much as possible from hikers, vehicles, and other possibilities of direct human disturbance. This will involve public awareness and education regarding the four fern taxa, and native habitats in general, and should be done in conjunction with public education for other listed plants and animals. Education efforts are underway to ensure that military training exercises avoid sensitive areas.

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

Where possible, roads and trails passing through habitats of the four fern taxa should provide access solely for necessary management activities (e.g., fire control, hunting, monitoring). Where this is not feasible, care should be taken during road or trail maintenance in or near habitat of the endangered ferns to avoid practices that would cause opening of canopies, excessive erosion, or other damage. If hiking is permitted in management areas, hikers should be informed of the presence of sensitive environments and precautions which should be taken to avoid disturbance of such areas. Hikers should clean their boots and clothing and stay on existing trails to avoid disturbing sensitive environments. Outreach efforts should inform hikers of these and other appropriate precautions. Appropriate conservation agencies should monitor all potentially disturbing activities.

146. Control all other identified threats.

The need for control of other threats may become apparent as more is learned about the four fern 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 should be implemented to reduce and/or eliminate their effects.

2. Expand existing wild populations.

Populations of the four fern taxa may expand naturally as current threats are eliminated through management. However, in certain instances, wild populations may need to be augmented to reach down/delisting objectives. This should be done only after careful consideration, particularly of the threat of introducing detrimental organisms into the wild populations. Augmentation efforts should always be well-documented as to lineage and methods.

21. Select populations for expansion.

Evaluate the need to expand current populations, and create site-specific plans to augment wild populations. These plans should describe the plant material to be used and the most appropriate methods to employ.

22. Prepare sites and plant.

Each selected site must be prepared and protected, including the building of exclosures and controlling alien species within them.

After sites are protected, plants should be added to existing wild populations in quantities and at times deemed appropriate based on population and growth studies (provided for in Task 3). Normally, progeny from plants of the same site/population should be used to augment a population to avoid contamination of the existing local gene pool with genetic material from other origins. Methods used should 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 because cultivated plants may have been grown in the presence of other plants carrying pathogens to which wild populations may have low resistance. Care should be taken to match soils when transplanting already-started plants, due to differences in water retention around the root areas. For example, if surrounding soil is more absorptive, the soil directly around the roots could become overly dry and weaken or kill the newly transplanted specimen. (These same concerns apply when reestablishing populations, Task 52.).

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

3. Conduct essential research.

Research into various aspects of the life history, habitat, reproductive biology, symbionts, optimum requirements for growth, requirements for population viability, and control of threats for each of the four fern taxa is needed to better understand the requirements for perpetuation of these plants. Such additional knowledge would allow more appropriate management and assessment techniques to be developed, and is needed in to determine meaningful parameters to define specific recovery criteria for each taxon.

31. Collect diagnostic data on crucial associated ecosystem components.

Composition of flora and invertebrate, bird, and other fauna populations within each management area should be established to attempt to gain an understanding of any relationships between these organisms and the four fern taxa in this plan.

32. Map alien vegetation.

Periodic mapping of alien vegetation is recommended using various techniques, including direct ground observations as well as aerial color and/or infrared photographs. Advantages of aerial techniques include: (1) the sensitive habitats of the endangered plants are not invaded; and, (2) large, otherwise inaccessible areas may be monitored. Mapping would allow changes in distributions and abundance of alien plants to be followed so that appropriate management actions may be taken.

33. Study selected aspects of growth and reproductive viability.

Various aspects of the growth and reproductive viability of each taxon need to be studied, including: optimum conditions for growth and limiting factors; seasonal differences in temperature and light needs; water sources and requirements; and soil and nutrient requirements.

34. Determine parameters of viable populations.

Definitions of viable populations will enable the USFWS to more precisely determine downlisting or delisting criteria. These definitions should 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.

35. Determine effective control methods for feral animals and alien weed threats, as needed.

Effective control methods should be developed for feral animals and alien weed threats.

36. Evaluate results and use in future management.

Management should reflect the results of the above studies.

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

Regular monitoring should yield current information for each taxon. A detailed monitoring plan should be designed and implemented for each taxon. Permanent plots should be set up for each population, and individuals mapped by size class, to establish baseline information regarding population size, local distribution patterns and threats.

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

5. Reestablish wild populations within the historic range.

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

51. Investigate feasibility and desirability of reintroduction.

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

52. Develop and implement specific plans for reestablishment.

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

Each site must be prepared appropriately, including construction of exclosures and control of alien species therein, as necessary. The selected material should then be planted. 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) (see Task 22).

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

6. Validate recovery objectives.

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

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

For each of the four fern taxa, determine the number of populations and individuals needed for long-term survival. Information from Task 3 (research) and Task 4 (monitoring) will provide relevant information, as will experience with managing the populations.

62. Refine/revise downlisting and delisting criteria.

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

4. Literature Cited

Cobb, B. 1963. A field guide to the ferns and their related families. Houghton Mifflin Company, Boston, 281 pp.

Cuddihy, L.W. and C.P. Stone. 1990. Alteration of native Hawaiian vegetation; effects of humans, their activities and introductions. Coop. Natl. Park Resources Stud. Unit, Hawaii, 138 pp.

Culliney, J.L. 1988. Islands in a far sea: nature and man in Hawaii. Sierra Club Books, San Francisco, 410 pp.

Degener, O., and I. Degener. 1957. Fl. Hawaiiensis, fam. 17b. *Ctenitis squamigera.* Published privately., 2 pp.

Dyer, A.F. 1994. Natural soil spore banks — can they be used to retrieve lost ferns? Biodiversity and Conservation 3:160-175.

Gagné, W.C., and L.W. Cuddihy. 1990. Vegetation: in Wagner, W.L., D.R. Herbst, and S.H. Sohmer, Manual of the flowering plants of Hawai'i. University of Hawaii Press and Bishop Museum Press, Honolulu. Bishop Mus. Spec. Publ. 83:45-114.

Hawaii Heritage Program. 1991. Field notes from a rare plant survey of the Waianae Mountains, Oahu, and Lanai. Unpubl.

Hawaii Heritage Program. 1993. Biological Inventory of the Schofield Barracks Military Reservation, Oahu, Hawaii. Prepared for U.S. Fish and Wildlife Service.

Hawaii Heritage Program. 1995a1. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.001, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a2. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.002, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a3. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.003, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a4. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.004, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a5. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.006, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a6. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.007, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a7. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.010, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a8. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.011, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a9. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.012, dated September 19, 1991, Honolulu. Unpubl., 2 pp.

Hawaii Heritage Program. 1995a10. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.013, dated September 19, 1991, Honolulu. Unpubl., 2 pp.

Hawaii Heritage Program. 1995a11. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.014, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a12. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.016, dated September 19, 1991, Honolulu. Unpubl., 2 pp.

Hawaii Heritage Program. 1995a13. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.017, dated September 19, 1991, Honolulu. Unpubl., 2 pp.

Hawaii Heritage Program. 1995a14. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.018, dated September 19, 1991, Honolulu. Unpubl., i p.

Hawaii Heritage Program. 1995a15. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.021, dated September 19, 1991, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995a16. Element Occurrence Record for *Asplenium fragile* ssp. *insulare*, PPASP021T1.022, dated March 24, 1995, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b1. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.001, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b2. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.003, dated August 14, 1993, Honolulu. Unpubl., 2 pp.

Hawaii Heritage Program. 1995b3. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.004, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b4. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.005, dated August 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b5. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.007, dated August 14, 1993, Honolulu. Unpubl., 2 pp.

Hawaii Heritage Program. 1995b6. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.008, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b7. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.014, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b8. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.015, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b9. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.018, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b10. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.019, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b11. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.020, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b12. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.021, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b13. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.022, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b14. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.023, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b15. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.024, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b16. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.025, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b17. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.026, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b18. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.027, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b19. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.028, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995b20. Element Occurrence Record for *Ctenitis squamigera*. PPASP05070.029, dated Aug. 14, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c1. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.002, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c2. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.004, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c3. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.005, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c4. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.006, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c5. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.007, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c6. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.008, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c7. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.009, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c8. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.010, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c9. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.011, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c10. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.012, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c11. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.013, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c12. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.014, dated May 8, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995c13. Element Occurrence Record for *Diplazium molokaiense*. PPASP0B090.015, dated Aug. 25, 1993, Honolulu. Unpubl., 1p.

Hawaii Heritage Program. 1995d1. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.001, dated August 25, 1993, Honolulu. Unpubl., 2 pp.

Hawaii Heritage Program. 1995d2. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.004, dated August 25, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995d3. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.005, dated August 25, 1993, Honolulu. Unpubl., 2 pp.

Hawaii Heritage Program. 1995d4. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.006, dated August 25, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995d5. Element Occurrence Record for *Pteris lidgatei*. PPADI0LC C0.007, dated August 25, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995d6. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.008, dated August 25, 1993, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995d7. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.009, dated October 4, 1994, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995d8. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.010, dated October 4, 1994, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995d9. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.011, dated October 4, 1994, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995d10. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.012, dated October 4, 1994, Honolulu. Unpubl., 1 p.

Hawaii Heritage Program. 1995d11. Element Occurrence Record for *Pteris lidgatei*. PPADI0L0C0.013, dated October 4, 1994, Honolulu. Unpubl., 1 p.

Hillebrand, W. 1888. Flora of the Hawaiian Islands: a description of their phanerogams and vascular cryptogams. Carl Winter, Heidelberg, Germany; Williams & Norgate, London; B. Westermann & Co., New York, 673 pp. (Facsimile ed., 1965, Hafner Publ. Co., New York, 673 pp.)

Morton, C.V. 1947. Some notes on Hawaiian Asplenieae. Amer. Fern J. 37:114-119.

Peck, J.H., Peck, C.J. and D.R. Farrar. 1990. Influences of life history attributes on formation of local and distant fern populations. American Fern Journal 80 (4):126-142.

Robinson, W.J. 1913. A taxonomic study of Pteridophyta of the Hawaiian Islands - III. Bull. Torrey Bot. Club. 40:193-228.

Scott, J.M., S. Mountainspring, F.L. Ramsey, and C.B. Kepler. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Stud. Avian Biol. 9:1-431.

Shaw, R.B. 1992. Assessment of the status and recovery of rare plants from the Multipurpose Range Complex, Pohakuloa Training Area, Hawaii, Hawaii; Phase II, Complete Survey. Unpubl. rpt., 98 pp.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's native biota: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 180-250.

Stern, K.R. 1988, Introductory Plant Biology. Wm. C. Brown Publishers, Dubuque, pp. 498.

Stone, C.P. 1985. Alien animals in Hawai'i's native ecosystems: toward controlling the adverse effects of introduced vertebrates: in Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 251-297.

Stone, C.P., and L.L. Loope. 1987. Reducing impacts of introduced animals on native biota in Hawaii: what is being done, what needs doing, and the role of national parks. Environmental Conservation 14:245-297.

Tomich, P.Q. 1986. Mammals in Hawaii. 2nd ed. Bishop Museum Special Publ. 76. Bishop Museum Press, Honolulu, 375 pp.

U.S. Army. 1997a. Draft endangered species management plan for Oahu training areas. Prepared by R.M. Towill Corporation with technical assistance from the Nature Conservancy of Hawaii. Unpublished draft report.

U.S. Army. 1997b. Draft endangered species management plan for Pohakuloa Training Area. Prepared by R.M. Towill Corporation with technical assistance from the Nature Conservancy of Hawaii. Unpublished draft report.

U.S. Fish and Wildlife Service. 1993. Recovery plan for Oahu tree snails of the genus *Achatinella*. U.S. Fish and Wildlife Service, Portland, OR. 63 pp. + appendices.

U.S. Fish and Wildlife Service. 1994a. Endangered and threatened wildlife and plants; endangered status for four ferns from the Hawaiian Islands. 59 FR 49025.

U.S. Fish and Wildlife Service. 1994b. Technical/Agency draft recovery plan for *Haplostachys haplostachya* and *Stenogyne angustifolia*. U.S. Fish and Wildlife Service, Portland, OR. 65 pp.

U.S. Fish and Wildlife Service. 1995a. Lanai plant cluster recovery plan. U.S. Fish and Wildlife Service, Portland, OR. 119 pp + appendices.

U.S. Fish and Wildlife Service. 1995b. Recovery plan for the Waianae plant cluster. U.S. Fish and Wildlife Service, Portland, OR. 205 pp.

U.S. Fish and Wildlife Service. 1996a. Molokai plant cluster recovery plan. U.S. Fish and Wildlife Service, Portland, OR. 146 pp.

U.S. Fish and Wildlife Service. 1996b. Big Island plant cluster recovery plan. U.S. Fish and Wildlife Service, Honolulu, HI. U.S. Fish and Wildlife Service, Portland, OR. 176 pp. + appendices. [Unpublished draft 1995a].

U.S. Fish and Wildlife Service. 1996c. Recovery plan for the Koolau Mountains plant cluster. U.S. Fish and Wildlife Service, Portland, OR. 102 pp.

U.S. Fish and Wildlife Service. 1997. Maui plant cluster recovery plan. U.S. Fish and Wildlife Service, Portland, OR. 123 pp. + appendices.

U.S. Fish and Wildlife Service. 1998. Draft recovery plan for Multi-Island plants. U.S. Fish and Wildlife Service, Portland, OR. 200 pp. + appendices.

Wagner, W.H., Jr. 1949. A reinterpretation of *Schizostege lidgatei* (Baker) Hillebrand. Bull. Torrey Bot. Club. 76:444-461.

Wagner, W.H., Jr. 1995. Evolution of Hawaiian ferns and fern allies in relation to their conservation status. Pacific Science 49:31-41.

Wagner, W.H., Jr., and F.S. Wagner. 1992. Pteridophytes of Hawaii: Identification Key. Unpubl., dated July 9, 1992.

Wagner, W.L., D.R. Herbst, and S.H. Sohmer. 1990. Manual of the flowering plants of Hawai'i. University of Hawaii Press and Bishop Museum Press, Honolulu. Bishop Mus. Spec. Publ. 83:1-1853.

Wagner, W.L., D.R. Herbst, and R.S.N. Yee. 1985. Status of the native flowering plants of the Hawaiian Islands: *in* Stone, C.P., and J.M. Scott (eds.), Hawai'i's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu, pp. 23-74.

IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated cost for the recovery program for four species of Hawaiian ferns, 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 Implementation Schedule

FWS	—	U.S. Fish & Wildlife Service, Pacific Islands Ecoregion, Honolulu, Hawaii
DLNR	—	Department of Land and Natural Resources, State of Hawaii
BRD	—	Biological Resources Division, U.S. Geological Survey
NPS	—	National Park Service
BOT	—	Various Botanical Gardens (e.g., National Tropical Botanical Garden, Lyon Arboretum, Waimea Botanical Garden)
OTHER	—	Various Private Landowners

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE FOUR SPECIES OF HAWAIIAN FERNS

Priority #	Task #	Task Description	Task Duration (Yrs)	Re-sponsible Party	Cost for recovery	Cost, 1997-2001	Cost Estimates ($1,000's), by fiscal year				
							1997	1998	1999	2000	2001
1	11	Identify and map all extant wild populations	5	DLNR*	75.0	75.0	15	15	15	15	15
				FWS	15.0	15.0	3	3	3	3	3
				DOD	15.0	15.0	3	3	3	3	3
				NPS	5.0	5.0	1	1	1	1	1
				OTHER	15.0	15.0	3	3	3	3	3
1	12	Delineate management units	3	FWS*	15.0	15.0		5	5	5	
				DLNR	6.0	6.0		2	2	2	
				DOD	3.0	3.0		1	1	1	
				NPS	1.0	1.0		1			
				OTHER	6.0	6.0		2	2	2	
1	13	Ensure long-term protection of habitat	O	DLNR*	75.0	25.0	5	5	5	5	5
				OTHER	45.0	15.0	3	3	3	3	3
				DOD	45.0	15.0	3	3	3	3	3
				NPS	15.0	5.0	1	1	1	1	1
				FWS	75.0	25.0	5	5	5	5	5
1	1411	Construct and maintain fencing, wherever possible	C	DLNR*	390.0	90.0			30	30	30
				DOD	390.0	90.0			30	30	30
				FWS	390.0	90.0			30	30	30
				OTHER	390.0	90.0			30	30	30

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE FOUR SPECIES OF HAWAIIAN FERNS

Priority #	Task #	Task Description	Task Duration (Yrs)	Re-sponsible Party	Cost for recovery	Cost, 1997-2001	Cost Estimates ($1,000's), by fiscal year				
							1997	1998	1999	2000	2001
2	1412	Consider eradication programs for control of ungulates	3	DLNR*	15.0	15.0		5	5	5	
				FWS	15.0	15.0		5	5	5	
				OTHER			TBD				
1	142	Conduct alien plant control	O	DLNR*	450.0	150.0	30	30	30	30	30
				DOD	225.0	75.0	15	15	15	15	15
				FWS	75.0	25.0	5	5	5	5	5
				OTHER	45.0	15.0	3	3	3	3	3
1	143	Provide necessary fire protection	C	DLNR*	140.0	40.0		10	10	10	10
				DOD	70.0	20.0		5	5	5	5
				FWS	70.0	20.0		5	5	5	5
				OTHER	42.0	12.0		3	3	3	3
1	144	Propagate and maintain genetic stock of each fern taxon *ex situ*	O	DLNR*	375.0	125.0	25	25	25	25	25
				FWS	75.0	25.0	5	5	5	5	5
				DOD	75.0	25.0	5	5	5	5	5
				OTHER	75.0	25.0	5	5	5	5	5
				BOT	75.0	25.0	5	5	5	5	5
1	145	Protect areas from human disturbance	O	DOD	45.0	15.0	3	3	3	3	3
				DLNR*	75.0	25.0	5	5	5	5	5
				FWS	15.0	5.0	1	1	1	1	1
				OTHER	15.0	5.0	1	1	1	1	1

Priority #	Task #	Task Description	Task Duration (Yrs)	Re-sponsible Party	Cost for recovery	Cost, 1997-2001	Cost Estimates ($1,000's), by fiscal year				
							1997	1998	1999	2000	2001
1	146	Control all other identified threats	TBD	DLNR*			TBD				
				DOD			TBD				
				FWS			TBD				
				OTHER			TBD				
Tasks for Need 1: Protect habitat and control threats. Total costs.					3,943.0	3,259.0	150	194	313	313	293
2	21	Select populations for expansion	2	DLNR*	2.0	2.0				1	1
				FWS	2.0	2.0				1	1
				OTHER	0.0	0.0				TBD	
2	22	Prepare sites and plant	TBD	DLNR*	0.0	0.0					TBD
				FWS	0.0	0.0					TBD
				OTHER	0.0	0.0					TBD
Tasks for Need 2: expand existing wild populations. Total costs					4.0	4.0	0	0	0	2	2
2	31	Collect diagnostic data on crucial associated ecosystem components	5	BRD*	50.0	50.0	10	10	10	10	10
				DLNR	15.0	15.0	3	3	3	3	3
2	32	Map alien vegetation	O	BRD*	75.0	25.0	5	5	5	5	5
				DLNR	75.0	15.0	3	3	3	3	3
				FWS	45.0	15.0	3	3	3	3	3

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE FOUR SPECIES OF HAWAIIAN FERNS

Priority #	Task #	Task Description	Task Duration (Yrs)	Re-sponsible Party	Cost for recovery	Cost, 1997-2001	Cost Estimates ($1,000's), by fiscal year				
							1997	1998	1999	2000	2001
2	33	Study selected aspects of growth and reproductive viability	5	BRD*	25.0	25.0	5	5	5	5	5
				DLNR	15.0	15.0	3	3	3	3	3
				FWS	15.0	15.0	3	3	3	3	3
	34	Determine parameters of viable populations	5	FWS*	25.0	25.0	5	5	5	5	5
				BRD	15.0	15.0	3	3	3	3	3
2	35	Determine effective control methods for feral animals and alien weed threats, as needed	TBD	DLNR*	0.0	0.0	TBD				
				FWS	0.0	0.0	TBD				
				BRD	0.0	0.0	TBD				
2	36	Evaluate results and use in future management	0	DLNR*	30.0	10.0	2	2	2	2	2
				FWS	30.0	10.0	2	2	2	2	2
				BRD	30.0	10.0	2	2	2	2	2
				OTHER	0.0	0.0	TBD				
Tasks for Need 3: essential research. Total costs.					415.0	245.0	49	49	49	49	49

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE FOUR SPECIES OF HAWAIIAN FERNS

Priority #	Task #	Task Description	Task Duration (Yrs)	Re-sponsible Party	Cost for recovery	Cost, 1997-2001	Cost Estimates ($1,000's), by fiscal year				
							1997	1998	1999	2000	2001
3	4	Develop and maintain long-term monitoring programs for all species	C	DLNR*	120.0	20.0				10	10
				DOD	60.0	10.0				5	5
				FWS	60.0	10.0				5	5
				OTHER	60.0	10.0				5	5
Tasks for Need 4: develop and maintain monitoring plans. Total costs.					300.0	50.0	0	0	0	25	25
3	51	Investigate feasibility and desirability of reintroduction	2	FWS*		0.0					
				DLNR		0.0					
				BRD		0.0					
3	52	Develop and implement specific plans for reestablishment	TBD	FWS*		0.0	TBD				
				DLNR		0.0	TBD				
				BRD		0.0	TBD				
				OTHER		0.0	TBD				
Tasks for Need 5 : Reestablish wild populations within the historic range. Total costs.					20.0	0.0	0	0	0	0	0

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR THE FOUR SPECIES OF HAWAIIAN FERNS

Priority #	Task #	Task Description	Task Duration (Yrs)	Re-sponsible Party	Cost for recovery	Cost, 1997-2001	Cost Estimates ($1,000's), by fiscal year				
							1997	1998	1999	2000	2001
3	61	Determine number of populations and individuals needed for long-term survival	2	FWS*		0.0					
				DLNR		0.0					
				NBS		0.0					
3	62	Refine/revise downlisting and delisting criteria	2	FWS*		0.0					
				DLNR		0.0					
				BRD		0.0					
Tasks for Need 6: Validate recovery objectives:					60.0	0.0	0	0	0	0	
TOTAL COST					4,742.0	3,558.0	199	243	362	389	

APPENDIX A - Agency and Peer Reviewers

Marie Bruegmann
USFWS
300 Ala Moana Blvd.
P.O. Box 50088, Rm. # 3-122
Honolulu, HI 96850

Mick Castillo
USFWS
300 Ala Moana Blvd.
Box 50088, Rm. # 3-122
Honolulu, HI 96850

Betsy Harrison-Gagné
Division of Forestry and Wildlife
Natural Area Reserves System
1151 Punchbowl St.
Honolulu, HI 96813

Paul Higashino
Kahoolawe Island Reserve Commission
33 S. King St., Rm 501
Honolulu, HI 96813

Robert Hobdy
Division of Forestry and Wildlife
State Office Building
54 South High Street
Wailuku, HI 96793

Joel Lau
The Nature Conservancy of Hawaii
1116 Smith St., Suite 201
Honolulu, HI 96817

Daniel Palmer
1975 Judd Hillside St.
Honolulu, HI 96822

Linda Pratt *
BRD
P.O. Box 44
Hawaii Volcanoes National Park, HI
96718

Elizabeth Sharpe
USFWS
300 Ala Moana Blvd.
P.O. Box 50088, Rm. # 3-122
Honolulu, HI 96850

Robert Shaw
Colorado State University
Center for Ecological Management of
Military Lands
Dept. of Forest Sciences
Fort Collins, Colorado 80523

Talbert Takahama
Division of Forestry and Wildlife
1151 Punchbowl St.
Honolulu, HI 96813

Warren H. Wagner Jr.
Dept. of Botany
University of Michigan
Ann Arbor, MI 48109

Ron Walker
USFWS
300 Ala Moana Blvd.
P.O. Box 50088, Rm. # 3-122
Honolulu, HI 96850

Frederick R. Warshauer
BRD
P.O. Box 44
Hawaii Volcanoes National Park, HI
96718

Lyman Perry*
DOFAW
19 E. Kawili St.
Hilo, HI 96720

*** Comments Received**

APPENDIX B - Summary of Landownership/Management for Current Populations

Federal

Department of Defense

- Kawailoa Training Area - *Pteris lidgatei*
- Makua Military Reservation - *Ctenitis squamigera*
- Pohakuloa Training Area - *Asplenium fragile* var. *insulare*
- Schofield Barracks - *Pteris lidgatei*

National Park Service

- Hawaii Volcanoes National Park - *Asplenium fragile* var. *insulare*

State

Department of Hawaiian Home Lands - *Diplazium molokaiense*

Department of Land and Natural Resources

- Ewa Forest Reserve - *Pteris lidgatei*
- Hanawi Natural Area Reserve - *Asplenium fragile* var. *insulare*
- Hauula Forest Reserve - *Ctenitis squamigera*
- Honuaula Forest Reserve - *Asplenium fragile* var. *insulare*
- Kapapala Forest Reserve - *Asplenium fragile* var. *insulare*
- Kau Forest Reserve - *Asplenium fragile* var. *insulare*
- Mauna Loa Forest Reserve - *Asplenium fragile* var. *insulare*
- Mokuleia Forest Reserve - *Ctenitis squamigera*
- Waianae Kai Forest Reserve - *Ctenitis squamigera*
- West Maui Natural Area Reserve - *Pteris lidgatei*

Department of Corrections (Kulani) - *Asplenium fragile* var. *insulare*

Private Landowners

- *Asplenium fragile* var. *insulare*, *Ctenitis squamigera*, and *Pteris lidgatei*

APPENDIX C - Recovery Priority System

The Recovery Priority System uses the criteria of degree of threat, recovery potential, and taxonomy (level of genetic distinctiveness) to assign all listed species a number (1-18). A fourth factor, conflict, is a supplementary element in determining what actions are to be implemented for species recovery. This factor gives priority, within each category, in preparation of recovery plans to species that are, or may be in conflict with construction or development projects. Thus, the species retains its numerical rank and acquires the letter designation of "C", indicating conflict (1C-18C). A detailed discussion of the Recovery Priority System can be found in 48 FR 51985.

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

APPENDIX D - Summary of Comments

The U.S. Fish and Wildlife Service received comments on the Draft Recovery Plan for Four Species of Hawaiian Ferns from the Division of Forestry and Wildlife and the Biological Resources Division, U.S. Geological Survey. These comments provided additional information on locations of recent sightings, threats to the species, and editorial changes. Most of these comments have been incorporated into the final plan. Additional comments are addressed specifically below.

Comment: Because there are so few recent sightings of the endangered fern (*Asplenium fragile* var. *insulare*) in the Park (e.g. Hawaii Volcanoes National Park on Mauna Loa), Hawaii Volcanoes can not be considered to be an important part of any future protection scheme for the species, despite the presence of apparently suitable habitat for the fern in the Park.

Service Response: The Service has considered the dearth of fern sightings in Hawaii Volcanoes National Park on Mauna Loa and recommends further surveys for its presence within the Park. Due to the presence of suitable fern habitat within the Park's boundaries and that future recovery efforts will depend on the availability of such habitat, it is integral that the Park play a role in establishing geographically distinct colonies of this fern. Establishment of separate colonies will better ensure its survival and recovery.

Region 1
U.S. Fish and Wildlife Service
Ecological Services
911 N.E. 11th Avenue
Portland, Oregon 97232-4181

March 1998